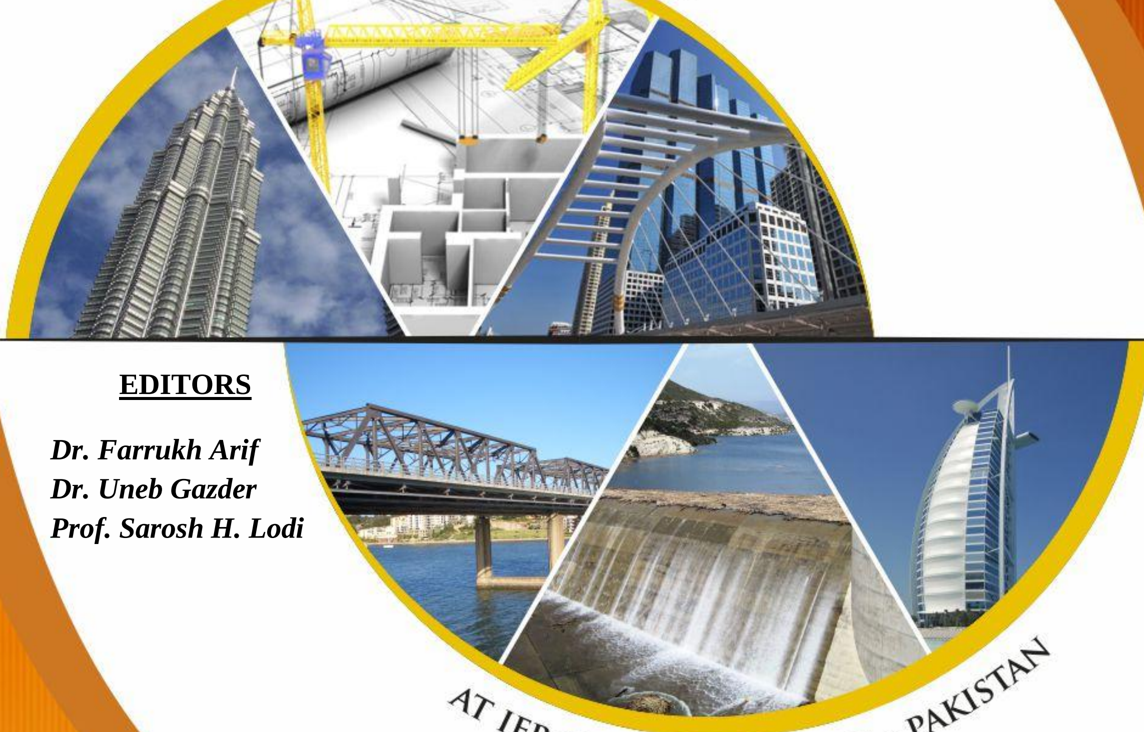
7TH INTERNATIONAL CIVIL ENGINEERING CONGRESS

CONGRESS PROCEEDINGS

12TH & 13TH JUNE, 2015



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AT IEP CENTRE, KARACHI - PAKISTAN

"SUSTAINABLE DEVELOPMENT THROUGH ADVANCEMENT IN CIVIL ENGINEERING"

Jointly Organized by

The Institution of Engineers Pakistan
Karachi Centre

&

NED University of Engineering & Technology
Karachi

in collaboration with

The Asian Civil Engineering Coordinating Council

Federation of Engineering Institutions of Islamic Countries (FEIIC)

Federation of Engineering Institutions of South & Central Asia (FEISCA)

7th International Civil Engineering Congress

(ICEC-2015)

"Sustainable Development through Advancements in Civil Engineering"

June 12-13, 2015, Karachi, Pakistan.

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Congress Introduction

Pakistan is among the developing countries which unfortunately face challenges like insufficient infrastructure, energy crisis, pollution, traffic congestion among others. Construction projects initiated serve as the catalyst to the economic prosperity of any country by providing jobs and infrastructure to fulfill basic needs of shelter health and education. Like many other industries in Pakistan, this sector has also been lacking the use of state-of-the-art technologies. This situation has led to poor quality construction and increased maintenance costs. This conference provides an opportunity to the professionals, and academicians of civil engineering to share their knowledge and experience. It is expected that such collaboration will lead to improvement in the current industry practices leading to sustained development for the community.

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ICEC – 2015 is jointly organized by two prominent engineering institutions in Pakistan; Institute of Engineers Pakistan and NED University of Engineering & Technology.

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The Institution of Engineers Pakistan (IEP) was established in 1948. It is the premier national body of engineers working for the advancement of the Engineering Profession. It has headquarters at Lahore and centers in all major cities of Pakistan as well as in Riyadh, Saudi Arabia & Bahrain. IEP has signed technical collaboration agreements with more than forty professional Engineering Organizations across the globe. IEP is also the member of six international / regional engineering bodies and has the honor to represent Pakistan at these forums. IEP Karachi Centre is the biggest center of IEP. IEP Karachi Centre has been organizing International Civil Engineering Congresses since 2000. Since then it has organized 5 more, the last being in 2013.Seventh International Civil Engineering Congress will be a 2 days event, spread over an inaugural and six technical sessions on the 12 and 13 June 2015.

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NED University is one of the oldest engineering institutions in Pakistan. It offers Bachelors, Masters and Doctoral degree programs. The programs are aimed at preparing students to shoulder their professional responsibilities and enable them to contribute in research and development in related fields. Various seminars and conferences are held every year which not only provide practical exposure to students but also a platform for academia-industry collaboration.

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Construction Safety Research in Pakistan: A Review and Future Research Direction

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Abstract
Comprehensive review of construction safety research is presented in this paper, aiming at summarizing the completed research work in Pakistan. It includes eleven journal papers, two dissertations and thirty two conference papers. Construction accidents are mostly caused by; fall from height, followed by electrocution. Safety non-compliance is attributed to; non-existence of a regulatory authority, delusion that investing in safety will increase the project cost, workers' unawareness, and unrealistic deadlines. Though Pakistan Engineering Council (PEC) is conducting safety awareness workshops for engineers and supervisors, no training is planned for construction workers. Few private institutes are also providing safety training but only on commercial basis. The deteriorating safety situation can be enhanced by ensuring management's commitment and employees' involvement, effective supervision and communication, safety education and training, and accident reporting mechanism. It has also been recommended to establish occupational health and safety regulatory authority, redefine and enforce safety laws, and launch media campaigns to create awareness among workers. PEC is suggested to enhance the safety performance by; allocating the safety budget and responsibilities in contract documents, incorporating *safety credit points* in contractor licensing process, and maintaining accident statistics. Potential research areas are also identified to kindle the construction safety research in Pakistan.

Keywords
Safety management system, Safety climate, Safety practices, Review, Pakistan.

1. Introduction

The construction industry is suffering from higher fatality and injury rates because of its unique nature, unpredictable site conditions, diversified human behaviour, and unsafe procedures (Ahmed et al. 2000). The developed countries are implementing various safety, health and environmental management systems to minimize these fatalities (Chan et al. 2008). Various safety schemes have also been introduced which resulted into a consistent decrease in the accident rate during the last 20 years (Choudhry et al. 2008).

Contrary to this, in the developing countries like Pakistan, stakeholders' emphasis is primarily on improving the construction quality, and reducing cost and time, whereas safety is least on their agenda. Safety regulatory authority is almost ineffective and contractors are reluctant to share the actual record of injuries and fatalities (Farooqui et al. 2007; Ali, 2006). Primary construction regulatory body i.e. Pakistan Engineering Council (PEC) has yet to lay down safety regulations to be followed in the industry (Farooqui et al. 2007). According to Farooqui et al. (2008b) most clients demand maximum speed and good quality of work at the lowest possible cost, whereas no budget is specified for safety compliance. Small construction firms do not have any safety policy so unsafe conditions exist on their work sites and labourers are exposed to hazardous conditions, however, most of the large firms, registered with PEC in category C-A *(category of the contractor having no financial limit)*, do have a safety policy, provide safety training to their workers, and maintain safety personnel on their worksites (Raheem and Hinze, 2013b; Farooqui et al. 2008b).

According to the annual reports of *Pakistan Bureau of Statistics*, 7.4% *(4.424 Million)* of the total labour force *(59.79 Millions)* are associated with the construction industry (PBS, 2012-2013; 2010-2011). Consistent increase has been observed in the injuries/accidents from 14.55% in 2006 to 15.24% in 2012 in the construction industry (Table 1). Hence, it has emerged to be the 2nd most injury prone industry after the agriculture. Conversely, increase in its employment rate is relatively lower than other industries. According to Table 2, employment rate has gradually increased from 6.56% in 2006 to 7.4% in 2012. It can therefore be inferred that construction industry is employing only 7.4% of total labour force whereas its injury rate is alarmingly high (15.24% of total labour force).

Table 1: Occupational injuries/diseases – Percentage distribution by major industries in Pakistan

Occupational Injuries/Diseases – Distribution by Major Industries (%) in Pakistan							
	Financial Year						Ranking
Type of Industry	**2006-2007**	**2007-2008**	**2008-2009**	**2009-2010**	**2010-2011**	**2012-2013**	
Agriculture, Forestry, Fishing	40.94	46.84	50.43	50.2	49.8	49.1	1
Mining/Quarrying	0.29	0.09	0.33	0.1	0.2	0.2	
Manufacturing	15.21	12.72	13.96	12.8	15.8	13.3	3
Electricity, gas and water	0.87	0.51	0.71	0.4	0.2	0.5	
Construction	14.55	14.93	14.54	14.3	13	15.2	**2**
Retail Trade, Restaurants and Hotels	9.26	7.96	7.54	10.6	10.3	9.2	4
Transport/Communication	7.98	8.02	8.14	8	7.1	7.3	
Community/Social Services	10.56	8.39	4.33	3.5	3.3	5.1	
Other Industries	0.34	0.54	0.02	0.1	0.3	0.1	

Table 2: Percentage distribution of employed persons by major industries in Pakistan

Percentage Distribution of Employed Persons by Major Industries in Pakistan							
	Financial Year						Ranking
Type of Industry	**2006-2007**	**2007-2008**	**2008-2009**	**2009-2010**	**2010-2011**	**2012-2013**	
Agriculture, Forestry, Fishing	43.61	46.84	44.91	45	45.1	43.7	1
Manufacturing	13.54	12.72	13.02	13.2	13.7	14.1	3
Construction	6.56	14.93	6.62	6.7	7	7.4	**5**
Retail Trade, Restaurants and Hotels	14.42	7.96	15.16	16.3	16.2	14.4	2
Transport/Communication	5.39	8.02	5.23	5.2	5.1	5.5	6
Community/Social Services	14.41	8.39	2.58	11.2	10.8	13.3	4
Other industries	2.07	1.14	12.48	2.4	2.1	1.6	7

2. Objectives

This paper is aimed at reviewing the safety research carried out in the construction industry of Pakistan, with following objectives:

a. Carry out a comprehensive review of construction safety research conducted in Pakistan.
b. Examine the safety regulations and their enforcement in Pakistan.
c. Find the gap for future research in the field of construction safety in Pakistan.

3. Research Methodology

A systematic literature review is conducted in three stages for investigating the research work carried out in the field of construction safety in Pakistan. In stage-1, a comprehensive desktop search was conducted with the search keywords; safety, safety climate, safety practices, construction and Pakistan. The databases such as Scopus, EBSCO, Science Direct, Google, Google scholar and Web of science were searched to find the related journal papers. The search result indicated that only fourteen journal papers have been published related to the construction safety in Pakistan. In the second stage, proceedings of International conferences were searched using the above mentioned search engines. Using the snow ball technique, references given at the end of each paper were also checked so as to find the related papers. In stage-3, google scholar profiles of Pakistani researchers, who are actively involved in construction safety research, were explored. As a result, all related papers had either been downloaded (if available) or obtained from the authors via personal email requests. Hence, a total of 14 journal papers, two dissertations (one PhD and the other M. Phil), and 32 international conference papers from 12 conference proceedings had been selected for review.

4. Overview of Construction Safety Research in Pakistan

4.1 Categories of the Research Papers

Out of the fourteen shortlisted journal papers related to safety in Pakistan, 3 were related to roads, 1 for Engro-food industry and 10 were related to the construction industry (8 International and 2 Pakistani journals). Topics covered in these journal papers include safety performance, safety culture, safety climate, national culture, safety policy formulation and enforcement, use of wireless technology (Riaz et al. 2014) and Building Information Modelling. Only four of these journal papers have been published in the top peer-reviewed journals. In most of the papers, basic statistical techniques had been used to analyze the data collected through questionnaire survey and interviews; however Mohamed et al. (2009) have also used factor analysis. Four scholars including *Dr. Rafiq M. Choudhry, Dr. Rizwan U. Farooqui, Engineer Rehan Masood* and *Adeeba A. Raheem* are actively involved in safety research in Pakistan. Out of the thirty two conference papers, twenty two are written by these researchers. Most of their papers are related to safety policies, safety culture, safety climate, safety practices and safety management systems.

4.2 Questionnaires being adopted by the Researchers

Questionnaire designed by McDonald and Hrymak (2001) for the Irish construction industry, Mohamed (2002) for the Australian construction industry, and Choudhry et al. (2008 and 2009) for the Hong Kong construction industry had been used by the researchers to explore the construction safety performance in Pakistan. Mohamed and Ali (2005) and Mohamed et al. (2009) have also designed a questionnaire to analyze the influence of national culture on safety behaviour. Similarly, 70 statements questionnaire under 10 groups by Ahmed (2013) and 31 statements safety climate questionnaire by Choudhry et al. (2009) were also adopted to assess the construction safety climate in Pakistan (Choudhry and Masood, 2011).

4.3 Current Safety Practices

Though technological advancement is the need of hour, it has adversely affected the construction safety especially in the developing countries, where emphasis had always been on the productivity than the safety (Farooqui et al. 2008a; Masood et al. 2014). Injury/fatality statistics of construction projects are yet to be maintained at the industry or national level (Khan, 2013b, Raheem et al. 2012), so the lagging indicators of accident statistics cannot be used to analyze the safety performance. Raheem and Hinze (2012 and 2013b) have highlighted that most of the construction companies do not update their safety manuals. Similarly, safety policies are made only for the documentation purposes (Jafri, 2012; Masood et al. 2012c). Mohamed and Ali (2005) and Qazi et al. (2006) have analyzed the effect of *awareness and beliefs*, *physical environment* and *supportive environment* on safety culture, and highlighted the neglected safety practices, as; poor quality scaffolding without guard rails, defective ladders not tied properly, working on roof without edge protection, temporary laid power lines and manual deep excavation without bracing. Safety training has been identified as the most neglected aspect (Haider et al. 2013; Zahoor and Choudhry, 2012). Managers and the workforce have varied opinion about safety compliance on their work sites (Masood et al. 2012b).

4.3.1 Causes of accidents

Major causes of construction accidents, in descending order, are; fall from height, electrocution, caught in between the machinery and struck by falling objects (Hassan, 2012; Nawaz et al. 2013). Higher unemployment ratio and more number of unskilled workers are also the main causes of accidents (Jafri et al. 2012). Few indirect cost effects have also been identified like cost of employing additional manpower, lost work hours of fellow crew members due to temporary halts and lowering of morale (Farooqui et al. 2008a).

4.3.2 Reasons for safety non-compliance

Non-compliance to safety regulations is attributed to; non-existence of any regulatory authority, greed for making more profit, delusion that investing in safety will increase the project cost, workers' non-cooperation and ignorance for their rights, poor safety management techniques, political influence, pervasive corruption, meeting unrealistic deadlines, extended working hours, less wages, no maintenance and inspection schedule, no safety training, no requirement of safety certification for the workers, shortage of safety personnel, and giving least value to human lives (Farooqui, 2012; Farooqui et al. 2008a; Raheem et al. 2011; Saqib et al. 2010; Choudhry et al. 2012 and 2006).

4.3.3 Recommendations by the researchers

The significant safety climate factors have been identified as *managements' commitment* and *employees' involvement* (Choudhry and Masood, 2011). Mohamed et al. (2009) have concluded that under collectivist, feminist and higher uncertainty avoidance environment, safety performance can be improved. It has been emphasized to bring a cultural change and a shift in the mind set of upper echelons in the government to improve the deteriorating safety situation (Ahmed, 2013). Stakeholders need to be educated that accident not only causes an injury but also results in time delay, morale lowering, indirect labour replacement cost, equipment repair cost, and most importantly brings bad name to the company (Hinze, 2000). The researchers have also recommended to enhance the safety performance by; redefining and enforcing safety rules and regulations, establishing health and safety regulatory authority, appointing safety inspectors, allocating sufficient budget for safety training and education, and developing an effective communication and accident reporting mechanism (Memon et al. 2013; Nawaz et al. 2013; Hassan, 2012).

Choudhry et al. (2008) have suggested that safety incentives, green card scheme and safety management system in Hong Kong are equally applicable to Pakistan and their implementation can bring positive change in the working environment. They have also suggested that *Directorate of Workers Education* (DWE) should take a leading role towards enhancing safety standards in all the industries. PEC is recommended to; ensure safety through contractual obligations, allocate safety budget in contract documents, incorporate 'safety credit points' in the contractor license renewal process, employ safety staff, and maintain accident statistics (Raheem and Hinze, 2013a; Zahoor and Choudhry, 2012). Two (2) credit hours Occupational Health and Safety (OH&S) course has also been recommended for civil, architect and town planning students, so as to strengthen the safety awareness among the key stakeholders (Masood et al. 2012a).

5. Safety Enforcement and Training Institutes

At the Federal government level, DWE working under the *Ministry of Capital Administration & Development* is primarily responsible to create awareness among workers for their rights and to educate them about their social and economic problems including OH&S training; however its performance is not satisfactory. In the province of Punjab, the department of Labour & Human Resource has established an ancillary body *'The Centre for Improvement of Working Conditions & Environment'* (CIWCE) at Lahore, which is providing professional services in the fields of OH&S. Few private institutes are also providing OH&S training but on commercial basis, including; *Occupational Safety and Loss Prevention* (OSALP), O*ccupational Training Institute* (OTI), and V*ivid Institute of Occupational Safety and Health* (VIOSH).

PEC is also conducting safety awareness workshops and compulsory 'Continuing Professional Development' (CPD) short courses but these training sessions are only for engineers and supervisors, whereas no training is organized for construction workers (Khan et al. 2013a). PEC has incorporated following OH&S clauses in its contract documents but these are mostly not enforced due to the absence of a regulatory authority.

a. *Safety, security and protection of the environment:* It is clause 19.1 of part-I (General conditions of contract) of PEC standard form of bidding documents (PEC, 2007, *p.90*).
b. *Safety precautions:* It is clause 19.3 of part-II (Particular conditions of contract) of PEC standard form of bidding documents (PEC, 2007, *p.152*).

6. Challenges for the Safety Researchers in Pakistan

6.1 Scarcity of Construction Safety Research

Research in the field of construction safety in Pakistan remained almost neglected, as the key stakeholders had been focusing on productivity only. Accident statistics have not been maintained at the industry level so it has proven to be the major obstacle in the data collection. Only a few researchers have worked in this area using the leading safety indicators. They have mostly used descriptive statistics for the data analysis. Moreover, sample sizes are also not quite reliable. Likewise, Structural Equation Modeling and Social Network Analysis have not been used for the data analysis and validation. Hence, very few researches had been published in the peer reviewed journals.

6.2 Future Research Directions

Detailed study may be carried out to identify the safety climate factors affecting the safety performance in the Pakistani construction industry using the exploratory factor analysis. Causal relationship among various safety climate factors using the structural equation modeling (confirmatory factor analysis) needs to be examined. A study may be conducted to examine the safety practices being practiced in the tall buildings construction as they are suffering from higher accident rates (Zahoor et al. 2015). Research may also be instigated to assess the applicability of successful construction safety management practices of the developed countries in Pakistan. Unsafe behavior of the workers, which is intrinsically linked to the workplace accidents, needs to be explored to ascertain the root causes of accidents and study the varied behaviour of different tradesmen. Likewise, applicability of innovative (information and communication) technologies to effectively monitor the safety performance on construction sites needs to be explored. There is also a need to compare the cost of accidents with the investment needed for safety compliance. Contractual obligations of various construction departments may also be examined. Standardized safety rules and regulations are also required to be established for the construction industry of Pakistan.

7. Conclusions

Construction safety research in Pakistan is in its embryonic stage. Very few researches have been published in the journals; however many have been published in the conference proceedings which are mostly not accessible online. This paper is an attempt towards summarizing the completed research work and identifying the research gap for further consideration by the researchers.

In Pakistan, construction companies are reluctant to share the accident statistics; however fatalities are mostly reported due to the fear of litigation (Choudhry et al. 2008; Mohamed, 2002). Higher unemployment ratio, unawareness and illiteracy rate force the workers to work under unfavorable site conditions. Fall from height is key cause of construction accidents (Choudhry et al. 2014). PEC Contractors' selection criterion is only based on financial strength and not the safety performance. Though PEC has incorporated safety clauses in its contract documents, they are not enforced due to the absence of a regulatory authority. PEC is also conducting CPD webinars and seminars to create awareness among its graduate members; however no attention is paid towards workers' training. PEC is recommended to: launch safety awareness campaigns; establish *OH&S regulatory authority*; revise the contracting and bidding documents for provision of safety budget by the clients; incorporate safety credit points in the contractors' selection criteria; and establish an effective accident reporting and investigation mechanism. Future research directions have also been recommended for actuating the research process in the field of construction safety in Pakistan.

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References

Ahmed, S.M. (2013). "A strategic framework to improve construction safety practices in Pakistan". *International Conference, "Safety, Construction Engineering & Project Management (ICSCEPM-2013)"*. Islamabad, 9-17.

Ahmed, S.M., Kwan, J.C., Ming, F.Y.W. (2000). "Site safety management in Hong Kong". *Journal of Management in Engineering*, 16(6), 34-42.

Ali, T.H. (2006). "Influence of national culture on construction safety climate in Pakistan". *Doctoral Dissertation*, Griffith University, Gold Coast Campus, Australia.

Chan, A.P.C., Wong, F.K., Chan, D.W., Yam, M.C., Kwok, A.W., Lam, E.W., and Cheung, E. (2008). "Work at height fatalities in the repair, maintenance, alteration, and addition works". *Journal of construction engineering and management*, *134*(7), 527-535.

Choudhry, R.M., Tariq, B., and Gabriel, H.F. (2014). "Investigation of fall protection practices in the construction industry of Pakistan". In *CIB W099 International Health and Safety Conference,"Achieving Sustainable Construction Health and Safety", 2-3 June*, Sweden, 211–221.

Choudhry, R.M., Ahmad, W., Azhar, S., and Hinze, J.H. (2012). "Safety management practices in the construction industry of Pakistan". *3rd International Conference on Construction in Developing Countries (ICCIDC-III).* 4-6 July 2012, Bangkok, 314-319.

Choudhry, R.M., and Masood, R. (2011). "Assessment of multi-level safety climates of working groups to drive perceptual unification". *Proceedings of CIB W099 International Conference on "Prevention: Means to the End of S&H Injuries, Illnesses and Fatalities".* Washington, D.C. USA.

Choudhry, R.M., Fang, D., and Lingard, H. (2009). "Measuring safety climate of a construction Company". *Journal of Construction Engineering and Management*, 135 (9), 890-899.

Choudhry, R.M., Fang, D., and Rowlinson, S. (2008). "Challenging and enforcing safety management in developing countries: A strategy". *International Journal of Construction Management*, 87-101.

Choudhry, R.M., Rowlinson, S., and Fang, D. (2006). "Safety management - Rules, regulations and their implementation in developing countries". *CIB W099 International Conference on "Global Unity for Safety & Health in Construction"*. Beijing, 28-30 June 2006, 482-493.

CIWCE. *The Centre for Improvement of Working Conditions & Environment, Government of Punjab.* Online at http://goo.gl/X3EAA5, Accessed on April 23, 2015.

Directorate of Workers Education (DWE), *Ministry of Capital Administration & Development.* Online at http://goo.gl/O9un2k, Accessed on April 25, 2015.

Farooqui, R.U. (2012). "An exploratory study probing into the factors causing safety Non-Performance in the Pakistani construction industry". *45th Convention of Institute of Engineers, Pakistan.*

Farooqui, R.U., Ahmed, S.M. and Lodi, S.H. (2008a). "Assessment of Pakistani construction industry – Current performance and the way forward". *Journal for the Advancement of Performance Information and Value*. 1(1), 51-72.

Farooqui, R.U., Arif, F., and Rafeeqi, S.F.A. (2008b). "Safety performance in construction industry of Pakistan". *In 1st International Conference on Construction in Developing Countries (ICCIDC-I)*, Karachi, 74-87.

Farooqui, R.U., Ahmed, S.M., and Panthi, K. (2007). "Developing safety culture in Pakistani construction industry - An assessment of perceptions and practices among construction contractors". *In proceedings of 4th International Conference on Construction in the 21st Century (CITC-IV)*, Gold Coast, 420-437.

Haider, Z., Choudhry, R.M., and Aslam, M. (2013). "Analyzing safety training needs of construction industry in Pakistan". *International Conference, "Safety, Construction Engineering & Project Management (ICSCEPM-2013)"*. Islamabad, 90-95.

Hassan S.A. (2012). "Health, Safety and Environmental practices in the Construction sector of Pakistan". *Masters Dissertation*, Uppsala University, Sweden.

Hinze, J.W. (2000). *Incurring the costs of injuries versus investing in safety*. Chapter 2: Construction Safety and Health Management, (Ed.), Prentice Hall, New Jersey.

Jafri, S.F., Rao, Z.I., and Sheeraz, K. (2012). "Policy formulation of construction safety associated with labor requirements - Substantial approach for the metropolitan city, Karachi, Pakistan". *IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE).* 1(1)1-6.

Jafri, S.F. (2012). "Safety and security policies, pre and planned construction phase". *3rd International Conference on Construction in Developing Countries (ICCIDC-III).* 4-6 July 2012, Bangkok.

Khan, A.A., Ajmal, S., and Farooqui, R.U. (2013a). "Investigation of labor and management perception, commitment and attitude towards safety". *International Conference, "Safety, Construction Engineering & Project Management (ICSCEPM-2013)"*. Islamabad, 78-83.

Khan, M.I. (2013b). "Developing a safety culture in developing countries". *International Conference, "Safety, Construction Engineering & Project Management (ICSCEPM-2013)"*. Islamabad, 26-31.

Masood, R., Mujtaba, B., Khan, M.A., Mubin, S., Shafique, F., and Zahoor, H. (2014). "Investigation for safety performance indicators on construction projects". *Science International*, *26*(3) 1403-1408.

Masood, R., Choudhry, R.M., Riaz, Z., Waseem, U., Khursheed, N., and Khan, M.Z.A. (2012a). "Strengthen the formal education of construction safety for civil engineers- Bridging the gap". *CIB W099 International Conference "Modeling and Building Health and Safety".* Singapore, 10-11 September 2012, 290-302.

Masood, R., Choudhry, R.M., Riaz, Z., Azhar, S., and Hinze, J.W. (2012b). "Role of managers in establishment of construction safety culture". *CIB W099 International Conference "Modeling and Building Health and Safety".* Singapore, 10-11 September 2012, 651-659.

Masood, R., Farooqui, R.U., Choudhry, R.M., Riaz, Z., and Munir, Y. (2012c). "Analyzing Health and Safety (H&S) policy to evaluate top management commitment level". *CIB W099 International Conference "Modeling and Building Health and Safety".* Singapore, 10-11 September 2012, 721-731.

McDonald, N., and Hrymak, V. (2001). "Safety behaviour in the construction industry". *Report to the Health and Safety Authority (Dublin) and the Health and Safety Executive (Northern Ireland).*

Memon, Z.A., Khatri, K.L., and Memon, A.B. (2013). "Identifying the critical factors affecting safety program performance for construction projects within Pakistan construction industry". *Mehran University Research Journal of Engineering & Technology, Pakistan.* 32(2) 269-276.

Mohamed, S., Ali, T.H., and Tam, W.Y.V. (2009). "National culture and safe work behaviour of construction workers in Pakistan". *Safety Science*, 47, 29-35.

Mohamed, S., and Ali, T.H. (2005). "Safety behavior in the construction industry in Pakistan". *CIB 021, 47th Triennial International Conference, "Rethinking and Revitalizing Construction Safety, Health, environment and Quality",* South Africa. 17-20 May 2005, 64-74.

Mohamed, S. (2002). "Safety climate in construction site environments". *Journal of Construction Engineering and Management.* 128 (5), 375-384.

Nawaz, T., Ishaq, A., and Ikram, A.A. (2013). "Trends of safety performance in construction and civil Engineering projects in Pakistan". *Civil and Environmental Research, 3(5)*23-40.

OSALP. *Occupational Safety and Loss Prevention*. Online at http://www.osalp.com.pk/safety/, Accessed on April 14, 2015.

OTI. *Occupational Training Institute.* Online at http://www.oti.com.pk/index.htm, Accessed on May 14, 2015.

PBS (2012-2013). Pakistan Bureau of Statistics - Labour Force Statistics. Online at http://goo.gl/BGIoZu, Accessed on April 14, 2015.

PBS (2010-2011). Pakistan Bureau of Statistics - Labour Force Statistics. Online at http://goo.gl/CmJSYb, Accessed on May 18, 2015.

PEC (2007). "Pakistan Engineering Council (PEC) Standard form of bidding documents". Online at http://goo.gl/b7yzgb, Accessed on April 25, 2015.

Qazi, A., Ye, L., and Choudhry, R.M. (2006). "Demand and awareness of construction safety in Pakistan". *CIB W099 International Conference on "Global Unity for Safety & Health in Construction".* Beijing, 28-30 June 2006, 470-475.

Raheem, A.A., and Hinze, J.W. (2013a). "Improving the existing regulatory infrastructure for worker safety in the construction industry of Pakistan". *International Conference, "Safety, Construction Engineering & Project Management (ICSCEPM-2013)".* Islamabad, 72-77.

Raheem, A.A., and Hinze, J.W. (2013b). "Understanding the safety culture of construction companies in Pakistan by analyzing safety policy manuals". *International Conference, "Safety, Construction Engineering & Project Management (ICSCEPM-2013)".* Islamabad, 66-71.

Raheem, A.A., Hinze, J.W., and Azhar, S. (2012). "Injury/fatality data collection needs for developing countries". *3rd International Conference on Construction in Developing Countries (ICCIDC-III).* 4-6 July 2012, Bangkok, 308-313.

Raheem, A.A., and Hinze, J.W. (2012). "Reasons for the poor implementation of worker safety in the construction industry of Pakistan: A contractor's Prospective". *CIB W099 International Conference "Modeling and Building Health and Safety".* Singapore, 10-11 September 2012, 54-63.

Raheem, A.A., Hinze, J.W., Azhar, S., Choudhry R.M., and Riaz, Z. (2011). "Comparative analysis of construction safety in Asian developing countries". 6th *International Conference on Construction in 21st Century (CITC-VI) "Construction Challenges in New Decade" July 5-7, Kuala Lumpur.* 14-21.

Riaz, Z., Arslan, M., Kiani, A.K., and Azhar, S. (2014). "CoSMoS: A BIM and wireless sensor based integrated solution for worker safety in confined spaces". *Automation in Construction*, *45*, 96–106.

Saqib, M., Farooqui R.U, Saleem, F., and Lodi S.H. (2010). "Developing safety culture in Pakistani construction industry - Site safety implementation and safety performance improvement". *2nd International Conference on Construction In Developing Countries (ICCIDC-II)*, August 3-5, 2010. Cairo. 376-383.

VIOSH. Vivid Institute of Occupational Safety and Health. Online at http://www.vividpk.com/contact-us.html, Accessed on May 20, 2015.

Zahoor, H., Chan, A.P.C., Utama, W.P., and Gao, R. (2015). "A research framework for investigating the relationship between safety climate and safety performance in the construction of multi-storey buildings in Pakistan". *International Conference on Sustainable Design, Engineering and Construction (ICSDEC-2015).* Chicago, 11-13 May.

Zahoor, H., and Choudhry, R.M. (2012). "The most neglected construction safety practices in Rawalpindi/Islamabad". *CIB W099 International Conference "Modeling and Building Health and Safety".* Singapore, 10-11 September 2012, 312-322. Online at http://goo.gl/bpwghH, Accessed on April 11, 2015.

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Developing An Expert System for Controlling Cost and Time Overrun (ESCCTO) in Construction Projects

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Abstract
Nowadays Artificial Intelligence especially Expert System is used in the fields of Science, Engineering, Business, Manufacturing, Management, Construction Management and many others. This paper delineates development of an Expert System Frame-Work for controlling time & cost overruns in construction project. The purpose of this paper is to assess the significant level of causative factors of cost and time overrun on project success throughout the lifecycle of construction process. Expert system will be completely attached with the whole project schedule to the approximate outcome of the causative factors, which are not properly controlled. This will be goaled by applying the techniques of artificial intelligence, such as rule based system and case based system. The purpose of system will also be capable for suggesting the mitigation measures for controlling the causative factors. In the last various reports can be made up for controlling the causative factors of cost and time overrun by applying the appropriate mitigation measures.

Keywords
Artificial Intelligence, Expert System, Time Overrun, Cost Overrun, Significant Factors.

1. Introduction

A project can be successful by measuring of different ways of performance such as time, cost, quality etc. Atkinson (1999), expressed that cost, time in addition with quality assists on Iron Triangle to meet a project successful . Time in addition to cost performance will be the most important warning regarding project accomplishment . It shows not only the productivity of an organization but also firm's profitability throughout any construction project. It can be witnessed and always used to achieve the estimated performance of the project.

However, poor cost and time performance makes a construction project un capable to complete with its estimated time and budget. This persistent issue is increasing to critical condition and it can be observed worldwide. A research work regarding the cost overrun issues was conducted by Flyvbjerg et al. (2003), throughout the world in which they found that 9 out of 10 projects suffer with an average of more than 28% cost escalation . The issue of poor performance of cost and time overrun is frequent issue in both developed and developing countries like USA, UK, Portugal, Malaysia, Pakistan and others. The succeeding section presents literature review of some previous studies related to cost and time overrun.

2. Literature Review

In 1994, a study in usa was conducted. It showed that only 16% of the projects were according to the criteria of cost, time and quality . A case study on four projects on cost performance was conducted by chang (2002), it identified that 12.3% to 51.3% projects were facing cost overrun problem, which is an average of 24.8% of a contract . In contrast, barrick, (1995) studied throughout the uk, that almost a third of the owners' complaints that their own projects usually overrun funds . Even more, Department of Environment, Transport and the Regions (DETR, 2000) stated that 55% of projects experienced a huge amount of cost overrun . An audit report between 1985 and 2002 was published by National Court of Audit Portugal (NACL, 2000) as summarize by (Moura, Teixeira, & Pires, 2007). It included cost effectiveness of 26 motorway and 98 expo projects. The report of these projects showed that 35% of motorway and 41% of expo projects had cost overrun . Construction industry is facing the common issues of cost and time overrun problems . In 2008 Malaysian Auditor General highlighted report which reviewed by other researchers (Khamidi, Khan, & Idrus, 2011). It reported that RM 1.43 billion cost overrun in the completion of double track electrified project between Rawang and Ipoh . A total of 359 projects were analyzed by Endut et al. (2009), in which they found 46.80% projects completed within the estimated budget and remaining projects faced cost overrun . Moreover, a research conducted by Abdullah et al. (2009) in the Majlis Amanah Rakyat (MARA) large construction projects, revealed that more than 90% of MARA large construction projects experiencing delay since 1984 with major effects of time and cost overrun . Like other countries, cost and time overrun are common problem in construction projects of Pakistan. A Research study conducted by Nida Azhar et. el. (2008) mentioned that cost overrun is the major problem in Pakistan. Every construction project exceed 100% of its time and budget . Recently a research study was conducted on time overrun in construction projects by Saiful Haq et al. (2014), which revealed that 99% of construction projects delay due to the time overrun. This indicates that the construction projects are mostly facing the problem of poor time and cost performance and it must be addressed .

3. Factors Affecting Cost and Time Overrun in Construction Projects

Several factors and reasons can cause delays in construction projects or cost overrun issues. Construction performance in terms of time and cost is prone to risk due to several governing factors. Hence, comprehensive literature review on causative risk factors regarding time and cost overrun is carried out to understand these issues. Various researchers have highlighted number of factors which basically become the cause for time and cost overrun. It's quite important to control these factors to limit the cost and time overrun.

In 2006, Assaf and Al-Hejji studied the reasons for delays in huge construction projects in Saudi Arabia and revealed the utmost important causes of delay, that includes the change orders by owner during construction, delay in progress payments, ineffective planning and scheduling by contractor, poor site management and supervision by contractor, shortage of labors, difficulties in financing by contractor, changes in government regulations, traffic control and restrictions at site, effect of social and cultural factors and accidents during construction .

A questionnaire survey was conducted by Frimpong et al. (2003). It consisted of 26 factors to study major contributors of cost overrun in groundwater drilling projects in Ghana. Out of 26 factors considered, top 10 factors are monthly payment difficulties, poor contract management, material procurement, inflation, contractor's financial difficulties, escalation of material prices, cash flow during construction, planning and scheduling deficiencies, bad weather and deficiencies in cost estimates prepared . Time overrun issues in construction building projects in Ghana from views of clients, consultants and contractors were focused by Fugar and Agyakwah-Baah (2010), Time overrun factors which influenced much, were delay in honoring certificates, underestimation of the cost of project, underestimation of complexity of project, difficulty in accessing bank credit, poor supervision, underestimation of time for completion of projects by contractors, shortage of materials, poor professional management, fluctuation of prices/rising cost of materials and poor site management .

The causes of construction delay in traditional contracts in Jordan were studied by Odeh and Battaineh (2002). The major causes which were found by the authors includes owner interference, inadequate contractor experience, financing and payments of completed work, labor productivity, site management, slow decision making, construction methods, improper planning and subcontractors . Later, through Sweis et al. (2008), it came to be known that all of the respondents (i.e. clients, contractors, consultants). Too many change orders from owner and poor planning and scheduling are the main critical causes of consultant's part. The shortage of manpower and too many orders from owner were major causes of time overrun in view of contractors. While incompetent technical staff working on the project, poor planning and scheduling done are the most critical factors in view of owners . Le-Hoai et al. (2008) studied the causes of time and cost overrun in large construction project of Vietnam using questionnaire survey. It included 21 causative factors and top 5 common and intense causes of cost overrun were poor site management and supervision, poor project management assistance, financial difficulties of owner, financial difficulties of contractor; design changes .

In UK, Jackson(2002) studied the reasons of budget overrun through questionnaire survey and found that major reasons of overrun were design changes, design development factors, information availability, method of estimation, performance of design team and project management . Another investigation was carried out by Olawale & Sun (2010) for finding time and cost overrun factors through an administered questionnaire and found that cost control inhibiting factors were (in ranking order) design changes, risk and uncertainty associated with projects, inaccurate evaluation of project's time/duration, non-performance of subcontractors and nominated suppliers, complexity of works, conflict between project parties, discrepancies in contract documentation, contract and specification interpretation disagreement, inflation of prices, financing and payment for completed works, lack of proper training and experience of project manager, low skilled manpower, unpredictable weather conditions, dependency on imported materials, lack of appropriate software, unstable interest rate, fluctuation of currency/exchange rate, weak regulation and control, project fraud and corruption, and unstable government policies .

Schedule delay was identified as the major reason of cost overrun; as found in summary of Malaysians Auditor General 2008 report by Khamidi et al. (2011). Ali & Kamaruzzaman, (2010) conducted a study to identify main causes of cost overrun in large building projects in Klang Valley and found that major factors contributing to cost overrun included inaccurate or poor estimation of original cost, inflation of project costs, improper planning, fluctuation in price of raw materials, poor project management, lack of experience, obsolete or unsuitable construction equipments and methods, unforeseen site conditions, mistake in design, insufficient fund, poor contract management, high cost of machineries, and construction cost underestimation . In 2007, Alaghbari et al, the problems of time overrun and were studied and found that the top ten important factors included financial difficulties by owner, financial problems by contractor, supervision too late, slowness in making decisions and slow give instructions by consultant, lack of material by external factor, poor site management, materials shortage, construction mistakes and delay delivery of materials by contractor, slowness making decision by owner, lack of experience and incomplete documents by consultant . Another study by Sambasivan and Soon (2007) revealed the most important causes of time overrun and those were contractor's improper planning, mistakes during construction stage, inadequate contractor experience, inadequate client's finance and payments for completed work and lack of communication between parties .

In 2008, Nida Azhar et al, conducted a research concerning the Pakistan's construction industry to identify the major causes of cost overrun and determined major factors of contributing the cost overrun including the fluctuation in prices of raw materials, unstable cost of manufactured, management/ poor cost control, delays between design and procurement phases, incorrect/ inappropriate methods of cost estimation, additional work, improper planning, and unsupportive government policies, materials, high cost of machineries, lowest bidding procurement procedures, poor project (site) .

Later Naeem Ejaz et al. (2013) studied that these are the main causes of time and cost overrun in Pakistan construction projects. The authors identified escalation of material prices, inadequate control procedure, shortage of technical persons, delays in work approval and shortage of materials, plant/equipment are most critical factor of time and cost overrun . These factors of time and cost overrun throughout the world in construction projects are the part of the whole literature review. On the basis of this comprehensive literature review 27 common factors of time and cost overrun are identified, which are shown in table 1.

Table 1: Mapping Factors Affecting Cost and Time Overrun

No.	Factors Affecting Time and Cost Overrun	Origin
1	Change orders by owner during construction	Fugar and Agyakwah - Baah (2010), Sweis et al. (2008), Le-Hoai et al. (2008).
2	Delay in progress payments	Assaf and Al-Hejji (2006), Frimpong et al. (2003), Odeh and Battaineh (2002).
3	Ineffective planning and scheduling by contractor	Assaf and Al-Hejji (2006), Sweis et al. (2008).
4	Poor site management and supervision	Frimpong et al. (2003), Assaf and Al-Hejji (2006), Fugar and Agyakwah - Baah (2010), Le-Hoai et al. (2008).
5	Shortage of labors	Assaf and Al-Hejji (2006), Odeh and Battaineh (2002), Naeem Ejaz et al. (2013).
6	Difficulties in financing by contractor	Assaf and Al-Hejji (2006), Frimpong et al. (2003), Fugar and Agyakwah - Baah (2010), Odeh and Battaineh (2002), Le-Hoai et al. (2008).
7	Changes in government regulations	Assaf and Al-Hejji (2006), Olawale & Sun (2010).
9	Material procurement	Frimpong et al. (2003), Assaf and Al-Hejji (2006).
10	Escalation of material prices	Frimpong et al. (2003), Fugar and Agyakwah - Baah (2010), Olawale & Sun (2010), Khamidi, Khan, & Idrus, (2011).
11	Unpredictable weather	Frimpong et al. (2003), Olawale & Sun (2010),
12	Shortage of material	Assaf and Al-Hejji (2006), Fugar and Agyakwah - Baah (2010), Olawale & Sun (2010).

13	Inadequate contract experience	Odeh and Battaineh (2002), Sweis et al. (2008), Sambasivan and Soon (2007).
14	Improper planning and subcontractor	Odeh and Battaineh (2002), Olawale & Sun (2010), Khamidi, Khan, & Idrus, (2011), Sambasivan and Soon (2007), Nida Azhar et. el. (2008).
15	Incompetent technical staff	Sweis et al. (2008), Olawale & Sun (2010), Alaghbari et al. (2007).
16	Design Changes	Le-Hoai et al. (2008), Jackson (2002), Olawale & Sun (2010), Khamidi, Khan, & Idrus, (2011).
17	Conflicts between project parties	Olawale & Sun (2010), Khamidi, Khan, & Idrus, (2011).
18	Lack of appropriate software	Olawale & Sun (2010), Alaghbari et al. (2007).
19	Lack of experience	Khamidi, Khan, & Idrus, (2011), Alaghbari et al. (2007).
20	Mistakes in design during construction	Khamidi, Khan, & Idrus, (2011), Alaghbari et al. (2007), Sambasivan and Soon (2007).
21	Lack of communication between parties	Sambasivan and Soon (2007), Olawale & Sun (2010).
22	Delays between design and procurement phases	Olawale & Sun (2010), Nida Azhar et. el. (2008).
23	Inappropriate cost estimation methods	Olawale & Sun (2010), Nida Azhar et. el. (2008).
24	Unsupportive government policies	Olawale & Sun (2010), Nida Azhar et. el. (2008), Sambasivan and Soon (2007).
25	High cost of machineries	Nida Azhar et. el. (2008), Sambasivan and Soon (2007).
26	Inadequate control procedure	Nida Azhar et. el. (2008), Naeem Ejaz et al. (2013).
27	Delays in approval of documentation	Olawale & Sun (2010), Alaghbari et al. (2007).

4. Expert System for Controlling Cost and Time Overrun (ESCCTO)

The purpose of “ESCCTO” is to provide a user interface friendly system for determining the various causative factors of time and cost overrun performance; it will also be able to suggest the possible mitigation measures for controlling the time and cost overrun factors. Following tasks are involved in developing the ESCCTO.

1. Determining the causative factor of time and cost overrun in each phase of construction project life cycle.
2. Determining the significant level of causative factor through (SPSS) Statistical Package for Social Science.
3. Incorporating expert system in proposing mitigation measures for controlling causative factors of time and cost overrun.

This research will use quantitative and qualitative approach in determining the causative factors of time and cost overrun in each phase of construction project life cycle. The data will be analyzed by using SPSS. The key fulfillment of this research is incorporating the expert system with experience based mitigation measure for controlling the identified/ expected causative factor of time and cost overrun.

4.1 Conceptual Frame-Work of ESCCTO

For determining the various causative factors of time and cost overrun, ESCCTO will provide a user interface friendly system and this system will also support the users in suggesting the mitigation measures of the causative factors. The figure 1: is shows the conceptual Frame-Work of ESCCTO system.

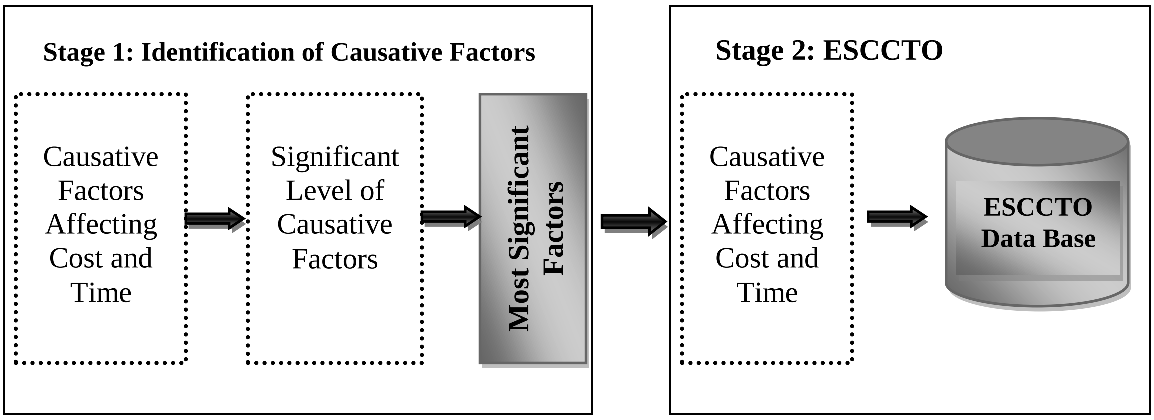

Figure 1: Conceptual Frame-Work of ESCCTO

The conceptual frame-work of ESCCTO is divided in two stages as explained bellow;

Stage 1: Give the clear image of the determining the causative factors of time and cost overrun. This will be completed through quantitative approach technique using questionnaire survey and interviews with the experts involved in construction projects. From that stage users will be capable to find out the significant factors of cost and time overrun for exploring the mitigation measures.

Stage 2: A data base of mitigation measures will be developed on the basis of the causative factors. The expert system will help in selecting the most appropriate measure from the data base to control the causative factors of cost and time overrun.

5. Conclusion

This research study is presenting a conceptual frame work of software development for controlling the problem of time and cost overrun is faced by construction industry since decades. As mentioned most of the construction projects throughout the world are concerned with time and cost overrun. These overruns are the outcome of various causative factors which are the main barriers to project completion. ESCCTO – frame work will be able in determining the various causative factors in affecting the project time and cost. On the basis of determined factors the proposed system will be capable to suggest the mitigation measure for controlling the causative factors of time and cost overrun and consequently improve the project performance.

5. Reference

Abdullah, MR, AA Abdul Azis, and I Abdul Rahman. "Causes of Delay and Its Effects in Large Mara Construction Project." *International journal of Integrated Engineering (Issue on Mechanical, Materials and Manufacturing Engineering)* (2009).

Alaghbari, Wa'el, Mohd Razali A Kadir, and Azizah Salim. "The Significant Factors Causing Delay of Building Construction Projects in Malaysia." *Engineering, Construction and Architectural Management* 14, no. 2 (2007): 192-206.

Ali, AS, and SN Kamaruzzaman. "Cost Performance for Building Construction Projects in Klang Valley." *Journal of Building performance* 1, no. 1 (2010).

Assaf, Sadi A, and Sadiq Al-Hejji. "Causes of Delay in Large Construction Projects." *International Journal of Project Management* 24, no. 4 (2006): 349-57.

Atkinson, Roger. "Project Management: Cost, Time and Quality, Two Best Guesses and a Phenomenon, Its Time to Accept Other Success Criteria." *International journal of project management* 17, no. 6 (1999): 337-42.

Azhar, Nida, Rizwan U Farooqui, and Syed M Ahmed. "Cost Overrun Factors in Construction Industry of Pakistan." Paper presented at the First International Conference on Construction In Developing Countries (ICCIDC–I), Advancing and Integrating Construction Education, Research & Practice, 2008, 499-508.

Barrick, A. . "Poll Reveals One in Three Jobs Late. Building, 28 July, 10." (1995).

Chang, A. S.-T. , and "Reasons for Cost and Schedule Increase for Engineering Design Projects." *Journal of Management in Engineering* 18, no. (1) (2002): 29–36.

Ejaz, Naeem, Imran Ali, and Muhammad Fiaz Tahir. "Assessment of Delays and Cost Overruns During Construction Projects in Pakistan." (2013).

Endut, Intan Rohani, Akintola Akintoye, and John Kelly. "Cost and Time Overruns of Projects in Malaysia." *retrieved on August* 21 (2009): 243-52.

Flyvbjerg, Bent, Mette K Skamris Holm, and Søren L Buhl. "How Common and How Large Are Cost Overruns in Transport Infrastructure Projects?". *Transport Reviews* 23, no. 1 (2003): 71-88.

Frame, JD. "Establishing Project Risk Assessment Teams." *Kähkönen K. and Artto KA (eds.) Managing Risks in Projects, St. Edmunsbury Press Ltd., Suffolk, UK* (1997): 22-27.

Frimpong, Yaw, Jacob Oluwoye, and Lynn Crawford. "Causes of Delay and Cost Overruns in Construction of Groundwater Projects in a Developing Countries; Ghana as a Case Study." *International Journal of Project Management* 21, no. 5 (2003): 321-26.

Fugar, Frank DK, and Adwoa B Agyakwah-Baah. "Delays in Building Construction Projects in Ghana." *Australasian Journal of Construction Economics and Building* 10, no. 1/2 (2010): 103-16.

Hamzah, N, MA Khoiry, I Arshad, NM Tawil, and AI Che Ani. "Cause of Construction Delay-Theoretical Framework." *Procedia Engineering* 20 (2011): 490-95.

Haq, Saiful, Yahya Rashid, and Muhammad Shakeel Aslam. "Effects of Delay in Construction Projects of Punjab-Pakistan: An Empirical Study." (2014).

Hussin, Jamilus Md, Ismail Abdul Rahman, and Aftab Hameed Memon. "The Way Forward in Sustainable Construction: Issues and Challenges." *International Journal of Advances in Applied Sciences* 2, no. 1 (2013): 15-24.

Jackson, Simon. "Project Cost Overruns and Risk Management." Paper presented at the Proceedings of Association of Researchers in Construction Management 18th Annual ARCOM Conference, Newcastle, Northumber University, UK, 2002.

Khamidi, Mohd Faris, Waris Ali Khan, and Arazi Idrus. "The Cost Monitoring of Construction Projects through Earned Value Analysis." Paper presented at the International conference on economics and finance research, Singapore, 2011.

Le-Hoai, Long, Young Dai Lee, and Jun Yong Lee. "Delay and Cost Overruns in Vietnam Large Construction Projects: A Comparison with Other Selected Countries." *KSCE journal of civil engineering* 12, no. 6 (2008): 367-77.

Moura, Helder M Pinto, José M Cardoso Teixeira, and Brígida Pires. "Dealing with Cost and Time in the Portuguese Construction Industry." (2007).

Odeh, Abdalla M, and Hussien T Battaineh. "Causes of Construction Delay: Traditional Contracts." *International Journal of Project Management* 20, no. 1 (2002): 67-73.

Olawale, Yakubu Adisa, and Ming Sun. "Cost and Time Control of Construction Projects: Inhibiting Factors and Mitigating Measures in Practice." *Construction Management and Economics* 28, no. 5 (2010): 509-26.

Sambasivan, Murali, and Yau Wen Soon. "Causes and Effects of Delays in Malaysian Construction Industry." *International Journal of Project Management* 25, no. 5 (2007): 517-26.

Sweis, Ghaleb, R Sweis, A Abu Hammad, and A Shboul. "Delays in Construction Projects: The Case of Jordan." *International Journal of Project Management* 26, no. 6 (2008): 665-74.

Study of Merits and Demerits of Appointing the Design Consultant as Supervision Consultant in the Construction Industry in Pakistan

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Abstract
When clients select the contract type, they need to analyze the design work and the supervision work to be arranged. Should it be carried out by a single consulting firm having the required qualification and capacity? This research presents a questionnaire based on a study of merits and demerits of appointing the design consultant as construction supervision consultant in the construction industry in Pakistan. The questionnaire was designed and comprised of five sections of the project phases including the project initiating phase, project planning and design phase, project execution phase, project monitoring and control phase, and project closing phase. Responses of 98 valid questionnaires were analyzed by using the SPSS (Statistical Package for Social Sciences) for Windows software package. The results show that clients, consultants, contractors, and researchers strongly support appointing the same design consultant as supervision consultant. The results indicate that the number of merits for appointing the design consultant as construction supervision consultant in the industry more than doubles the number of demerits of appointing the same design consultant as supervision consultant in the construction industry. Results further indicate that it is not appropriate to employ different professionals on a project for these two services when close coordination is generally required for the successful completion of the same. Research concludes that there is no harm in appointing a third party for proof engineering and design vetting. This work could make a solid contribution for clients, consultants and contractors who desire good services from designers and consultants.

Keywords
Construction Sites, Design, Design Consultant, Supervision Consultants, Project Phases

1. Introduction

In planning and developing a construction project, feasibility studies, planning, design, procurement, construction, supervision, project commissioning, all stages are tightly linked (Yi and Xu, 2011). The project consulting services can cover the whole project lifecycle. The consulting services include counseling services, feasibility studies, detailed design, preparation of contract documents, specialized design and design development, supervision, project management, and program management (Bunni, 2005, p.66-82). Fédération Internationale Des Ingénieurs-Conseils (FIDIC), in 'FIDIC policy statement on selection of consultants', states that consulting engineering industry (CEI) undertakes activities related to planning, designing, constructing, inspecting and managing the infrastructure required for meeting the ever-increasing demands for energy, transportation, shelter, health and water (FIDIC, 2004).

During the selection process, the owner of a project needs to select a responsible consultant or a team of consultants for design and supervision of works (Bunni 2005). Correct selection of a consultant has major bearing on the quality, overall project cost, and on the success of the project as well as on the overall value of the delivered project (FIDIC, 2011a). At the time of organizing the project, the owner or sponsor has questions in front of him i.e. how to manage the design work and the supervision work?

The construction industry of Pakistan is one of the main industries in the country which presents both opportunities and challenges (Choudhry and Iqbal, 2013). There are enormous investment opportunities in the construction industry of the country including heavy engineering construction: dams, highways, airports, ports, power generation plants, irrigation, oil and gas; industrial construction: petroleum refineries, petrochemical plants, manufacturing plants; building construction: hospitals, schools, universities, commercial towers, warehouses, government buildings, recreation centers; residential construction: single-family homes, multi-unit townhouses, high-rise apartments, and condominiums. The construction industry provides 7% of employment which comes after agriculture 43.7%, sales 14.4%, manufacturing 14.1%, and services 13.3% (MOF, 2014). 'FIDIC guidelines for integrity management in consulting' states that one of the important factor in success of a project is obtaining the services of the most competent and experienced consultant (FIDIC, 2011b). Nonetheless, it is not clear how consultants are selected for construction projects. Perhaps, there is little published information available on this topic. This study is conducted to investigate reasons to best hire the consultants for construction projects. Specifically, the objective is to evaluate merits and demerits of appointing the same design consultant as supervision consultant on construction projects for the benefit of stakeholders.

2. Methodology

This is an empirical study reports the results of the questionnaire survey and interviews conducted in the construction industry of Pakistan. A rigorous study was conducted to assimilate the relevant literature (e.g. Oppenheim, 1992; Yin, 1984) in understanding the research domain. The researcher used secondary sources such as journals, reports, previous studies related to the research topic to gather information about the questionnaire. Based on the literature review a questionnaire is designed to collect data. Many ideas about the structure and content of the questionnaire were provided by experts in the industry. The questions introduce the concept to the participants simply and smoothly to achieve the research objectives. Checklist format is used for the development of the questionnaire. The designed questionnaire consisted of 42 questions and comprised of 5 sections outlining project phases including project initiating phase, project planning & design phase, project execution phase, project monitoring & control phase, and project closing phase. Each question has three categories i.e. 'merit', 'demerit', and 'not sure'. Respondents are required to choose only one category out of the three.

A pilot survey is conducted with experts in the industry before finalizing the questionnaire. For this purpose, 12 questionnaires are presented to experts – universities (3), clients (3), consultants (3), and contractors (3), followed by interviews. The questionnaire is further modified by the feedback from the pilot survey to adopt it for the construction industry. A cover letter is attached to the questionnaire for each respondent in order to relay objectives of the survey. Final questionnaire is distributed to engineers and architects for their responses who used to work with firms registered with the Pakistan Engineering Council (PEC, 2013).

For this 40,000 firms registered with PEC, Dillman (2000) reported that a sample size of 61 is enough with ±10% sampling error and 95% confidence level. The judgmental sampling method is used, and questionnaire was sent to 175 top registered firms. Out of the 175 questionnaire sent out, 98 valid responses were analyzed representing a response rate of 56%.

From the 98 valid responses, client response rate was 28.6%, consultants 40.8%, contractors 25.5%, and academia 5.1%. Approximately 46% had over 10 years of experience, 65.3% of the respondents belong to private organization, and 52% of the respondents had acquired MS degree whereas 42.9% had acquired bachelor degree. Of the organizations, 38.8% respondent's organizations employ more than 500 employees and most of respondents were used to work at buildings and infrastructure projects. For the cost of the projects, 63.3% organizations undertook construction projects having cost more than rupees 500 Million (1 US$ = 99.5 rupees).

Twelve interviews were conducted and analyzed. These persons who had accumulated extensive working experience provided valuable information to the researcher. The study used the analytical descriptive method. The collected data were analyzed using the Statistical Package for Social Sciences (SPSS-19) through analysis explained by Pallant (2007). A 0.05% level of significance presents a statistically significant relationship in the data.

3. Results and Analysis

3.1 Ranking of Merits

The results show that by appointing the same design consultant as supervision consultant merits were 61%, demerits 28% and not-sure respondents were 11% (see Figure 1). The results clearly indicate that merits are double to that of demerits of appointing the same design consultant as supervision consultant. Overall 89% respondents were well conversant with the involvement of designer and supervision consultant in the construction industry.

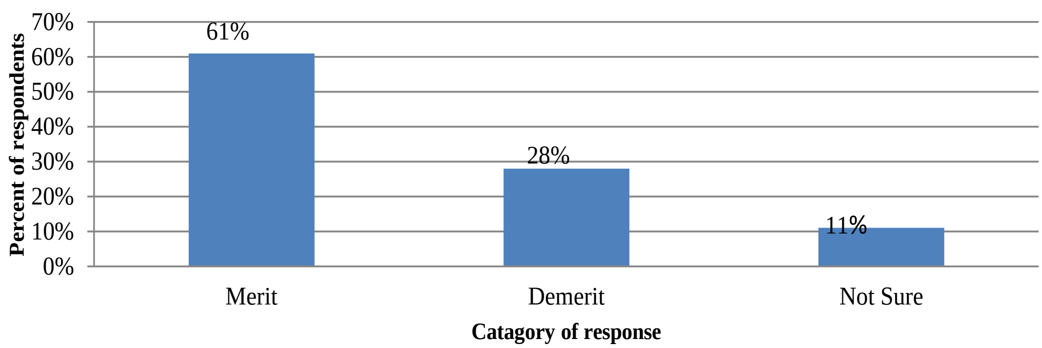

Figure 1: Overall Response by Respondents

Responses show that there were 31 merits and 11 demerits out of 42 questions asked from the respondents. The results indicated that by appointing the same design consultant as the supervision consultant, merits were more than double to that of demerits. Overall response of the respondents related to merit, demerit, and not sure was ranked. Overall response of respondents concerning merit was ranked. The responses with higher percentage were rank as "1". The frequency (percentage) "by appointing the same design consultant as the supervision consultant, there shall be comfortable coordination and communication between the designer and the supervision team" was 90.8% and this factor was ranked as number 1. This indicates that 90.8% of the respondents ranked this issue as the top merit out of the 42 factors. The frequency "by appointing the same design consultants as the supervision consultant, consultants become fully conversant with the project background right from the initial phase of the project" was 87.8% and this factor was ranked at number 2. All 42 factors were ranked according to the frequency in term of merit.

3.2 Ranking of Demerit

Overall responses of the respondents concerning demerits were ranked. The frequency "by appointing the same design consultant as the supervision consultant, domination in the consultant's decision may increase" was 68.4% and this was ranked at the top (68.4%) out of the 42 factors. The frequency "by appointing the same design consultants as the supervision consultant, client can be kept in dark by the consultant concerning quality and defects in the project" was 67.3% and this was ranked at the 2nd position. Similarly all the factors were ranked in terms of demerit.

3.3 Ranking of Not-Sure

Overall response of the respondents concerning "not-sure" category was ranked. The frequency "by appointing the same design consultant as the supervision consultant, consultant-contractor interaction can be considered closely related to protect their rights by the client" was 20.4% and this was ranked at the top from out of the 42 factors. The frequency "by appointing the same design consultants as the supervision consultant, consultancy fee or charges for the consultant can be reduced" was 19.4% and this was ranked at the 2nd position. All the 42 factors were ranked according to their frequency in term of "not-sure" responses.

3.4 Stakeholders Ranking

The results indicate that stakeholders strongly support "appointing the same design consultant as the supervision consultant". The clients indicate that "by appointing the same design consultant as the supervision consultant" merits were 62.76%, demerit 26.70%, and not-sure responses were 10.54%. The consultants indicate that "by appointing the same design consultant as the supervision consultant" merits were 63.15%, demerit 27.86%, and not-sure responses were 8.99%. The contractors show that "by appointing the same design consultant as the supervision consultant" merits were 54.48%, demerit 30.19%, and not-sure responses were 15.33%. The academia and researchers indicate that "by appointing the same design consultant as the supervision consultant" merits were 60.95%, demerit 24.29%, and not-sure responses were 14.76% (see Figure 2). The results indicate that the merits were more than the double to that of the demerits of "appointing the same design consultant as the supervision consultant" in the Pakistan construction industry.

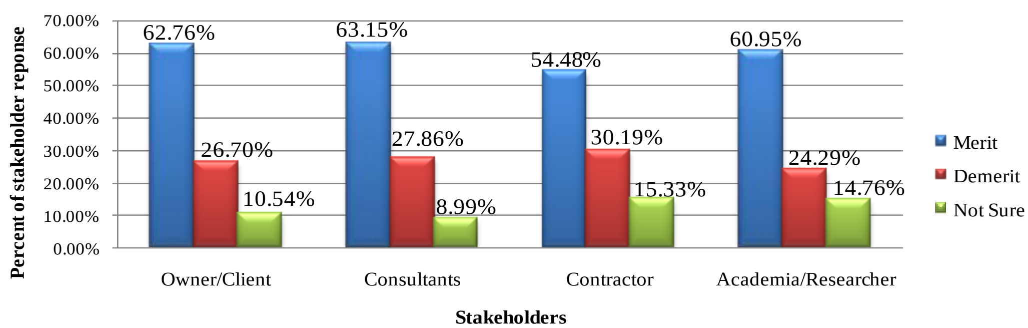

Figure 2: Response by Owners, Consultants, Contractors and Academia

Ratio of merit and demerit for client is 2.35, consultants 2.27, contractor 1.80, and academia & researcher 2.51. Although, the contractors have little low ratio, nonetheless, all stakeholders had almost similar perceptions. The respondents consider that "by having the same design consultant as the supervision consultant" at project initiating phase merits were 84.03%, and they ranked this phase at the top. The respondents consider that "by having the same design consultant as the supervision consultant" at project planning & design phase merits were 65.6%, and they ranked this phase at the 2nd position. Respondents ranked the execution phase; the monitoring & control phase; and closing phase at position 3rd, 4th, and 5th respectively (see Figure 3).

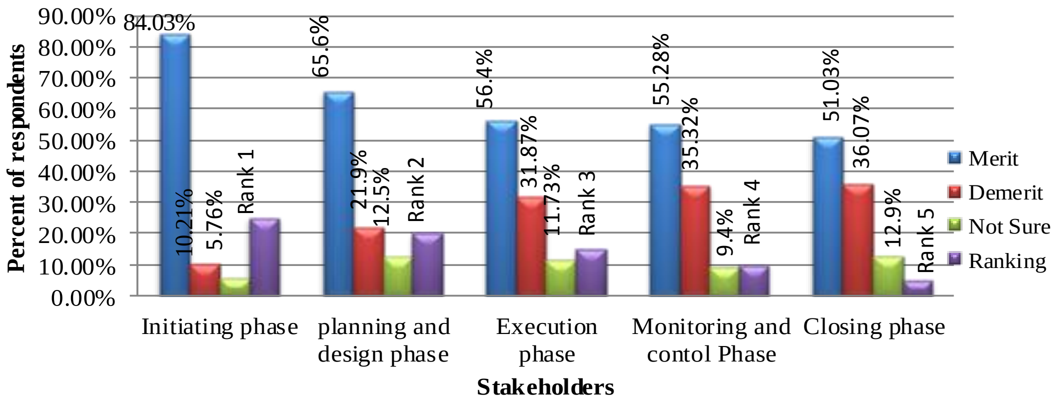

Figure 3: Project Phases and Ranking

4. Discussion

Results of this study clearly indicate that it is appropriate to appoint the same design consultant as the supervision consultant on construction projects. The results showed that majority of the respondents were well conversant with the involvement of consultants in a project. Results indicated that merits were more than double to that of demerits for "appointing the same design consultant as the supervision consultant". In this research, the clients score was 62.76%, consultants 63.15%, contractors 54.48%, and academia 60.95% which indicate that the stakeholders had the high perceptions for "appointing the same design consultant as the supervision consultant" on construction projects.

The response of the respondents for merit at project initiating phase was 84.03%, at project planning & design phase 65.6%, at project execution phase 56.4%, at monitoring & control 55.28%, and at project closing phase 51.03%. These results indicated that respondents had high perceptions for appointing the same design consultant as the supervision consultant during all phases of projects. The results showed that the trend was declining from the project initiating phase towards the project closing phase. This indicates that it is more beneficial to have the same design consultant as the supervision consultant at the project initiating phase as compare to the project closing stage. The authors postulate that there is no harm to appoint a third party for the design vetting, irrespective of whether the same design consultant is appointed as the supervision consultant or vice versa.

5. Conclusions

This work was carried out to investigate whether design work and the supervision work is to be performed by a single consulting firm having the required qualification and capacity. The clients, consultants, contractors and researchers strongly support appointing the same design consultant as the supervision consultant in the construction industry. Stakeholders perceived that it is quite appropriate to have the same design consultant as the supervision consultant at all project phases. Results showed that by appointing the same design consultant as the supervision consultant, merits were more at the project initiating phase as compared to the project closing phase. By appointing the same design consultant as the supervision consultant, the strongest merit is the comfortable coordination and communication between the designer and the supervision team. By appointing the same design consultant as the supervision consultant, the strongest demerit is the domination in the consultant's decisions making. Results indicated that it is not appropriate to employ different professionals on a project for these two services when close coordination is generally required for the successful completion of the project.

6. References

Bunni, N. (2005). "The FIDIC Forms of Contract." 3rd Edition, Wiley Online Library/Blackwell Publishing Ltd.

Choudhry, R. M., and Iqbal, K. (2013). "Identification of risk management system in construction industry in Pakistan." *Journal of Management in Engineering*, Vol.29, No.1, pp 42-49.

Dillman, D. A. (2000). "Mail and Internet Surveys: The Tailored Design Method." 2nd Ed. Wiley, New York.

International Federation of Consulting Engineers (FIDIC). (2004). "Policy Statement on Selection, Engagement and Remuneration of Consulting Engineers." Geneva.

International Federation of Consulting Engineers (FIDIC). (2011a). "Quality Based Consultant Selection Guide." Geneva.

International Federation of Consulting Engineers (FIDIC). (2011b). "Guidelines for Integrity Management in Consulting Industry." 1st Ed., Geneva.

Ministry of Finance (MOF). (2014). "Pakistan Economic Survey 2013-2014." Government of Pakistan, Islamabad, Pakistan.

Oppenheim, A.N. (1992). "Questionnaire Design, Interviewing and Attitude Measurement." Pinter Publisher, London.

Pakistan Engineering Council (PEC). (2013). "Contractors/Firms." http://www.pec.org.pk/ (Jan. 8, 2013)

Pallant, J. (2007). "SPSS Survival Manual: A Step by Step Guide to Data Analysis SPSS for Windows." 3rd Edition, Allen & Unwin, NSW.

Yi, B., and Xu, W. (2011). "Primary study on the combination mode of design and supervision in the construction project consulting service in China." *Journal of Politics and Law*, Vol.4, No. 2, pp 61-66.

Yin, R. K. (1984). "Case Study Research: Design and Methods." Newbury Park, CA: Sage.

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Review Of Financial Practices in Construction Industry of Pakistan

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Abstract
Finance management and time objective restraints are the two main players that become cause of failure of construction industry projects. This research takes in to account the identification of problems faced in financial management and discusses the predominant practices followed for financial management in construction industry of Pakistan. After the collection and analysis of data collected via surveys, it was revealed that financial managers act as the facilitator for the completion of the projects instead of playing part in strategic management and project selection in significant proportion of construction industry. The methods used for monitoring and evaluating financial status of the organization and the company are customized to suite the unique and short - term nature of construction projects.

Keywords
Financial practices; Construction industry; Pakistan; Review

1. Introduction

Construction industry plays a significant role in boosting a county's economy. Financial management practices, in this industry, affects time and cost overcome problems encountered in construction projects. The danger of business failure due to lack of sound financial management practices is real. Gaskill, and VanAuken (1993) has reported that the most internal problems identified by small US firms relate to inadequate capital, cash flow management and inventory control. Berryman, (1983) indicated that 'poor' or 'careless' financial management is a major cause of small business failure.
Deficiencies in financial management have been repeatedly cited as a root cause of business failure (Najak and Greenfield 1994). More construction Companies fail due to a lack of liquidity for supporting their daily activities than because of inadequate management of other resources (Singh and Lakanathan 1992; Navon 1994)
The financial practices of construction industry of Pakistan are matters of consideration of this paper. The goals of the research are the identification of financial management practices in the construction industry of Pakistan. In future, this study can be further extended to recommend benchmarking in financial management practices for construction industry of Pakistan.
The proceeding sections are arranged as follows. Section 2 presents a comprehensive study carried out for identification of general finance management practices which is followed by collection and analysis of

data from Pakistan construction industry via survey questionnaires. Section 3 describes the approach used for this study. Finally, data is compiled and analyzed in section 4. Last section contains the conclusion drawn from the analysis of the collected data from industry.

2. Financial Management

Financial management is concerned with the fund raising needed to finance the enterprise's assets and activities, the allocation of these scare funds between competing projects, and with ensuring that the funds are used efficiently in achieving goals. Financial management practice is classified, by Chung and Chuang (2009) into five areas: capital Structure management, working capital management, financial reporting and analysis, capital budgeting and accounting information system. Ross et al (1999) kept financing decision, decisions concerned to short term finance and decisions involving net working capital, investment and financial reporting, in the decision domain of a Financial Manager.

Use of financial statements, book keeping and financial reports collectively aid in decision making. Project selection is made on the basis of Net present value (NPV), internal rate of return (IRR) and accounting rate of return and payback period. Moreover, with a good cash flow management, industries can be operated with good financial health (Morgan and Tang, 1992; Cowton and Pilz, 1995).

McMahon et al., (1993) summarize their review of financial management practices in Australia, UK and USA. In their review the context of financial management practices included the following areas: accounting information systems, financing decisions, investing decisions. However, these previous researchers, though looked into financial management, they did not include some key areas like working capital management which would include accounts receivable, inventory, cash management and accounts payable management

3. Design of Study

Initially, secondary data that included knowledge about financial management, was collected from research papers and articles, books and journals, and related publications. The data was thoroughly studied and analyzed to prepare questionnaires for primary data of the research.

Primary data was collected through conduct of surveys with the help of survey form that was designed on basis of diagnostic evaluation and qualitative design approach. Survey respondents all key stakeholders from construction industry including clients, design consultants, contractors and construction managers.

Diagnostic evaluation is designed to inform the researcher about the present situation in the organization. It highlights current problems, trends, forces, resources and the positive consequences of various types of interventions. The chosen research design helped the researcher to evaluate the current state of the financial management practices of the construction industry.

Questionnaire was distributed by hand as well as through emails and social networks. In addition to that, Masters students of NED University, who are also associated with construction firms, were also asked to fill the survey.

4. Results

This section presents the results of the survey. Contractors were in majority (67%) among respondents and mostly building contractors (50%).

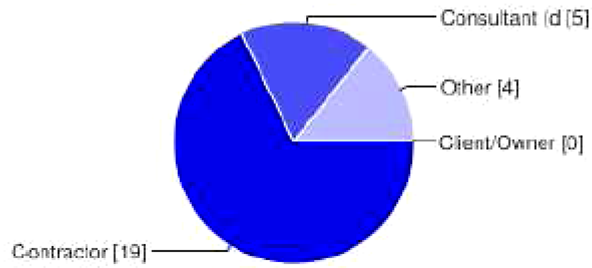


Figure 1: Distribution respondents

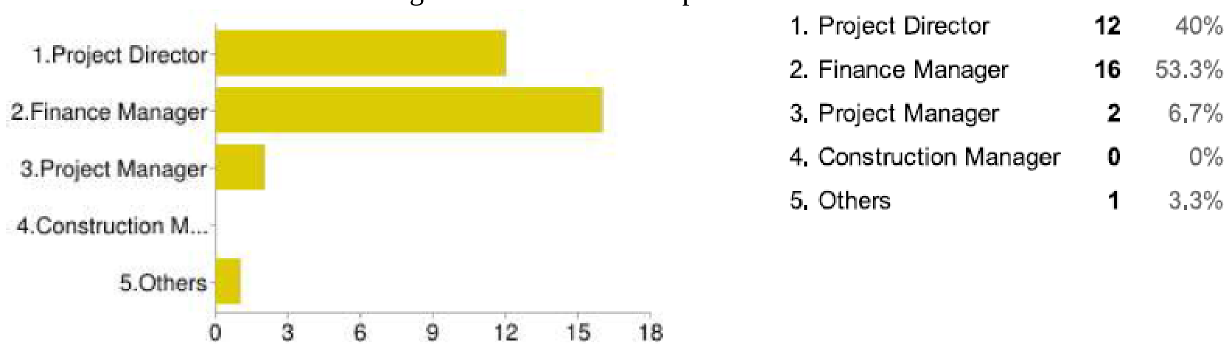


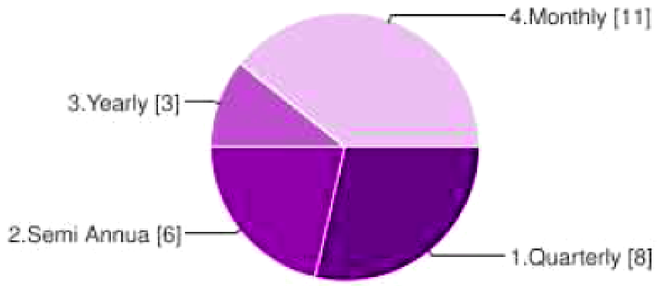
Figure 2: Person responsible for managing project finances

Figure 2 shows that majority of the companies have allocated the responsibility of project finances to their financial managers. However, there is a substantial proportion (46.7%) of companies in which project finances are managed by project related people such project director/manager. These people which have in - depth knowledge for the project may lack the skill and experience required for effective financial management.

Table 1: Responsibilities for person managing project finances

Responsibilities	**Response proportion**
Forecast the costs	34.6%
Assure that project and overheads are accurately tracked	57.7%
Ensuring proper accounting system has been set up and operating properly	26.9%
Ensures that the organization has ample cash to acquire project	26.9%
Devise an income tax projection	11.5%
Arranging finances to cover the need of organization	34.6%
Making financial decisions	19.2%
Allocation of funds in different areas of business	46.2%

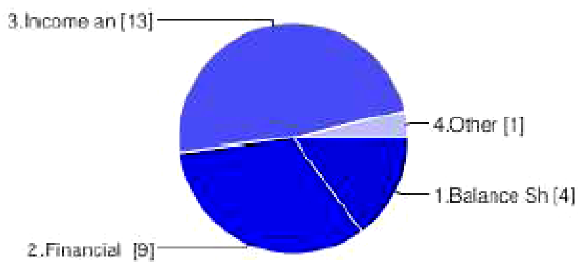
It can be observed from table 1 that person managing the finances of the project mainly acts as the facilitator with often lack decision power. His/her major responsibilities includes tracking the project cost (57.7%), allocation of available funds (46.2%) and arranging finances to carry out routine activities of the business (i.e. construction projects) (34.6%). Financial decision making and dealing with government (in the form of income taxes) is carried out by the owner himself.



1. Quarterly	8	28.6%
2. Semi Annually	6	21.4%
3. Yearly	3	10.7%
4. Monthly	11	39.3%

Figure 3: Forecasting cost of the project

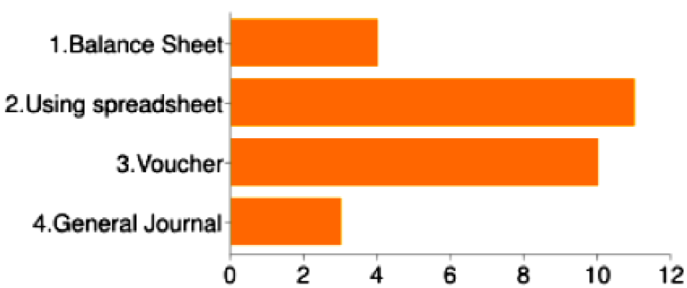
Figure 3 shows that majority of the organizations perform project cost forecasting on short term basis (monthly/quarterly). This feature is different from organizations of other sectors due to the nature of construction projects. These projects often experience significant changes in terms of cost, time and scope, especially in Pakistan where the economic and political conditions are often unstable.



1. Balance Sheet	4	14.8%
2. Financial Statement	9	33.3%
3. Income and profit Loss Statement	13	48.1%
4. Other	1	3.7%

Figure 4: Methods used for evaluating appropriateness of project costs

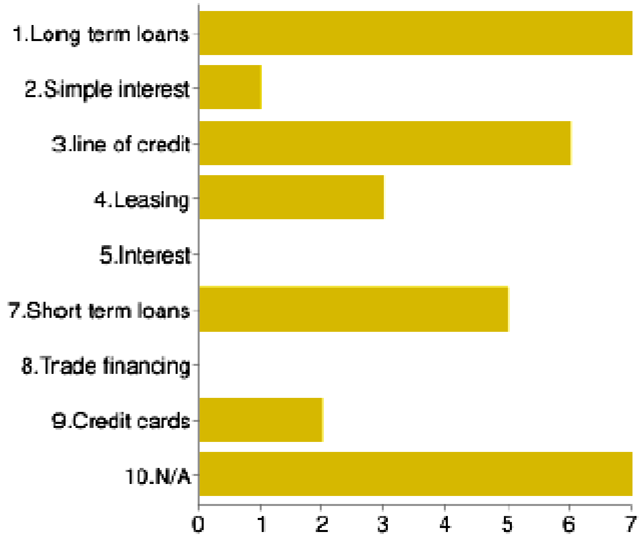
The most commonly used method for determining the appropriateness is project cost is income and profit loss statement, as shown in figure 4. These statements are widely used by organizations working at multiple projects at a time. The other dominant method is financial statement.



1. Balance Sheet	4	14.8%
2. Using spreadsheet	11	40.7%
3. Voucher	10	37%
4. General Journal	3	11.1%

Figure 5: Methods of recording cash flow

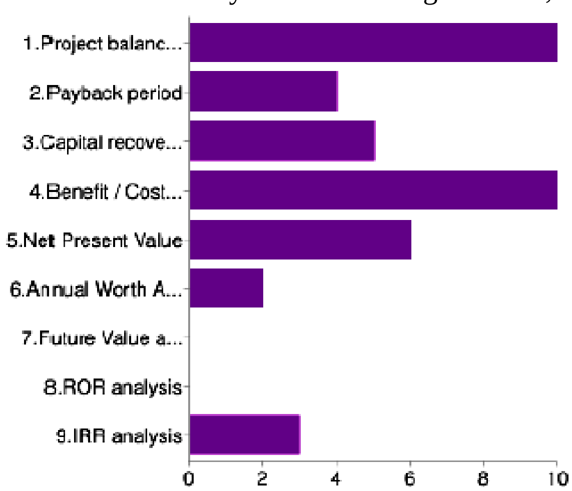
Figure 5 shows that the cash flow for the projects is mainly recorded by using spreadsheets and vouchers. Both these practices are customized according to the organization and nature of project. Other methods, which are more commonly used in other industries such as balance sheets, are implemented by a small proportion of the organizations in construction industry of Pakistan.



1. Long term loans	7	25.9%
2. Simple interest	1	3.7%
3. line of credit	6	22.2%
4. Leasing	3	11.1%
5. Interest	0	0%
7. Short term loans	5	18.5%
8. Trade financing	0	0%
9. Credit cards	2	7.4%
10. N/A	7	25.9%

Figure 6: Methods of project financing

Construction organizations in Pakistan are often run by people who are financially stable from other sources. It can be observed from figure 6 that more than 50% of the projects are financed by the organization itself or through long – term loans. Even in the case of long – term loans, the creditor will ensure the credibility of the liable organization, which can only happen if it is financially sound.



1. Project balance analysis	10	38.5%
2. Payback period	4	15.4%
3. Capital recovery with return on investment	5	19.2%
4. Benefit / Cost Ratio	10	38.5%
5. Net Present Value	6	23.1%
6. Annual Worth Analysis (EUAC)	2	7.7%
7. Future Value analysis	0	0%
8. ROR analysis	0	0%
9. IRR analysis	3	11.5%

Figure 7: Financial tools for decision making

Among the financial tools for decision making, balance analysis and benefit/cost ratio are more commonly implemented by construction organizations in Pakistan. This is evident from figure 7. As stated above, many organizations rely on self – funding or long – term loans for project financing. Hence the financial tools which are usually applied for strategic planning of organizations, including IRR analysis, future value analysis and pay back period are not applied commonly. Possible reasons for this could be that most of the construction organizations are looking to generate short – term benefits from the project rather than long – term strategic goals.

5. Conclusions

Construction projects are unique in nature and often involve huge investments. Financial management of construction organizations affects the time, cost and scope of the project. This study was conducted to determine the financial practices in construction organizations of Pakistan.

The results of the study showed that the role of financial managers is mostly as the facilitator of the projects rather than investment decision making for the organization. The organizations are often run by financially sound professionals who often depend on self – finances for project costs. The tracking and evaluating mechanism for project costs are also set to be used by the project managers/directors instead of financial managers. Hence, their nature is also different from the commonly used financial tools in other industries. These trends have resulted in lack of strategic planning in construction sector in Pakistan.
This study will be further extended in the future to determine the factors affecting project success/failure in construction organizations.

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References

Adler, M. & Ziglo, E. (eds.) 1996. Gazing into the Oracle: The Delphi Method and its Application to Social Policy and Public Health, London and Philadelphia: Jessica Kingsley publisher

Ang, J. S, 1992, On the theory of finance for privately held firms. The Journal of Small Business Finance, 1(3), p. 185 – 203

Barton, S. L. Maththews, C. H, 1989. Small firm financing: implications from a strategic management perspective, Journal of Small Business Management, January, p. 1 – 7.

Berryman J (1983). Small Business Failure and Bankruptcy, A Survey of the Literature. Eur. Small Bus. J., 1(4), 47-59.

Chung S. H., & Chuang J. H., (2009), the effect of financial management practices on profitability of small and medium enterprises in Veitnam, Meiho University.

Correia, C., Flynn, D., Uliana, E. & Wormald, M. 2003. Financial management. 5th edition. Lansdowne: Juta

Cowton, J. and G. Pilz, 1995. "The investment appraisal practices of UK retailers", The International Review of Retail, Distribution and Consumer Research, 5: 457-71.

D'Amboise, G. Gasse, Y, 1980, *Performance in small firms and utilization of formal management techniques*, Proceeding of the Joint National meeting TIMS/ORSA, Washington

Lakew, Deresse Mersha & Rao, D. Prabhakara, Effect of financial management practices and characteristics on profitability, journal of research in commerce & management volume no.2, ISSUE NO.5

Hani M. Gharaibeh (2013) Cost Control in Mega Projects Using the Delphi Method. Journal of Management in Engineering

Kieu M. N., (2004), Financial Management and Profitability of SME in Vetinam, DBA thesis, Southern Cross University, Australia

Linstone, H. & Turloff, M, (1975) "The Delphi method: Techniques and applications", London, UK: Addison of the International Research Network on Organization by Projects, IRNOP V Conference, the Netherlands

McMahon, R. G. P., Holmes, S., Hutchinson, P. J., Forsaith, D. M, 1993, Small Enterprise Financial Management: Theory and Practice, Harcourt Brace, Sydney.

Meridith and J R and Mantel S J, 2003, Project Management: A managerial Approach, 5th edition, Wiley and Sons, NJ, USA.

Mohd A. A., Harif M., Osman H.B., & Hoe C. H., (2010), Financial Management Practices: An In-Depth Study Among The CEOs of Small and Medium Enterprises (SMEs), International Review of Business Research Papers Volume 6. Number 6. December 2010 Pp.13 – 35

Morgan, E. and Y. Tang, 1992. “Reviewing investment after completion: an exploratory analysis”, The International Review of Retail, Distribution and Consumer Research, 1: 217-231.

Morse, J.M. 1991. Qualitative nursing research: A contemporary dialogue. Newbury Park, Calif.: Sage

MostafaKhanzadi, ShahinDabirian, HosseinHeshmatnejad (2008) Applying Delphi Method and Decision Support System for bidding, ICCIDC-I, Karachi

Mouton, J. 2001. How to succeed in your master’s and doctoral studies: A South African guide and resource book. Pretoria: Van Schaik.

Khan, A. R., Saleem, F., Saqib, M., & Umer, M. (2013). Benchmarking of Client’s Financial management practices in the construction sector of Pakistan.

Olawale, Y., and Sun M. (2010). Cost and time control of construction projects: Inhibiting factors and mitigating measures in practice. Construction Management and Economics, 28 (5), 509 – 526.

Ross, S. A. Westerfield, R. W. and Jaffe, J, 1999, Corporate Finance, 5 edition, Irwin and McRaw-Hill, Boston

Nazir, S. (1991). Practices of financial management by working home makers and its implications on goal achievement. (Doctoral dissertation, University of the Punjab, Lahore).

Skulmoski, G., Hartman, F., & Krahn, J. (2007). The Delphi method for graduate research. Journal of Information Technology Education: Research, 6(1), 1-21.

Turyahebwa Abanis, Arthur Sunday, Aluonzi Burani & Byamukama Eliabu, (2013) Financial Management Practices In Small And Medium Enterprises in Selected Districts In Western Uganda. Research Journal of Finance and Accounting Vol.4, No.2, 2013

Welman, J.C. & Kruger, S.J. 2001. Research methodology for the business and administrative sciences. Cape Town: Oxford University Press

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Developing a Standard Safety Manual for the Construction Industry in Afghanistan

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Abstract
This study aimed to provide a general view and description of safety structure of the construction industry in Afghanistan including private projects, government projects, NGO projects, PRT projects, U.S. army projects and other donors who are working in this sector in Afghanistan. Several interviews were conducted with thne officials of governmental ministries in Kabul and their related departments in Herat province to find out how they manage safety in construction sites such as sewer systems, water supply and power projects inside the country. Beside the interviews, several contracts and reports were reviewed in order to find out the current safety procedures in the construction industry of the country. The policy makers have not developed a unique standard safety manual to be applied all over the country, yet. Furthermore, accurate data of annual occupational accidents are not available and policy makers have not taken any step to make a structure for recording accidents' characteristics up to now. Moreover, unfamiliarity with safety hazards and safety promotion techniques has led to increasing frequency and severity of accidents in construction jobsites. It is highly recommended that decision makers and top management develop a standard safety and health manual for the construction industry to be applied all over Afghanistan.

Keywords
Safety structure, Occupational safety, Construction industry, Safety promotion, Afghanistan

1. Introduction

"Construction is known as one of the most dangerous industries all over the word" (Amiri et al., 2014). The approach for controlling accidents in the construction industry needs considering several factors. Among them, an important factor is generating standard safety guidelines /manuals and proper application of these guidelines at construction sites. Lack of national safety manuals/guidelines in Afghanistan has resulted in various safety hazards.

Safety structure in Afghanistan can be studied in two time intervals as below:

- **Before 2002**: The construction industry was under the preemption of government of Afghanistan. In this period, few construction companies were established by the support of government to implement infrastructural projects inside the country. For instance, the following companies can be mentioned: Banai construction organization, Afghani construction organization, Helmand construction organization, Tasadi Khanah Sazi corporation in Kabul and some others. Generally, PPE were given to workers, but a complete/standard safety manual was not developed to be used at construction sites.

- **After 2002**: After the collapse of Taliban regime in Afghanistan in 2001 by the military assistance of USA , rehabilitation and reconstruction of infrastructures projects restarted at 2002 by the national and international communities financial aids. Military forces from several countries of NATO entered to Afghanistan and the Provincial Reconstruction Team (PRT) was established at each province to control security of the country. Besides taking care of the security issues, participating in the reconstruction of infrastructures was another objective of the PRTs as well. Furthermore, some other donors such as World Bank, Asian development bank, USAID and others tried to provide financial aid for the rehabilitation and reconstruction projects in the country. In addition, USA army allocated a big amount of found for reconstruction of army bases for national police and national army of Afghanistan. These projects were implemented according to safety culture/standard of each donor).

This study is based on the working experience with different donors and agencies including UN organization, government of Afghanistan, international and national construction companies in Afghanistan since 2002. In addition to personal experience, several interviews are conducted with different provincial departments in Herat and ministries at Kabul to find the exact safety and health structure in the construction industry of Afghanistan. However, the authors could not find any national safety document/guideline to be used nationwide.

The aim of this study is to encourage the policymakers of Afghanistan to start developing a comprehensive guideline in order to mitigate safety hazards at construction industry of Afghanistan.

Methodology, results, discussion, conclusion and references are coming in the next sections.

2. Methodology

The research methodology is based on the following points:

- The author conducted several interviews with officials in Herat and Kabul provinces and with different departments who are engaged in the construction industry (in order to check the availability of a national safety manual) and gathered information about safety structure in the country.

- Collecting information, reports, data, contracts, design drawings and photos related to safety structure of the country from individuals and related organizations.

- Searching online publications and published reports on safety procedure in different types of construction projects in Afghanistan.

- Review of relevant literature, including several reports and contracts, in particular, produced by Ministry of Energy and Water (MEW), Ministry of Agriculture Irrigation and Livestock (MAIL), Ministry of Rural Rehabilitation & Development (MRRD), Ministry of Urban Development (MUD), Food and Agriculture Organization (FAO), Asian Development Bank (ADB), World Bank and Corps of Engineers projects in-country.

- Subsequent analysis of the above mentioned data to introduce the construction safety structure of Afghanistan.

One of the challenges in considering safety measures in the construction industry in Afghanistan is lack of national safety manuals, accident data, low reliability and accuracy of the accident databases inside the country. "Unfortunately, a great deal of information, resources and institutional capacity of accurate monitoring and reporting on natural resources statistics were lost during the years of conflict." (Rout and Lee, 2008)

This study has focused on numerous information sources as presented in table (1) and (2):

Table 1: List of Departments and Authorized Persons Who Are Interviewed in Herat

ID	Organization	Position
1	Construction department of Herat municipality, Herat, Afghanistan	Director of construction
2	Lower Hari Rud-Morghab river basin department, Herat, Afghanistan	Director
3	Urban development affairs department of Herat, Afghanistan	Deputy director
4	Public work department of Herat, Afghanistan	Director
5	Rural rehabilitation and development department of Herat, Afghanistan	Director
6	Water supply and waste water department of Heart, Afghanistan	Director
7	Bania construction company, Herat, Afghanistan	Director

Table 2: List of Organizations Contacted in Kabul

ID	Organization	Position
1	Ministry of energy and water, Kabul, Afghanistan	Director of planning water department
2	Unite nation- food and agriculture organization, ministry of energy and water	Quality control manager
3	Ministry of urban development affairs	Construction director

4	Ministry of rural rehabilitation development- Nation Solidarity Project (NSP)	Senior irrigation design engineer
6	Ministry of urban development affairs	Former minister (2008)

3. Results and discussion

After collecting information from several in-charge organizations, it was found that safety structure in the construction industry of Afghanistan is based on the projects financial source. In this regard, at the present time, projects are divided into five main categories based on their financial source in Afghanistan as follows:

3.1 Governmental projects:

These projects, which are implementing by government, are divided into two categories based on the source of financial fund as below:

- **Projects which are financed by government's normal budget:** Most of these projects are implemented by local and international contractors without proper safety considerations. However, contractors must provide safe working-site and PPE for workers based on standard human resource management policy of Afghanistan which stipulates: "the contractor must provide proper safety equipment and PPE for the workers at construction site." (Standard Human Resource Management Policy, 2008).

  The Chapter 10 of standard human resource management policy of Afghanistan is dedicated to safety and health issues in construction. This chapter includes 13 separate items which provide instructions to clients and contractors. According to this chapter, they must provide enough considerations for safety of jobsite personnel in construction sites. However, detailed techniques of safety requirements are not defined clearly.

- **Projects which are financed by loans or grants of donors:** Safety considerations can't be observed in these projects as well, albeit contract documents obligate the contractor to provide proper safety environment and PPE for workers. However, there is not a complete safety manual/guideline attached to contracts in order to define all required safety techniques for minimizing safety hazards at all stage of construction. Furthermore, the contractors that are awarded these contracts are not screwed by the implementer agencies for using the standard safety techniques and protect workers from safety hazards. In addition, most of engineers who are working in government organizations are not aware of the criticality of safety hazards and their effects.

3.2 PRT's construction project

In 2002, the Provincial Reconstruction Teams (PRT) of NATO was established in Afghanistan and military forces of each NATO member entered a province to provide security and participate in reconstruction of infrastructures of that province. In this regard, they financed several projects such as schools, roads, bridges and other infrastructures. However, from construction safety point of view, they did not care safety in almost all their projects.

3.3 NGO's construction projects

Most of the construction projects which are implemented by NGOs, do not benefit from a standard safety plan. These construction sites are not safe for workers and PPE are not provided to them as well.

3.4 Projects implemented by the grant fund of the neighboring countries

The contractors of these projects were from the country that provided the fund of the projects and safety rules and regulations were based on safety standard of that country. For example the Salma dam is under construction in western region of Afghanistan and Indian government provides the fund of this project. So, the contractor of this project is an Indian construction company who manages safety at the project site based on his own safety rules and regulations.

3.5 US army funded military projects

Safety was the first priority in construction jobsites of projects that were implemented by corps of engineers and AFCEE in Afghanistan. All the safety rules and regulations were implemented in the US army projects according to safety and health requirement manual EM385-1-1, which has been developed by the US army corps of engineers. It was stipulated that "This manual prescribes the safety and health requirements for all Corps of Engineers activities and operations." (Safety and Health Requirements Manual, 2008)

The applicability of this manual is defined as: "This manual applies to Headquarters, US Army Corps of Engineers (HQUSACE) elements, major subordinate commands, district, centers, laboratories and field operation activities (FOA), as well as USACE contracts and those administered on behalf of the USACE. Applicability extends to occupational exposure for missions under the command of the Chief of Engineers, whether accomplished by military, civilian, or contractor personnel." (Safety and Health Requirements Manual, 2008)

The US Army projects that are executed in Afghanistan affected on afghan construction companies, engineers, foremen, skill labors, operators and labors and made them aware of latest construction systems and safety programs at construction jobsites. Actually, these projects were a job training course for the afghan human resources working in the construction industry of Afghanistan.

All in all, the findings of this study can be summarized as follows:

- Still the policymakers in Afghanistan have not developed a comprehensive national safety manual to be applied on Afghan construction jobsites.
- The role of insurance systems is not still defined in the construction industry of Afghanistan.
- Occupational accidents are not recorded in the Afghan hospitals; therefore, collecting proper data of the accidents are a challenge for researchers inside the country.
- Most of engineers working in governmental organizations do not have enough knowledge about safety and health rules and regulation.
- Lack of safety training for construction workers has resulted in a profound lack of interest in workers to follow safety rules and regulations in jobsites.

The US army has implemented billions dollars of construction projects in the past ten years with high standard of safety and health. Many engineers, foremen, supervisors, lab technicians, skill labors, operators and labors are trained at these jobsites and got proper information about safety hazards and manners to protect from these hazards. Opportunity of working with US army corps of engineers system has built the capacity of Afghan construction industry to continue the safety system that has been established by the U.S. army corps of engineers inside the country.

5. Conclusion

This study shows that the development of a standard safety manuals and its application is one of the most important priorities for the construction industry of Afghanistan. Further, this study can help to motivate the vision of the policy makers to start the development of standard safety manual for the country in order to have better control on prevention of the safety hazards at construction sites.

Moreover, it is recommended that officials collect more information about corps of engineers' systems in order to prepare a standard safety manual based on the EM385 and apply it all over the county.

6. References

Amiri, M., Ardeshir, A., Fazel Zarandi, M.H. (2014). "Risk-based analysis of construction accidents in Iran during 2007-2011- meta analyze study". *Iranian Journal of Public Health*, Vol. 43, No. 4, pp. 507-522.

Rout, B., Lee, C. (2008). *How the Water Flows: A Typology of Irrigation Systems in Afghanistan*, Afghanistan Research and Evaluation Unit, Kabul, Afghanistan.

Safety and Health Requirements Manual, EM385-1-1 (2008)**.** Department of Army, U.S. Corps of Engineers, Washington D.C., USA.

Standard Human Resource Management Policy (Dari Version) (2008), Independent Administrative Reform of Civil Services, Kabul, Afghanistan.

Latest Development in the Structural Material Consisting of Reinforced Baked Clay

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Abstract

A novel approach has been presented along with the research that has been carried out to prove its validity so that implementation regarding the use of indigenous materials like clay could be accomplished. It is strange to note that although clay has remained in use as major material of construction where it is available in plenty since the time immemorial, no scientific approach has been adopted to replace reinforced cement concrete with this cheap material of construction. With this particular intention in mind, a systematic programme of experimental study visualizing the future construction in the rural areas at relatively cheap and affordable prices for the poor masses, a large number of beam panels were cast, baked, post reinforced, cured and tested. The results of that experimental study have been presented in this paper. This study was carried out in terms of modulus of rupture, shear/ flexural behaviour, mode of failure, crack pattern and ultimate load of baked clay beams.

Keywords
Baked Clay, Construction, Compacted, Post-reinforced, plate support,

1. Introduction

Clay is a very common, abundant and inexpensive material. It is easy to extract and does not require significant transformation. Clay is also a capricious material with very variable physical properties. Clay creates many problems when it shrinks during drying and firing. Certain clays shrink more than others. The finished products of clay crack during cooling [Argile, 2007] . Advocating clay as the first choice for rendering straw bale walls as well as any other conventional wall system is predominantly linked to its great benefits to our health and the environment. Earth has a vast technical and architectural potential in the construction industry and the fact that it has been used in the simplest and most sophisticated structures all over the world supports its importance in this industry today [Strawtec]. Clay is cohesive material and this property improves if clay is micro-fined and properly kneaded after mixing the water. Wet clay having a sufficient quantity of water acts like a lubricant but with only a little quantity of water, it acts like a plastic body. It has no elastic limit and could be worked to any shape with little pressure without rupturing. Clay possesses the property of a binding agent [Kulkarni G. J. 1980]. International Resource Institute (IRI) has recently been involved in Natural Composite Architecture using a composite of bentonite clay/cellulose fibre/straw bale wall and roof system [Lance. D]. Polymer clay has been in use as man-made modelling material just like ceramic. It is being supplied by various suppliers under the brand name as FIMO. FIMO is easy to use extremely versatile plastic based modelling clay [Garie S]. A systematic review of a large number of journals pertaining to the field of Civil Engineering including those of ACI, ASCE and British Institute of Civil Engineering was carried out but as expected, there is no research conducted up to this time mentioned for studying the behaviour of the pre-fabricated, post-reinforced baked clay structural panels which would be used as replacement for pre-cast concrete panels for erection of buildings at relatively lower cost with out sacrificing durability, reliability and elegance. Although hundreds of technical publications regarding the properties and uses of clay for various purposes were found in the Journals, they mostly discussed the geotechnical, geological, chemical and agricultural aspects of clay. Complete series of booklet published by the United Nation's Economic & Social Commission for Asia & Pacific Region Bangkok, giving details of research conducted on indigenous materials of construction and low cost housing does not include any research on the structural panels as tested during present study [United Nation]. Baked clay brick fragments were used in cement concrete as coarse aggregate [Memon et-al, 1992] and the same aggregate was later treated with cement slurry to reduce its porosity and increase the strength [Memon et-al, 1995]. For several years hundreds of researchers worked on various aspects of concrete as major material of construction for buildings, bridges and other structures. However, economy could be achieved if local materials of construction are used instead of transporting heavy and expensive materials like hill sand, coarse aggregate of rock origin, cement and steel bars over long distance particularly in fertile plains of various countries. The most commonly and universally available materials of construction such as the clay, silt and pit sand have not been resorted to for the construction with pre-perceived notion that these are inferior and therefore could not be used for quality work. In fact clay has remained in use right from the early civilizations like that of Moen-jo-daro, Mesopotamia [Magnus M, 1977] and Nile delta in the shape of sun dried and burnt bricks for masonry. During preliminary experimental study by the authors [Memon M et-al, 1999] which consisted of moulding, compacting, baking and testing hundreds of clay cylindrical and cubical specimens having various intensities of compression for compaction and clay to pit-sand ratio as the parameters, it was clearly manifested that strength of this particular type of material could equally be as good as that of cement concrete, if properly compacted. The cement concrete used in common buildings for R.C construction is normally designed for compressive strength of 20 N/mm^2 (3000psi). But from our study it was quite visible that with properly controlled conditions and 70:30, clay: pit-sand ratio the strength could comfortably be increased much more beyond this limit by increasing the compacting force and decreasing the water content which obviously reduces the voids. All these aspects self-evidently imply to the direction where instead of bricks, structural panels could be manufactured, baked and used for swift quality construction of buildings at relatively lower cost than concrete.

2. Clay as Replacement of RCC

Clay has remained in use for erecting the most beautiful and durable structures even better than RCC even thousands of years ago. They were considered as the Wonders of the world. The Ziggurats of Mesopotamia and the Hanging Garden of Babylon are the evidence. One third of humanity of the world even today has made use of clay as the major material of construction. However, no systematic research has been carried out to make use of this material as a parallel to concrete. For the first time the authors under took this task. For ten years we wallowed in the wildness of clay and developed an idea to use pre-cast panels pre-perforated, baked, post-reinforced and grouted which could be factory made on mass scale and used for multistory buildings as a replacement of RCC [Ansari, 2007, Memon et-al, 1999, 2006, 2007, 2014, 2007, 2007], which has been named as R.B.C. The authors on their part have reached a stage where compressive strength resembling to that of concrete has been achieved. The material constants like

Poisson's ratio and modulus of elasticity are well within the range of RCC. The flexural and shear behaviour is also satisfactory. More research is required which is being carried out presently [Lakho, 2007] and remains un-published so far. Future buildings as per the vision of this project shall be of baked clay, particularly in the fertile plains where this material is abundantly available.

3. Present Study

Stiff steel moulds were fabricated for casting the specimens for beam panels. The design of these moulds was accomplished on the basis of stress analysis performed by using computer based numerical approach. The major force for which these moulds were to be designed was the lateral outward force induced by vertical compression applied for compaction. A Plate Bending, rectangular, eight-node Finite Element, originally formulated by Hinton and Owen was employed to perform elastic analysis particularly in terms of maximum deflection at free edges (upper edges of long walls of the moulds) and bending moments at fixed edges of the long sides of the mould, the thickness of which was assumed in the first instance. The base slab is firmly supported all over by the ground. The thickness of this plate was also assumed and then its adequacy was checked against induced stresses.
The long walls were analyzed as fixed at both the ends at the bottom while the top edge was a free edge. Since the compressive load was applied vertically downward for compaction and the clay was nearly in the plastic state, it was presumed that all the force was transferred to the long sides of the mould as lateral force which was normal to the inner surfaces of the long sides of plates. The distribution of this force was assumed to be uniform. Special arrangement for applying the pre-compression manually, (so that density could be improved, compaction to the desired degree could be achieved), was designed and fabricated. During casting of models it was observed that due to lateral deformation bulging took place beyond acceptable limits. Therefore a system of restraining the lateral deformation was designed and made use of after trying various options. This arrangement is presented in Fig 1.

Figure 1: Strengthening of the mould by welding the stiffeners and other strengthening system to avoid the bulging

which is the best and most efficient amongst those tried by authors. Mixing of materials depended upon best proportions of clay and pit sand with earlier research presented in [Memon et-al, 2006], Total water content as percentage in terms of dry material was maintained at about 20 percent on the basis of the results pertaining to workability and strength to be achieved. The clay was obtained from various sources at a depth of 4 ft from the ground level. It was dried at a temperature of 105°C for 24 hours. The clay was then pulverized for micro-fining. Then as in previous research conducted by the authors [Memon et-al, 2006] 30% of pit-sand, was mixed. Mixing of the materials and the water was done with the electrically operated Pan mixer.
Mixing was done for approximately 10 minutes for each batch. After delivery of the material in the mould, compressive force for first test series of 3.5 N/mm2 was applied and measured with the help of electric load cells and digital display amplifier system. Compression was applied by tightening the wing

nuts as shown in Fig. 2. Several impediments and hurdles were experienced. For example enormous shrinkage occurred during drying which caused cracking of the beams rendering them useless. The drying under the shade without exposure to sunshine with a thin plastic wrapper solved the problem. Special scheme was resorted to by providing a heavy wooden plank fitted with a very smooth surfaced metallic sheet properly oiled to support the beam specimen at the bottom during its drying period; so that shrinkage and consequent deformation did not cause any cracking. However, a system of slight compression with the help of springs was devised and used as shown in Fig 3.

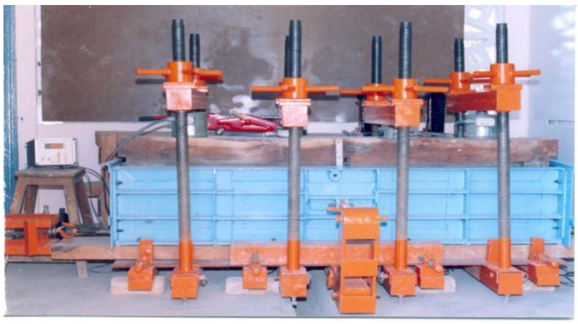

Figure 2: Compression was applied by tightening the wings and nuts

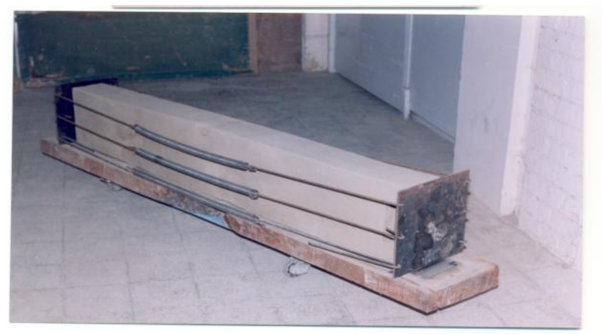

Figure 3: The system used to avoid the cracking in the clay beam due to shrinkage

It must be mentioned here that the beams cast, dried, baked and tested during this experimental investigation were 6 inches (150 mm) wide, 12 inches (300 mm) deep and 6.5 ft (1950 mm) long initially but were reduced in length by 4 inches (100 mm), breadth decreased by 0.3 inches (7.2 mm) while the depth showed a shrinkage of 0.6 inches (14.3 mm). After drying for sufficient time under the shade the beams were exposed to sunshine to exclude as much moisture as possible which was trapped deep inside them. The beams were then placed in the Kiln where the temperature was measured with the help of thermo-couples. Initially a lower temperature of 250°C was maintained for six hours. The temperature was then raised gradually to 950°C and was maintained at this level for 22 hours. Then the temperature was lowered slowly and the fire was stopped and the kiln was allowed to cool down over next two days. The temperature and time periods were selected after trying a large number of temperature and duration combinations to achieve the best possible results because the thickness of beams is obviously much more than bricks and therefore the complete baking of the beams could be possible only on the basis of experimental investigation. The beams were pre-perforated near the bottom with two holes of one inch diameter for placement of tensile reinforcement. However, a few beams were reinforced both at top and bottom hence there were two holes near top and two near the bottom in these beams. A few beams contained vertical holes at 6 inches centre to centre for shear reinforcement as shown in Figure 4.

Figure 4: Photographs showing the holes provided for tension & compression bars and at the top for shear reinforcement.

The steel bars of 3/8", ½" and 5/8 inch diameter were used as longitudinal reinforcement. A puller as shown in Fig. 5 was manufactured to pull out the steel shafts from the beams after their casting.

The bond between steel bars and the surrounding baked clay was achieved through forced grouting of cement slurry with fine aggregate in the ratio 1:1. The equipment manufactured for this purpose is shown in Fig 6. After grouting curing was done for 14 days. Curing tub is shown in Fig 7. This created sufficient bond to avoid the problem of slipping of bars up to the ultimate load. Initially the bond between steel bars and baked clay openings was investigated separately to ensure that the failure did not occur on this account. Special trolley was designed and fabricated for safe lifting of the beam from place to place.

Figure 5: Puller System **Figure 6: Grouting System** **Figure 7: Curing Tub**

Platform Lift was designed, manufactured and installed beside the kiln for safe lifting up of clay beam models which are so fragile that even a slight jerk could reduce them to pieces, as shown in Fig. 8.

Figure 8: The Photographs showing Platform Lift fabricated for lifting the beam to be placed in the kiln

Figure 9: Mobile lift manufactured for Baked Clay Beams

Mobile Lift as shown in Fig. 9 was designed and manufactured for carrying the beams to the testing laboratory for placement of these models on the machine for testing. Torsee Testing Machine that was used to test the beams. Load cells were used together with digital display system to measure intensity of the load independently. Demec Gauge was used to measure the strain at various locations with reference to the neutral axis. Thirteen pairs of demec pads were stuck on the beam to measure the strain with the help of demec gauge. To test the fundamental structural properties of the beam material itself specimens were cut from the intact portions of beams after testing.

4. Discussion of Test Results Regarding Flexure & Shear Behaviour of Beams

The flexural strength of the beams in terms of tension and compression was calculated by using the equations of BS CP 8110 and ACI-318 after removing all partial safety factors. The shear strength of the beams was also estimated in accordance with the above codes. All these values along with ultimate experimental loads are presented in Table 1, for the phase-I of the Main Test Series. It was expected that the failure would be dominated by shear strength of the beams. The failure of the beams did occur due to shear. The failure occurred due to diagonal cracks as shown in Fig. 10, which is indicating shear force behaviour. From the test results shown in Table 1, it is quite apparent that the failure occurred some where near the estimated load calculated on the basis of shear strength. This is clear indication that baked clay panels are sufficiently good when compared with the concrete. Initially the rectangular beams were roller supported subjected to point load at the centre. The load at failure is in the range which is averagely 1.33 times more than the shear strength calculated on the basis of BS CP-8110 and 1.04 times more than

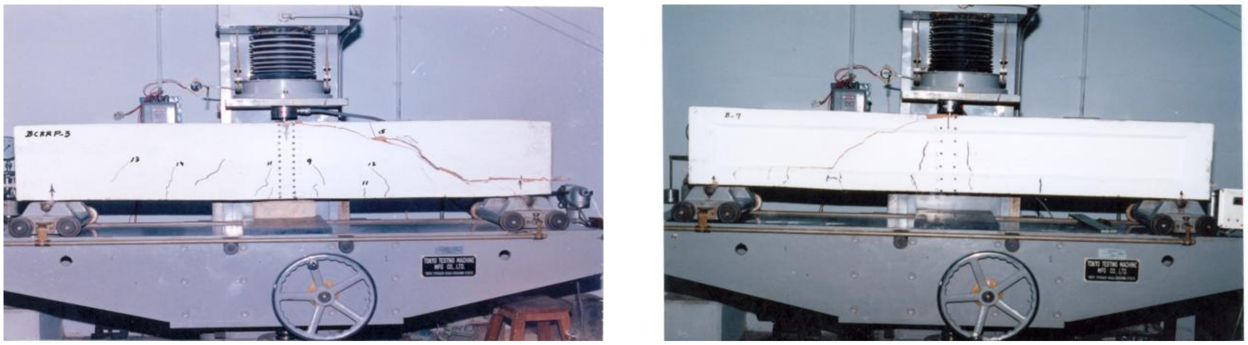

Figure 10: Photographs showing the crack pattern of the Baked clay Beam after testing

shear strength calculated on the basis of ACI-318. However, for I-section this relationship between ultimate experimental load and the estimated load was only 1.03 and only 0.79 respectively. It appears that BS CP-8110 is more conservative than ACI-318 when it comes to estimate shear strength of beams. From this it can be deduced that I-section baked clay beams which were basically tested in order to investigate the possibility of the use of a lighter section, can not be considered as suitable. Great improvement in terms of experimental load at failure was observed when uniformly distributed load (UDL) was applied in place of point load on the central portion of beam 1.15 metre wide as shown in Fig 10. UDL was applied only at the central portion because in the regions near the supports, the load would have been directly transferred to the supports thus giving false impression about the strength of the beams. The average ratio between estimated critical shear strength and the actual load at failure is found to be 3.19 and 2.13 respectively, which is quite good. The benefit in terms of uniformly distributed load is 100%. However, in terms of bending moment at the centre, this increase is found to be 31% where a component must have been due to (i) the resistance offered by the loading system, (ii) the reduction of concentration of stresses due to bending as compared to point load and (iii) due to gradual increase of shear force from centre towards the supports. The type of support when rollers were replaced by plates, affected the ultimate experimental load by approximately 12%. However, the increase of maximum bending moment at the centre was only 2%. It can be observed from Table 1, that although the failure was dominated by shear, the strain in baked clay at the level of flexural steel is an indication that the yielding point had already in the beams which were tested by applying UDL. Although maximum shear is at the supports and if the shear alone is responsible for the failure such an increase of ultimate load could not have been achieved. It may be mentioned here that the UDL was applied by the system so that the friction could be minimized in order to let the baked clay material undergo compression without being deterred by the load application system. However, since this was a relatively stiff steel beam transferring load through a number of circular bar pieces welded with it, this might have affected the behaviour of the beams and their ultimate load to some extent. Perhaps a system consisting of smaller separate hydraulic jacks or a multi-point electrically operated hydraulics load applying machine would have worked better. However, due to practical difficulties and un-availability of required gadgets this system could not be developed /tried. After testing the beams the bottom cover of a few beams was removed to ensure that bond failure between steel and surrounding concrete did not occur. Initially the load was measured in DVM units with the help of load cell and digital display system. Through calibration this load was converted into Newtons. One DVM unit was equal to 460 N. Since DVM units were same for all the five beams within

Table 1: Details of Estimated and Experimental Ultimate Loads For Different Baked Clay Reinforced Beams Tested by The Authors.

S#	Description	Flexural Strength in terms of Steel "N"		Flexural Strength in terms of Baked Clay "N"		Shear Strength Calculated "N"		Experi-mental load @ failure "N'	Exp. Shear strength / Calculated shear strength				Remarks
		CP8110	ACI	CP8110	ACI	CP110	ACI		CP8110	Av:	ACI	Av:	
1.	BCRRP – 1	95523	107804	134347	103968	21261	27740	56595	1.33	1.33	1.02	1.04	Roller supported rectangular beams subjected to point load at center
2.	BCRRP – 2	94282	106247	127480	103014	21261	26964	56595	1.33		1.04		
3.	BCRRP – 3	95521	107175	133489	103777	21261	27740	56595	1.33		1.02		
4.	BCRRP – 4	95523	106652	128338	103396	21261	27302	56595	1.33		1.04		
5.	BCRRP – 5	91801	104466	117607	101488	21261	25682	56595	1.33		1.10		
6.	BCIRP – 1	93042	100315	125290	101465	20832	26626	42795	1.03	1.03	0.80	0.79	Roller supported I-Section beams subjected to point load at center
7.	BCIRP – 2	95523	102239	132019	102027	20832	27425	42795	1.03		0.78		
8.	BCIRP – 3	93042	100817	124449	101091	20832	26560	42795	1.03		0.80		
9.	BCIRP – 4	94282	100779	125206	101278	20832	26527	42795	1.03		0.80		
10.	BCIRP – 5	93841	100944	125290	10465	20832	26626	42795	1.03		0.80		
11.	BCRRUD – 1	100321	107960	196032	159290	17886	27032	114095	3.18	3.19	2.11	2.13	Roller supported rectangular beams subjected to uniformly distributed load.
12.	BCRRUD – 2	99141	108032	196495	158703	17886	27133	114095	3.18		2.10		
13.	BCRRUD – 3	101501	107791	192937	158117	17886	26829	114095	3.18		2.12		
14.	BCRRUD – 4	97960	108019	196107	159290	17886	27133	115015	3.21		2.10		
15.	BCRRUD – 5	99141	107084	184152	156357	17886	25952	114095	3.18		2.19		
16.	BCIRUD – 1	100884	105096	201433	156893	17526	27322	79595	2.27	2.27	1.45	1.48	Roller supporter I-Section beams subjected to uniformly distributed load.
17.	BCIRUD – 2	99967	104277	192373	155453	17526	26494	79595	2.27		1.50		
18.	BCIRUD – 3	99769	104224	189134	159136	17526	26428	79595	2.27		1.51		
19.	BCIRUD – 4	100489	104236	196907	156029	17526	26924	79595	2.27		1.47		
20.	BCRPUD – 1	100911	108393	202633	159584	17886	27639	127435	3.56	3.55	2.30	2.33	Rectangular beams supported on plate on both ends subjected to uniformly distributed load.
21.	BCRPUD – 2	100619	108278	200650	159290	17886	27470	127435	3.56		2.32		
22.	BCRPUD – 3	100497	108028	196673	158703	17886	27133	127435	3.56		2.34		
23.	BCRPUD – 4	100136	107848	192732	158117	17886	26863	126975	3.56		2.36		

each group, so the values became same for all the beams of the same group. Thus it can be deduced that if buildings are to be constructed in the rural areas where hill sand, coarse aggregate and cement are not available locally this material can also serve the local population well within affordable prices. This material could prove suitable for multistory buildings of reasonable height. Therefore we shall stick to the original idea of producing structural panels on large scale with minimum quantity of reinforcement, no cement, no aggregate of hill origin but clay and pit-sand, dune-sand and river bed sand; all available locally and cheaply. A very respectable average of ultimate load for rectangular beams supported on steel plate with UDL has been achieved which is 3.55 and 2.3 (BS CP-8110 & ACI respectively) times more than the estimated strength in terms of shear. Beams which were tested, were only 1.95 meters long. However, in real structures beams could be very long and more commonly loads are distributed because slab transfers the load to the beam along its entire span, the structure produced with panels of pre-perforated post-reinforced baked clay shall exhibit even better performance.

5. Conclusions

01 As compared to normal cement concrete the compressive strength of baked clay panel with a proportion of 70:30 percent of clay:pit sand, holds promise to achieve strength as good as concrete with only moderate compression force of 3.5 N/mm^2 for compaction. A value of crushing strength as high as 31.39 N/mm^2 is reached.
02 Great improvement in terms of experimental load at failure was observed when Uniformly Distributed Load was applied in place of Point Load on the central portion of the beam.
03 The average ratio between estimated critical shear strength and the actual load at failure to be 3.19 and 2.13 respectively, which is quite good.
04 When roller supports were replaced by plate supports, affected the ultimate experimental load by approximately 12%. However, the increase of maximum bending moment at the centre was only 2%.
05 Split of bottom cover, slipping of bar or destruction of bond between steel and surrounding material did not take place
06 It can be deduced that if buildings are to be constructed in the rural areas where hill sand, coarse aggregate and cement are not available locally, this material can also serve the local population well within affordable prices.
07 It is quite apparent that the failure of beam is dominated by shear rather than flexure, therefore shear strength must be improved to ensure ductile failure due to yielding of steel in tensile zone.

6. Acknowledgement

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4. References

Ansari. A. A. (2008), "Experimental Study of the Behaviour of Pre-Perforated Post-Reinforced Baked Clay Panels of Beams", *A Ph.D thesis* , Quaid-e-Awam University of Engineering Science & Technology, Nawabshah, (Sindh).

Garie S., Creative clay for creative people. Electronic document: http://www.garieinternational.com.sg/clay/clay.htm

Kulkarni G. J. (1980), "A text book of engineering materials". *Eleventh edition, Kirit Ambala Patl,* Ahemednagar, pp. 55

Lance. D., "National composite architecture: *Building without use of lumber, concrete, steel, or petroleum products. The Last Straw Journal, No.17 Electronic document:* http://www.networkearth.org/naturalbuilding/composite.html

Lakho. N. A (2007)., "Experimental Study of Long term Behavior of Pre-perforated Post-Reinforced Baked Clay Beams", *PhD Project* , Quaid-e-Awam University of Engineering Science & Technology, Nawabshah.

Magnus M (1977), "The archaeology of the Bible lands. , *pp.195-208*

Memon. M, Memon M. A & Durrani N. A (1992)," Behaviour of concrete with indigenous aggregate. *Mehran University Research Journal of Engineering and Technology, Vol.11, No.4, p.25-30*

Memon M., Durrani N. A., & Memon N. A. (1995), "Treatment of indigenous aggregate. *Mehran University Research Journal of Engineering and Technology, Vol.4, No.2, p.13-19*

Memon. M, Ansari. A.A. and Shaikh. A.M. (1999), "Preliminary Study of Structural Properties of baked clay", *Mehran University Research Journal of engineering & Technology,* Vol. 18, No.3, pp. 161-166.

Memon. M. & Ansari. A. A. (2006), “Fundamental Structural Properties of Compacted Baked Clay Specimen”, *Quaid-e-Awam University of Engineering Science & Technology,* Vol. 7, No.2, pp. 39-44,

Memon. M. & Ansari. A. A. (2007), “Clay : The Environment Friendly Material of Construction”, *Proceedings of First National Conference on Assessment and Proper Utilization of Indigenous Energy Resources and Their Impact on Environment,* Organized by Energy and Environment Engineering Department, Quaid-e-Awam University of Engineering Science & technology, Nawabshah, Held on 26-28 February 2007.

Memon. M., Memon. A. H. & Ansari. A. A. (2007), “Mechanical Systems Developed for Reinforced Baked Clay Structural Panels”, *Paper presented in the Conference on Failure of Engineering Materials & Structures FEMS (2007), held on 22-23 Oct: 2007, University of Engineering & Technology, Texila, Pakistan.*

Memon. M. & Ansari. A. A. (2007), “Pre-Perforated Post Reinforced Baked Clay Structural Panels as Potential Replacement of Reinforced Concrete‖”, *Proceedings American Concrete Institute (ACI) Pakistan Chapter, CBM-CI,* International workshop, organized by NED University of Engineering & Technology, Karachi, held on 10-11 Dec: 2007 at pearl Continental Hotel, Karachi.

Memon. M. & Ansari. A. A. (2014), “Behaviour of Baked Clay Structural Beam Panels”, *Proceedings of Ninth International Summer Symposium,* Japan Society of Civil Engineers, Yokohama National University, Yotsuya 1-chome, Shinjuku-ku, Tokyo, 160-0004, Japan.

Pottery La Pipe d’Argile. (2007), “Clay Electronic document” *http://www.lapipedargile.com/argile/largile-ger.html*

Strawtec, “Clay: the highest quality from design to construction”, *Electronic document: Clay: the highest quality from design to construction,*

United Nation, “Booklet Series, on Low Cost Housing Indigenous Materials”, *United Nations Economics Social Commission for Asia and Pacefic Region, Bangkok 10200, Thailand*

Numerical Modelling of Masonry Structures

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Abstract
This paper presents the numerical modelling of masonry structures by Equivalent Frame Approach. Masonry is a composite material and behaves in complex manner under seismic loading. As computational technology has developed, many researchers have been focusing on numerical modelling of masonry structures for the last three decades. Equivalent Frame Method is a simplified approach to analyse the masonry structures. It is an efficient method to evaluate the in-plane stiffness of masonry structures using pushover analysis. In the present work, a methodology has been developed to analyse the masonry structures by Equivalent Frame Method. The technique has been applied on several 2-dimensional masonry structural walls and results have been compared with the experimental tests. The methodology has been extended to 3-dimensional masonry structures and good agreement has been found with experimental results.

Keywords: Masonary Structures, Equivalent Frame Approach, Seismic Loading

Role of Technical Textiles for building sustainable infrastructure

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Abstract

Infrastructure development is essential for every nation in this world. It is always desirable to build infrastructure which can sustain for a longer period. In this modern age, the new methods of construction and the materials used are helpful for this purpose.

It is believed that the textile products are only used for the clothing purpose. In the recent past the field of technical textiles has opened new dimensions of applications; ranging from aerospace to construction, electronics to automobiles and medicine to defense etc.

In the area of civil engineering; the fields of Agro-tech, Geo-tech, Build-tech and Oeko-tech are very common methods of application of textile material. The areas covered are agriculture, building road networks, building construction and environment.

In this review paper an overall picture of application of different textile products in the field of civil engineering are discussed. The author feels that there is a real need to do research in these areas by collaborating the efforts of textile and civil engineers working in the industry.

Keywords

Technical Textiles, Textile composites, Sustainable infrastructure, Build-tech, Geo-textiles and nonwoven

1 Introduction

Infrastructure of any country is necessary for the residents. A developed or an under-developed country is recognized by its infrastructure and the facilities provided to the residents. There is always continuous planning going on to build better facilities for the people and for that purpose a lot of money is spent every year all over the world.

Infrastructure of the mostly involves the construction of roads, parks, bridges, shopping complexes and other facilities for public. It is generally believed that the infrastructure should be sustainable for a longer period. It should also require less maintenance.

It is believed that the textile products are mostly used for the clothing purpose and also some products used at home such as sofa covers curtains etc. there is an emerging field of technical textiles developed in the recent past which covers products in almost every walk of life.

2 Technical Textiles:

The basic concept of technical textiles is related to the products which are not designed for aesthetic purpose, but are specifically designed to perform some functions. The technical textile products are divided into the following twelve categories. [Horrocks 2000]

1 Agrotech
2 Hometech
3 Mobitech
4 Geotech
5 Oekotech
6 Indutech
7 Packtech
8 Clothtech
9 Medtech
10 Protech
11 Sportech
12 Buildtech

2.1 Agrotech:

Textile products used in the area of agriculture, forestry, fishing and horticulture such as crop covers for protection, and fishing nets. These products are normally manufactured by using woven and nonwoven fabrics.

2.2 Hometech

Textiles products commonly used at home such as matress components, curtain tapes, dust cloths and fibre-fills for furniture. The main functions performed are insulation, comfort and wiping. These products are manufactured by using yarns, fibre-fills and nonwoven and woven fabrics.

2.3 Mobiltech

The textile products commonly used in this area are air bags, seat belts, car interiors and filters. The functions performed by these products are safety, protection and insulation. These products are manufactured by woven fabrics.

2.4 Geotech

The textile product commonly used for this area is geo-textile fabric for road separation, lining and drains. The functions performed by these products are soil separation, re-enforcement of soil, stabilization, drainage and filtration. These products are manufactured by woven and nonwoven fabrics.

2.5 Oekotech

The main products used in this area are filters for cleaning water, fabric for erosion control to cover the waste and reduction of fuel consumption by making light weight vehicles by using textile composites.

2.6 Indutech

The products used in this are filters, conveyor or driving belts and gasket seals. The functions performed by these products are purifying industrial products, cleaning effluent gases and transporting material between the processes. These textile products are manufactured by doubled yarns, coated woven fabric and non-woven fabric.

2.7 Packtech

The products used in this area are food soaker pads, performance envelops and nettings. The functions performed by these products are tying and packing. These products are manufactured by woven tapes, woven and kniited fabrics.

2.8 Clothtech

The products used in this area are clothing accessories such as fasteners, interlinings, labels and sewing thread. The functions performed by these products are comfort and insulation. These products are manufactured by narrow woven fabrics and non-woven fabrics.

2.9 Medtech

In the field of medicine the textile products used are disposable bed sheets, surgical drapes, and orthopedic paddings. The functions performed by these products are cleaning, covering and protection. These products are manufactured by non-woven, knitted and woven fabrics.

2.10 Protech

The products used in this area are ballistic protective clothing, heat and cold resistant fabric, and breathable water proof fabric. The functions performed by these products are protection from different hazards. These products are manufactured by layering fabrics, textile composites, woven and knitted fabrics.

2.11 Sportech

The products used in this area are sports bags, sports equipment and artificial turf. The functions performed by these products are carrying and providing strength and flexibility during the use of equipment. The equipment are manufactured by using textile composites and woven, non-woven and knitted fabrics.

2.12 Buildtech

The products used in this area are concrete re-enforced composites, fiberglass ceiling, and roofing material. The functions performed by these products are protection and re-enforcement. These products are manufactured by using textile composites.

In this sections the area covered by the technical textiles were discussed briefly and this gives an impression that the field of technical textiles has a great range of application. In this paper the fields of Geo-textiles and Textile Composites are discussed as author believes that both these areas have an impact on the infrastructure of the society.

3 Textile Composites

Composites are generally made of two components; reinforcement and matrix. The reinforcements are embedded in the matrix to improve its properties. The matrix is usually a thermo-set or thermoplastic material or sometimes metal. [Yousfani 2010]

The term ‘Textile Composites’ implies that the reinforcement is produced using a textile process, such as weaving, braiding, knitting or non-woven. In general the composites are of following types:

1 Metal Matrix Composites
2 Ceramic Matrix Composites
3 Carbon Matrix Composites
4 Polymer Matrix Composites

Textile composites are manufactured by using polymer matrix composite technique and textile material as re-enforcement.

Polymer matrix composites are classified into thermo-set and thermo-plastic composites; where as in thermo-plastic composites the polymer is melted and solidified to act as matrix. In thermo-set composites, a thermo-set resin is mixed with the hardener, it wets out the re-enforcement and finally solidifies to act as matrix. [Ogin 2000]

In the area of building infrastructure, the field of buildtech is very important and composite manufacturing techniques could be used to explore new materials. These materials could be useful for strengthening the existing structures, for the purpose of insulation and to give new dimension to the manufacturing techniques of building construction.

In this paper, textile fibres used for re-enforcement, classification of composites based on re-enforcement and manufacturing techniques for making composites are discussed briefly.

3.1 Re-enforcement

The commonly used textile fibres for re-enforcement are mentioned below:

1 Glass Fibre
2 Carbon Fibre

3.1.1 Glass Fibres

Manufactured by melting dry silica, limestone, boric acid, clay and other ingredients at about 1250^0C and then passing the molten material through the holes to make filament, these filaments are chopped to make fibre strands or could be processed to make fiberglass fabric for re-enforcement. [Vaidya 2002]

The following properties of glass fibres make them a potential candidate for different applications such as Electrical insulator and roofing material. The fiberglass fibres could also be used as re-enforcement for strengthening the beams. The common re-enforcements made from glass fibre are shown in Figure 1. [Vaughan 1998]

1 Resistant to fire as they are inorganic in nature and does not support combustion
2 Resistant to most of the chemicals and acids except phosphoric and hydrofluoric acid
3 Resistant to fungal bacterial and insect attack
4 Hydrophobic in nature
5 Do not conduct electricity

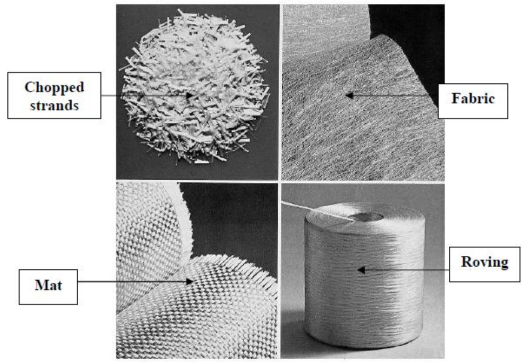

Figure 1 Re-enforcement made from Fibreglass [Vaughan 1998]

3.1.2 Carbon fibres

Carbon fibres are manufactured by using pitch or coal tar as raw material by heating it up to 3000^0C and passing it through the holes to make filaments. These filaments are then converted to tows and the fabric manufactured from it is used as re-enforcement for composite material. [Baker 2004]

The following properties of carbon fibres could make them a potential candidate for being used in the field of construction.

1 Moderate electrical and thermal conductivity
2 Resistance to corrosion
3 Chemically inert except oxidation
4 High thermal resistance

3.2 Composite classification based on re-enforcement

Based on the re-enforcement, composites are classified as: [Kopeliovich 2009]

1 **Particulate composites:** These are formed **w**hen the matrix material is filled with fillers or particles. These particles are either randomly oriented or they are oriented in a preferred direction as they consist of 2-dimensional flat platelets or flakes laid parallel to each other.

2 **Fibrous composites:** Two types of these composites i.e. short fibre and long fibre composites are available.

3 **Short fibre composite preforms:** are discontinuous in nature. The length to diameter ratio is normally less than 100 and these short fibres are either oriented randomly or in a preferred direction.

4 **Long fibre composite preforms**: are continuous in nature. The orientation of the fibres is either unidirectional such as yarns or filaments or it is bi-directional such as in woven fabrics.

5 **Laminate composites:** To achieve a certain thickness of the product, composites are formed using several layers in the preform. These composites are considered as multi-layered or laminated composites.

3.3 Manufacturing techniques for textile composites:

Textile composites are manufactured in different ways. The following are three commonly used techniques: [Cripps 2000, Mallick 2000 and Davallo 2009]

1 Hand Lay-up
2 Vacuum Bagging
3 Resin transfer Molding

In this section of the paper the field of textile composites was reviewed. It is concluded that this area needs to be explored to manufacture different materials which could be useful for making sustainable infrastructure.

4 Geo-textiles

Geotextiles mostly nonwovens manufactured from polypropylene fibres are commonly used for reinforcement of pavement. The adequacy of woven geotextiles in pavement is being investigated by many researchers. There are two basic properties that a geotextile fabric can offer:

Firstly it can act as a filter, so the filtration properties of the fabric are important and have been investigated by some researchers to predict the porosity of the fabric. [Ahmet 2004 and Aydilek 2006]

The second criterion of geotextile fabric is related to the mechanical properties of geotextile fabric and how these fabrics behave with-in the soil. This aspect of the geotextile fabric is also investigated by some researchers in terms of fabric`s shear properties [Anubhav 2010]

4.1 Functions of Geo-textiles

Geo-textile fabric layers are laid in the road pavements between the sub-soil and the aggregate, in order to perform the following functions: [Horrocks 2000]

1 Separation of sub-soil and aggregate layers
2 Act as re-enforcement for the sub-soil to stabilize it
3 Filtration of water in an adequate manner from aggregate to the sub-soil

Polyester and polypropylene are commonly used fibres for the production of geo-textiles because they are strong, polypropylene is light are non-biodegradable.

4.2 Manufacturing techniques

The most commonly used manufacturing techniques are as follows:

1 Needle punching
2 Melt blowing
3 Weaving

4.2.1 Needle Punching

Nonwovens are created by mechanically orienting and interlocking the fibers of a carded web. This mechanical interlocking is achieved with thousands of barbed felting needles repeatedly passing into and out of the web. The process of needle punching is shown in Figure 2. [Russel 2007]

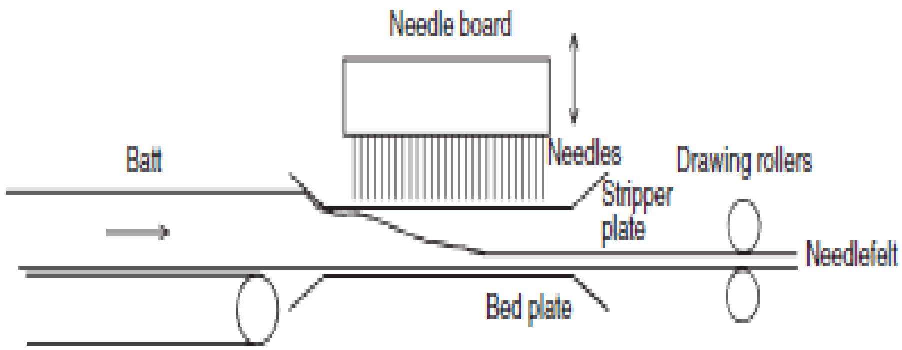

Figure 2 Needle Punching process [Russel 2007]

Nonwoven fabrics are manufactured by needle punching process in which a web from the carding machine is mechanically bonded with the help needles. The fabrics used for Geo-textiles are manufactured by this technique; the strength of the fabric is dependent on the type of fibres and layering of the webs. The porosity of the fabric is dependent on the punch density.

4.2.2 Melt Blowing

In this process a thermo-plastic fibre forming polymer is extruded through a linear die containing several hundred small orifices. Convergent streams of hot air exiting from the top bottom sides of the nose piece rapidly attenuate the extruded polymer streams to form extremely fine fibres (1-5 µm). These fibres are subsequently blown by high velocity air onto a collecting conveyor thus forming a fine fibred self bonded nonwoven web. The process of melt blown nonwoven manufacturing is shown in Figure 3. [Russel 2007]

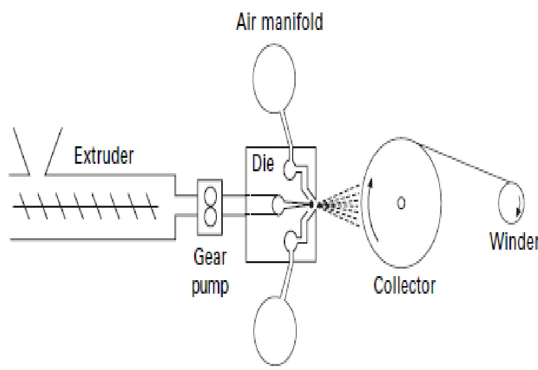

Figure 3 Melt blown nonwoven manufacturing process [Russel 2007]

The nonwoven fabric manufacturing from this process could also be used for geo-textiles. The strength of the fabric will depend on the type of the fibres and the porosity will depend on the arrangement of fibres on the surface of collector.

4.2.3 Weaving

The geo-textile fabric is also manufactured by using weaving process i.e. by the interlacement of warp and weft yarns. The basic designs are plain, twill and satin. The strength of the fabric will depend on the type of yarn and weaving methods. The porosity of the fabric is dependent on the type of the weave and it's variant. [Adanur 2000]

4.3 Application of Geo-textiles:

Geo-textiles grids or fabric could be used in different areas of civil engineering in order to fulfill the requirements of erosion control, soil separation, drainage, filtration and re-enforcement and stabilization. The products commonly used are shown in Figure 3.

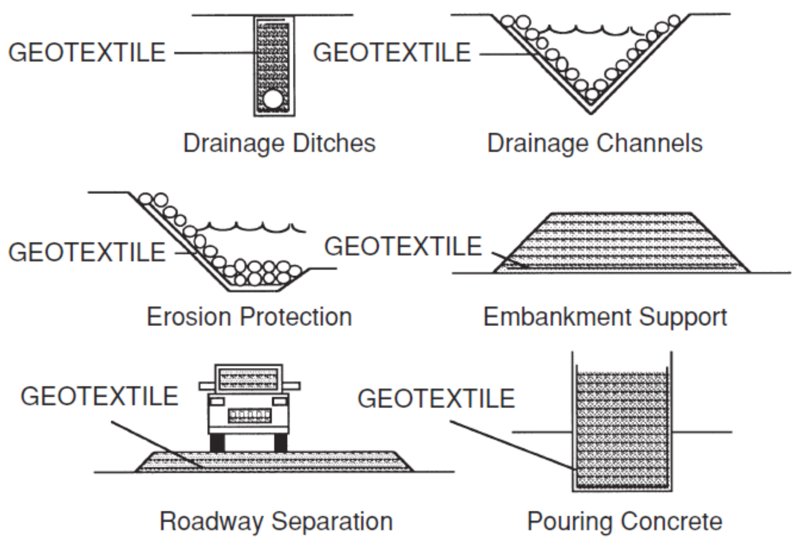

Figure 4 Application of Geo-textiles in civil engineering [Horrocks 2000]

5 Conclusion

From the discussion made earlier, the following conclusions were drawn:

1. Technical textile products have a great scope of application in different areas of life and also in the field of civil engineering
2. The field of textile composites has a great potential to manufacture different materials useful for developing the sustainable infrastructure
3. The field of geo-textiles is also being explored to build pavement, which can sustain for a longer period of time.
4. There is a need for collaborating the efforts of textile and civil engineers to think about some practical possibilities where textile products could be utilized to build sustainable infrastructure.

6 References:

1 Ahmet. H. Aydilek and Tuncer. B. Edil, (2004), Evaluation of woven geo-textile pore structure prameters using image analysis, Geotechnical Testing Journal Vol 27 No 1

2 A. H Aydilek, (2006), A semi-analytical methodology for development of woven geo-textile filter selection criteria, Geosynthetics International Vol 13 No 2

3 A. R Horrocks, S. C. Anand (2000), Handbook of Technical Textiles, Woodhead Publishing L.td, Cambridge England

4 Anubhav and P.K. Basudhar (2010), Modeling of siol-geotextile interface behavior from direct shear test results, Geotextile and Geomembreane 28

5 Baker. A, Dutton. S and Kelly. D (2004). Composite materials for aircraft structure, American Institute of Aeronautics and Astronautics.

6 Cripps, D. (2000). Open mold techniques for thermoset composites. Comprehensive composite material, Kelly. A and Zweben. C Elsevier Ltd

7 Davallo. M and Pasdar.H (2009). Comparison of mechanical properties of glass-polyester composites formed by resin transfer moulding and hand lay up technique, International Journal of Chem Tech Research **1**(3): 470 to 475

8 Kopeliovich. D. (2009). "Classification of composites." from http://www.substech.com/dokuwiki/doku.php?id=classification_of_composites&DokuWiki=1bcbec28b5a4a313d85ead7e32bcea15. Cited May 10, 2015

9 Mallick. P. K. (2000). Particulate and short fiber reinforced polymer composites. Comprehensive Composite Materials Kelly. A and Zweben. C Elsevier Ltd

10 Ogin. S. L (2000). Textile Reinforced composite material. Hand book of Technical Textiles.. Horrocks. A.R and Anand. S.C Cambridge, Wood head publishing Ltd

11 S.J. Russel (2007), Handbook of Nonwovens, Woodhead Publishing, Cambridge England

12 Sabit Adanur, (2001), Handbook of Weaving, CRC Press London, UK

13 Vaidya. N (2002). The Manufacturing of wet-laid hydro-entangled glass fibre composites for industrial application. Textiles. North Carolina, North Carolina State University. **Masters**.

14 Vaughan, D. J (1998). Fibreglass Reinforcements. Handbook of composites. Peter. S. T, Springer – Verlag

15 Yousfani. SHS (2010). Wet-laid Fibreglass Composites. Textiles. Manchester, The University of Manchester. Ph.D.

EXPERIMENTAL STUDY ON RECYCLED CONCRETE USING DISMANTLED ROAD AGGREGATE AND BAGGASE ASH

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Abstract
In this experimental work demolished road aggregate and sugarcane bagasse ash (SCBA) which are large disposal landfill materials are used as replacement materials in concrete. SCBA obtained from sugar mills is used. Total of 246 specimen of cubes and cylinders were cast with 100% coarse aggregate replaced with dismantled road aggregate whereas the cement replacement was in the percentages 5%, 10%, 15%, 20% and 25% by weight for curing period of 7, 14, 28 and 56 days. Compressive and tensile strength tests were done and the result showed that the concrete specimens made by replacing 10% of cement by SCBA at curing period of 7 and 14 days gave an unpredictable increase in test results that compete and almost reach the strength of traditional concrete. A decrease in strength was also observed at curing periods of 21 and 28 days. However, again an abrupt increase was also observed after curing period of 56 days. The workability of cement concrete was decreased with the addition of sugarcane bagasse ash.

Keywords
Recycling, Baggase Ash, Dismantled aggregate, Bitumen, Concrete

1. Introduction

Recycling and waste reduction both are extremely important elements in the framework of waste management, because they help to preserve mainly the natural resources and reduce demand for valuable landfill space (Ling *et al*., 2013). However, in major cities of Pakistan there is a rush in demolition and construction waste quantities posing an adverse effect on the environment. Utilization of such waste as recycled aggregate in concrete can be useful both for environmental protection and economical aspects in the construction industry. Global demand for construction aggregates exceeds 26.8 Billion tons per year. In Pakistan there is a significant increase in the use of natural aggregates due to infrastructure and construction development. The use of recycled aggregate in construction industry started since the end of Second World War by using a demolished concrete pavement as recycled aggregate.

On the other hand Sugarcane bagasse, is the fibrous residue that is obtained after crushing and extracting sugarcane juice, and is main industrial waste product from sugar mills in Pakistan. Nowadays, it is very common to reuse sugarcane bagasse as a biomass fuel in boilers for vapor and power generation in sugar factories. In spite of being a material of hard degradation and that presents few nutrients, the ash is also used on the farms as a fertilizer in the sugarcane harvests. Depending on the incinerating conditions, the resulting sugarcane bagasse ash (SCBA) might have high levels of SiO_2 and Al_2O_3, enabling its utilization as a supplementary pozzolanic material in concrete. Utilization of SCBA as a pozzolanic material to substitute ordinary Portland cement partially not only helps in reducing methane gas emissions from dumping of the organic waste and reduce the cement production, which is well-known for consuming high energy and CO_2 emission, but can also play a vital role to improve the compressive strength of cement-based materials (Sirirat *et al*., 2010). The work presented in this paper expresses the possibility to substitute virgin coarse aggregate with recycled concrete aggregate in structural concrete. To achieve this objective demolished road wearing coarse was collected from National highway (N-5) near Gambat city and number of cubes and cylinders were prepared using 100% virgin aggregate and 100% recycled aggregate obtained from dismantling road wearing coarse.

Tests were conducted for compressive and tensile strength of concrete. The results revealed that the road aggregate can be converted into useful recycled aggregate and could also be used in concrete for many structural applications around the world. Standard procedures were adopted to determine various concrete properties. A significant increase in the properties of cement concrete with the addition of SCBA was seen as compared to virgin aggregate concrete.

2. Materials and experimental program

2.1 Materials

2.1.1 Dismantled Road Aggregate

Dismantled road aggregate was obtained from national highway Near Gambat city in Sindh. This Material was obtained by milling or full depth removal of wearing course from a section of National Highway (N-5) that was under maintenance project. Large pieces of dismantled road were brought to the laboratory and were broken into required size by hammering. Sieves of sizes 1”, ¾” and ½” were used to get required size.

2.1.2 Sugarcane Bagasse Ash

Pakistan produces millions of tons of Sugarcane bagasse Ash each year from sugar mills. The SCBA used in this experimental work was collected from Ranipur sugar mill located around 80 kilometers far from the college on Ranipur – Kumb road in district Khairpur Sindh, Pakistan. The ash collected was the byproduct of sugarcane juice extraction of the session 2013-14. The collected ash was sieved due to present of straws of sugarcane and was made fine.

2.2 Methodology

The experimental work was conducted in the structural engineering laboratory of Civil engineering department at Quaid-e-Awam University College, of Engineering, Science & Technology, Larkana, Sindh, Pakistan. Total of 246 concrete specimens including cubes and cylinders were cast as shown in Figure 1. Dimensions of specimens were 150mm x150mm for cubes and cylinder specimen of 150mm diameter and height equal to 300mm. Aggregate ratio of 1:2:4 was used in preparing specimens by maintaining water cement ratio of 0.5 percent for all batches. After preparation of cube and cylinder samples, they were kept for curing period of 7, 14, 21, 28 and 56 days. The experimental work was done in two phases.

Figure 1: Casting of concrete specimens that are later put in curing tub.

Phase 1

In the first phase cubes and cylinders were cast without any cement replacement or supplementary material with 100% virgin coarse aggregate. The cube and cylinder specimens were cast with 1:2:4 aggregate ratio and 0.5 percent water cement ratio.

Phase 2

In the second phase cube and cylinder specimens were cast with 100% dismantled road aggregate as coarse aggregate. However, cement was replaced with sugarcane bagasse ash in the ranges of 5, 10, 15, 20 and 25 percent by weight.

2.3 Testing procedure

Total specimens cast i.e. cubes and cylinders after completing the curing period of 7, 14, 21, 28 and 56 days were tested for both compressive and tensile strength. Compressive strength of all the cubes and cylinders is evaluated using Tecnotest universal load testing machine.

Concrete specimens made by virgin as well as dismantled road aggregate were tested and the difference between two crushed samples can be seen in Figure 2.

Figure 2: Split cylinder specimens made by dismantled road aggregate and virgin aggregate.

3. Test Results and discussions

The results of the experimental work conducted in which different type of concrete samples cast are shown in Tables 1,2 and 3. Initially reference concrete specimens of traditional concrete were cast for comparison of results. The study showed that cement concrete made by recyling coarse aggregate 100% with dismantled road aggregate and replacing cement by 10% of sugarcane bagasse ash reveled postive result that almost compete with the strength of conventional cement concrete. However some values showed that the concrete made with recycled aggregate and with sugarcane bagasse ash crossed the strength of refernce concrete samples. It was observed that the peak values were obtained at curing periods of 7 and 14 days. However, the strength gradually decreased at curing periods of 21 and 28 days and abrubtly increased at curing period of 56 days again. Figure 4,5 and 6 shows the cube compressive strength results at different curing periods and cement replaced partially with different ratios.

3.1 Compressive Strength test of Cubes

Table 1 and Figure 3 shows the compressive strength test results of concrete made by replacing cement with different percentage of sugarcane bagasse ash. The results show that there is increase in compressive strength for cubes at 10% replacement of cement by SCBA for curing period of 7 and 14 days only and gave approximately same value as that of plain concrete.

Table 1: Compressive strength Test results of cube specimens

S.No	Concrete Sample	Compressive Strength (psi)				
		7 days	**14 days**	**21 days**	**28 days**	**56 days**
1	Plain Concrete (0% R.A + 0% B.A)	3276	3946	4000	4241	4425
2	Recycled Concrete (100% R.A)	2281	2334	2253	2192	3629
3	Recycled Concrete (100% R.A + 5%B.A)	2975	3254	2453	2256	3331
4	Recycled Concrete (100% R.A + 10%B.A)	**3186**	**3852**	**2687**	**2456**	**3587**
5	Recycled Concrete (100% R.A + 15%B.A)	3021	3107	2546	2345	2957
6	Recycled Concrete (100% R.A + 20%B.A)	1661	1801	1432	1360	1647
7	Recycled Concrete (100% R.A + 25%B.A)	1857	1972.6	1647	1588	1597

R.A = Recycled Aggregete
B.A = Bagasse Ash

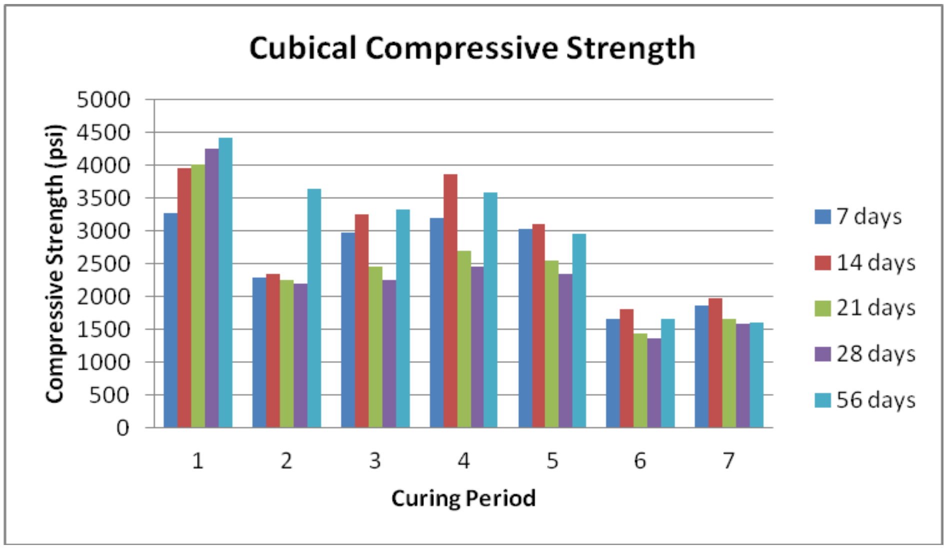

Figure 3: Compressive Strength test result of cubes at different curing periods

3.2 Compressive Strength Test of Cylinders

The results given in Table 2 and Figure 4 show the compressive strength test results of cylinder specimens made by replacing cement with different percentage of sugarcane bagasse ash with 100% replacement of coarse aggregate with dismantled road aggregate. The results obtained show that there is increase in compressive strength for cylinders at 10% cement replacement at curing period of 7 and 14 days that almost crossed the strength of plain concrete.

Table 2: Compressive strength Test results of cylinder specimens

S.No	Concrete Sample	Compressive Strength (psi)				
		7 days	14 days	21 days	28 days	56 days
1	Plain Concrete (0% R.A + 0% B.A)	2016	2132.5	2211	2504	**2886**
2	Recycled Concrete (100% R.A)	1275	1578	1518	1434	**1792**
3	Recycled Concrete (100% R.A + 5%B.A)	1225	2034	1425	1383	**2032**
4	Recycled Concrete (100% R.A + 10%B.A)	**2260**	**2392**	**2115**	**2043**	**2488**
5	Recycled Concrete (100% R.A + 15%B.A)	1086	2168	1496	1529	**1958**
6	Recycled Concrete (100% R.A + 20%B.A)	1000	1405	1196	1110	**1556**
7	Recycled Concrete (100% R.A + 25%B.A)	1626	1418	1216	1115	**1263**

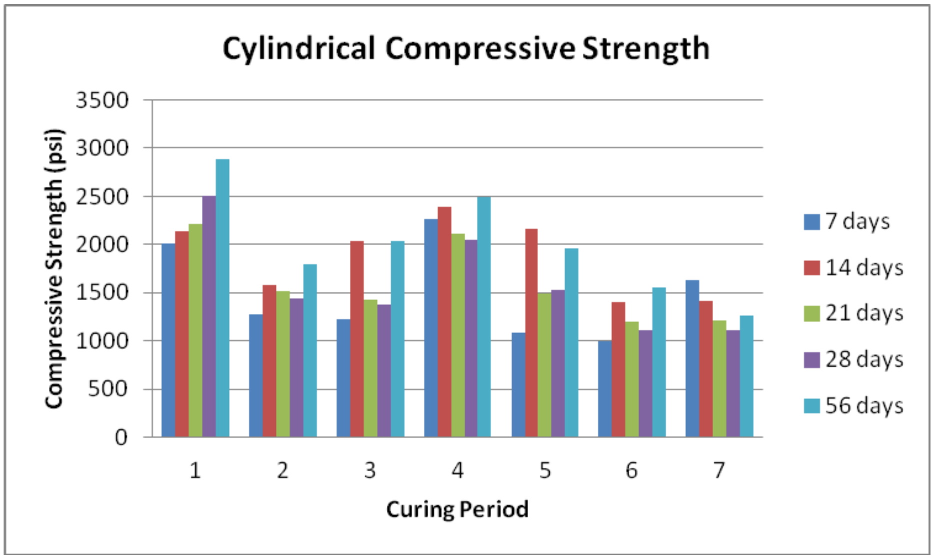

Figure 4: Compressive Strength test result of cylinders at different curing periods

3.3 Tensile Strength test of Cylinders

The results in Table 3 and Figure 5 show the tensile strength test values of cylinder specimens made by replacing cement with different percentage of sugarcane bagasse ash and 100% replacement of coarse aggregate with dismantled road aggregate. Peak values of tensile strength have been obtained at 10% cement replacement by sugarcane bagasse ash at curing period of 7 and 14 days.

Table 3: Tensile strength test results of cylinder specimens

S.No	Concrete Sample	Cylindrical Tensile Strength (psi)				
		7 days	**14 days**	**21 days**	**28 days**	**56 days**
1	Plain Concrete (0% R.A + 0% B.A)	164.2	219	233	251	**273**
2	Recycled Concrete (100% R.A)	102	138	118	95	**101**
3	Recycled Concrete (100% R.A + 5%B.A)	104	109	86	83	**117**
4	Recycled Concrete (100% R.A + 10%B.A)	**168**	**210**	**134**	**129**	**188**
5	Recycled Concrete (100% R.A + 15%B.A)	117	122	113	111	**140**
6	Recycled Concrete (100% R.A + 20%B.A)	82	101	71	70	**102**
7	Recycled Concrete (100% R.A + 25%B.A)	76	88	81	86	**96**

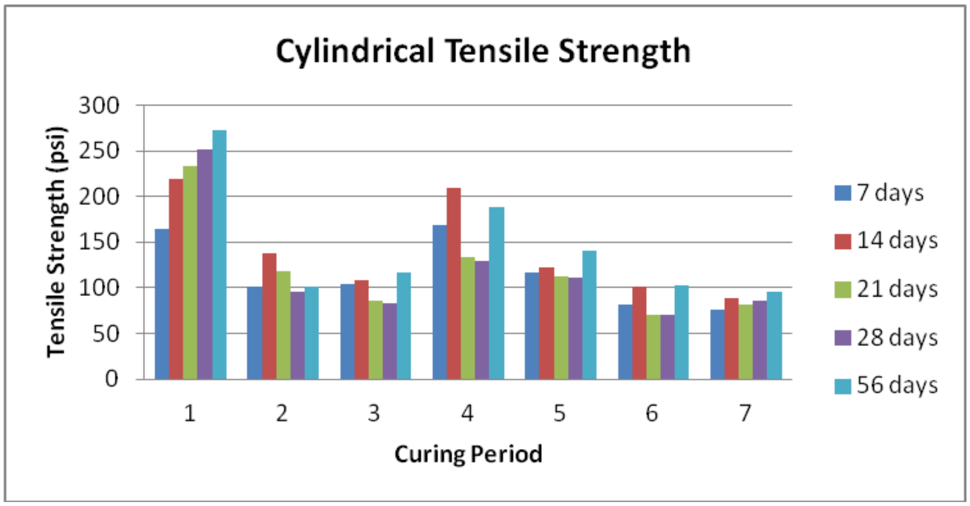

Figure 5: Tensile Strength test result of cylinders at different curing periods

4. Suggestions

Results presented above are based on the experimental evaluation of 246 concrete specimens consisting both cubes and cylinders made by recycled aggregate and sugarcane bagasse ash. The study has revealed positive and acceptable results at 7 and 21 days curing. To get more positive results and the reason behind the sudden increase of strength after 56 days curing may be investigated by using aggregate of different sources. Therefore, further analysis of recycled aggregates from various sources and experimental assessment of strength of more cubes and other models will not only give better perceptive but may also lead to better results. A supplementary material may also be used in order to get more accurate and higher values of compressive and tensile strength. This experimental work has been carried out by using sugarcane bagasse ash, however study can be carried out by using different pozzolanic materials in concrete made by recycled road aggregate.

5. Conclusions

The experimental study by using recycled aggregate and sugarcane bagasse ash revealed that,

1. The peak values were obtained when cement was replaced by 10% partially with sugarcane bagasse ash and coarse aggregate used was 100% recycled.
2. Increase in compressive strength value was obtained at curing periods of 7 and 21 days. The results almost reach the strength of plain concrete.
3. With increase of curing period that is 21 and 28 days the compressive strength was decreased. However, it was abruptly increased again at curing period of 56 days. This increase in strength again after 56 days can be because the bitumen stuck with the coarse aggregate became completely deactivated and the strength started to increase again.
4. Same results were also observed in tensile strength where the highest value was obtained at 10% cement replaced by SCBA after curing period of 7 and 14 days.

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References

Arundeb, G., Saroj, M., Somnath,G., (2011). “Direct compressive strength and Elastic modulus of recycled aggregate concrete” *International Journal of Civil and Structural Engineering*, Vol. 2, No. 1, pp 292-304.

Cordeiro, G.C., R. D., Toledo Filho, R.D., Fairbairn, E.M.R. (2010). “Ultrafine sugar cane bagasse ash: high potential pozzolanic material for tropical countries” *Ibracon Structures and Materials Journal*, Vol. 3, No. 1, pp 50-67.

Janjaturaphan, S., Wansom, S. (2010). “Pozzolonic Activity of Industrial Sugarcane Bagasse Ash” *Suranaree Journal of Science and Technology,* Vol. 17, No. 4, pp 349-357.

Kanhe, N.M., Awchat, G.D., (2013). “Experimental Studies on Polymer Modified Steel Fibre Reinforced Recycled Aggregate Concrete” *International Journal of Application or Innovation in Engineering & Management (IJAIEM)*, Vol. 2, No. 12, pp 126-134.

Ling, T.C., Poon, C.S., Wong, H.W. (2013). “Management and recycling of waste glass in concrete products: Current situations in Hong Kong” *Elsevier Journal of Resources, Conservation and Recycling*, Vol. 10, No. 6, pp 25-31.

Paula, M.O., Tinoco, E.F.F., Rodrigues, C.S., Saraz, J.A.O., (2010). “Sugarcane bagasse ash as a Partial Portland cement replacement material” *Journal of Dyna*, Vol. 77, No. 163, pp 47-54.

Rahman, I.A., Hamdam, H., Zaidi, A.M.A., (2009). “Assessment of Recycled Aggregate Concrete” *Journal of Modern Applied Science*, Vol. 3, No. 10, pp 47-54.

Sivakumar, N., Muthukumar, S., Sivakumar,V., Gowtham, G., Muthuraj, V., (2014). “Experimental Studies on High Strength Concrete by using Recycled Coarse Aggregate” *International Journal of Enineering and Science*, Vol. 4, No. 1, pp 27-36.

Sathe, P.D., Ingle, G.S., Patil, S.P., (2013). “Recycled Coarse Aggregate” *International Journal of Advanced Technology in Civil Engineering,* Vol. 2, No. 1, pp 27-33.

Yong, P.C., Teo, D.C.L., (2009). “Utilization of Recycled Aggregate as Coarse Aggregate in Concrete” *UNIMAS E-Journal of Civil Engineering*, Vol. 1, No. 1, pp 01-06.

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Performance of Blended Cements exposed to marine environment

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Abstract

Cement based materials when exposed to aggressive environments like the one near shore deteriorate due to ingress of moisture and other harmful chemicals. This study presents the performance of cements blended with pozolanic materials in extreme marine environment. An experimental study was conducted for this purpose in which mortar cubes of different cements including OPC, SRC, Slag cement and Blended OPC and SRC cements (varying percentages of 30% Fly Ash and 15% Silica Fume) were cast. Compressive strength of each was measured at 28 days initially. Samples were then immersed in sea water for 180 days to observe the impact of marine environment. Testing was done to determine the strength of the immersed samples after 90 days and 180 days. OPC samples showed the highest compressive strength after 28 days of curing but when exposed to extreme environment, strength degradation was observed and reduction was more as compared to OPC belended cements and slag cement. Maximum strength reduction was observed in SR belended cements. In addition to mortar cubes concrete cylinders were also prepared from all the cement types mentioned above to compare the pH resistance of each. All the cylinders were first cured in normal water for 28 days and pH values noted after 28 days curing. Samples were then exposed to marine environment for 28 days and pH values noted after 28 days exposure. Least change in pH was observed in samples cast with OPC blended with fly ash while maximum cahnge in pH was found in samples cast with OPC blended with silica fume. Results of OPC, Slag cement and SR blended cement samples were not found significantly different in terms of change in pH. Overall performance of samples cast with fly ash blended OPC cement was found to be the best.

Keywords

Performance, Blended Cements, Pozolans, Marine Environment, Compressive Strength.

1. Introduction

Concrete generally performs well under loads and have shown robustness as far as the strength is concerned; however, durability is the factor which has to be considered if the structures are to serve for their design life span. Concrete structures exposed to the severe conditions of marine environments can be affected by three types of deterioration mechanisms: 1) physical, such as freezing and thawing, wetting and drying, and abrasion, 2) chemical attack and 3) chloride induced corrosion (Zacarias, 2007). Corrosion, one of the main causes of deterioration in concrete structures, initiates due to its exposure to harmful chemicals that may be found in nature such as in some ground waters, industrial effluents and sea waters. The most aggressive chemicals that affect the long term durability of concrete structures are the chlorides and sulfates (Khan, 2009). The dissolved chloride in waters reacts with chemical constituents of concrete and results in leaching and thus increases the porosity of concrete, and leads to loss of stiffness and strength (Khan, 2009). Calcium, sodium, magnesium, and ammonium sulfates are, in increasing order

of hazard, harmful to concrete as they react with hydrated cement paste leading to expansion, cracking, spalling and loss of strength (Wee *et al.,* 2000).
Different Codes (ACI 357R-84 (1997), BS 6349-1:2000, RILEM Technical Committee (2013)) recommend certain guidelines for obtaining more durable concrete in marine environments. Specifications include least compressive strength of concrete, limiting water-cement ratio, minimum C_3A content and choice of cements and admixtures. ACI 318 requires Type II cement or Type I plus a pozzolan to resist the moderate sulfate attack from seawater. ACI 357 permits Type I, II, and III cement but recommends that the tricalcium aluminate (C_3A) content is between 4% and 10% (Suprenant, 1991). Fly ash, blast furnace slag, and silica fume are the most common pozzolans used in concrete mixtures for marine environments. Pozzolans combine with the calcium hydroxide and water in the mix to form hardened cementitious products. These hydrated products increase the strength and reduce the permeability of the concrete. Pozzolans also chemically combine with the lime to form less soluble products, thus reducing the effects of lime leaching (Mehta, P. K., 1988). Use of suitable coatings on concrete to decrease permeability and for better performance in aggressive marine environment has also been reported in literature (Aguiar *et al.*, 2008).

This research is aimed to compare the performance of different types of blended cements in marine environment. A testing programme was conducted for this purpose. Mortar cubes and concrete cylinders were cast and tested for determination of compressive strength and pH values for OPC, SRC, Slag cement, OPC and SRC with 30% and 15% fly ash and silica fume respectively. Compressive strengths of mortar samples were determined at twenty eight (28) days to be used as reference for comparison with compressive strengths after exposure to marine environment. Remaining samples were then immersed in sea water collected from local Karachi region for about 6 months (180 days). Compressive strengths were determined at 90 and 180 days for each sample. Initial pH of cylinders was determined after 28 days of curing. Remaining samples were immersed in sea water for another 28 days and final pH was determined.

2. Experimental Program

For comparing the performance of different cements, mortar cubes and concrete cylinders were cast and tested for comparison of their performance when exposed to marine environment. A total of seven (07) cement types were used for study including OPC, Sulphate Resistant Cement (SRC), Slag cement (SC) and blended cements. In blended cements, silica fume (SF) and class C fly ash (FA) were used in different percentages (15% and 30% respectively) with OPC and SRC. Compressive strength of mortar cubes were tested at 28 days for comparison with the strength after 180 days exposure to sea water. Initial pH value was determined after 28 days normal curing and then compared with final pH value after 28 days exposure to sea water. Sea water used for immersing the mortar samples was collected from local Karachi beach. Sea water characteristics were also tested in lab which was found high in magnesium and chloride content. Properties of sea water used to immerse mortar samples are presented in Table 1. It can be seen from Table 1 that sea water has high turbidity and TDS level along with high chloride and magnesium contents. High turbidity and TDS level can lead to severe deterioration in concrete structures on continuous exposure whereas high chloride content can cause carbonation and corrosion of steel and Magnesium in the form of Sulphates may invite sulphate attack and spalling of concrete.

Table 1. Properties of Sea Water

Parameter	Result
pH	6.6
Turbidity	5.63 NTU
TDS	38500 mg/L
Hardness	7500 mg/L
Calcium	800 mg/L
Magnesium	1576 mg/L
Chloride	2299 mg/L

2.1 Casting and Testing of $2'' \times 2''$ Mortar Cubes and $4'' \times 8''$ cylinders

Mortar cubes of size $2'' \times 2''$ were cast and tested according to ASTM C 109 standard. Cement and fine aggregates were mixed in a ratio of 1:5 and water cement ratio was kept at 0.5 for all types of cements mentioned above. After demolding, mortar cubes were cured in tap water for 28 days and were tested in uniaxial compression to determine compressive strength at 28 days. After 28 days remaining samples were then immersed in sea water collected from a Karachi beach for 180 days. They were tested after 90 and 180 days of sea water exposure for making comparisons with the control specimens.

Concrete cylinders of $4''$ dia. and $8''$ height**s** were cast and tested according to ASTM C 39 standard. Cement, fine and coarse aggregates were mixed in a ratio of 1:2:4 with water cement ratio of 0.5 for all types of cements used in the study. Fine sand used in the study was obtained by passing through sieve #4 and coarse aggregate used were retained on sieve $3/8''$ and passing through $1/2''$. Overall fourteen cylinders were cast, two concrete cylinders for each cement type. All the samples were initially cured for 28 days in tap water. After 28 days, initial pH values were determined by using one cylinder from each cement type. Remaining samples were then exposed to sea water for another 28 days. Final pH values were determined to compare them with initial pH values.

Summary of the number of mortar and concrete samples cast and tested is given in Table 2.

Table 2. Mortar and Concrete Specimen tested for Compressive Strength and pH Comparison

Type of cement	Mortar Cube	Concrete Cylinders
OPC	9	2
OPC+ 30% FA (OPCFA)	9	2
OPC+ 15% SF (OPCSF)	9	2
SRC	9	2
SRC+ 30% FA (SRCFA)	9	2
SRC+ 15% SF (SRCSF)	9	2
SLAG (SC)	9	2

3. Results and Discussion

Results were obtained in terms of compressive strength of mortar cubes and pH values of concrete cylinders. Compressive strengths of each type of mortar samples were compared with OPC at 28 days as well as after exposure of mortar samples to sea water for 90 days and 180 days. All the samples were visually inspected to qualitatively assess the damage after 90 and 180 days of sea water exposure before testing to determine the compressive strength.

3.1 Comparison of Strength of Mortar Samples

Compressive strengths were determined for mortar samples of each cement type at 28 days normal curing period as well as after 90 and 180 days exposure of sea water and are presented in the form of bar charts in Figure 1. Results presented here are average of three samples for each cement type.

It can be seen in Figure 1 that at 28 days strengths of OPC and Slag cement samples are comparable, but after exposure to sea water, both type of cements showed reduction in strength after 90 and 180 days with both types of cements showing similar response. Better response of Slag cement samples is in agreement with the results reported by Ferreira *et al*., 2004. Compressive strengths of blended cements at 28 days are not comparable with OPC except for SRCFA which gained strength comparable to OPC and SC. OPC blended cements showed gain in strength when immersed in sea water upto 90 days but after that reduction in strength was observed. This behaviour is in agreement with the findings of Wegian, 2010. The better resistance of Fly ash mortar samples against chemical penetration when immersed in sea water is in close agreement to the findings of Cao and Liana, 2000. Performance of SRC mortar samples was as expected and addition of fly ash and silica fume seems to have no effect on the performance enhancement of SR blended cements when exposed to marine environment. Performance in terms of better resistance against aggressive chemical attack is discussed in the following section.

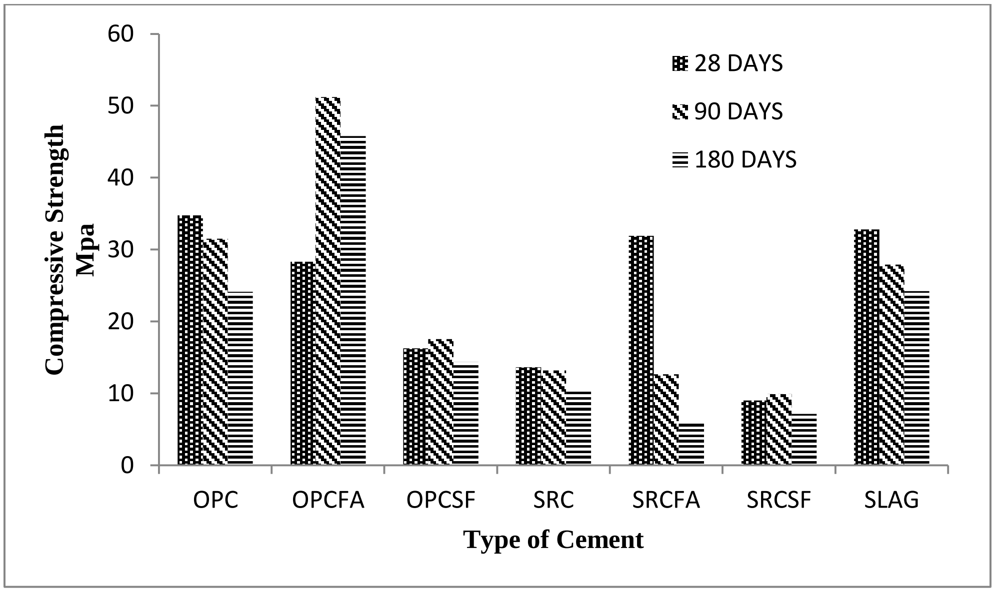

Figure 1: Comparison of Compressive Strengths Mortar Samples at 28, 90 and 180 days

3.2 Reduction in Compressive Strength of Mortar Samples

The degree of deterioration was also evaluated by measuring the reduction in compressive strength. The reduction in compressive strength was calculated as follows:

$$\text{Reduction in compressive strength (\%)} = \frac{B-A}{A} \times 100$$

where A is either the average compressive strength of three specimens after 28 days of normal curing or after 90 days of exposure to sea water in MPa; and B is either the average compressive strength of three specimens exposed to the sea water after 90 days or 180 days in MPa. Normally, strength reduction is calculated based on 28 days compressive strength but the trend seen in almost all the types of cements show that strength gain is up to 90 days of sea water exposure it seems appropriate that reduction in strength after 180 days is calculated with reference to 90 days sea water exposure strength.

Strength reduction for all types of cements used in the study is shown in Figures 2 and 3. Strength reduction after 90 days of exposure is shown in Figure 2. Maximum reduction (60.25%) was found to be in SRCFA samples followed by SC, OPC and SRC samples. No loss of strength was observed in OPCFA, OPCSF and SRCSF samples. In fact there was strength gain in these samples as can be seen in Figure 1.

Strength reduction after 180 days of exposure is shown in Figure 3. Maximum reduction (51.73%) was again found to be in SRCFA samples followed by SRCSF, OPC and SRC samples. Minimum loss of strength (10.54%) was observed in OPCFA followed by SC (13.28%) and OPCSF (18.05%) samples. This is also reflected in Figure 1. It can be noticed from observed results that OPC blended cements have performed better than other types of cements used in the study and hence can be recommended for use in marine environment.

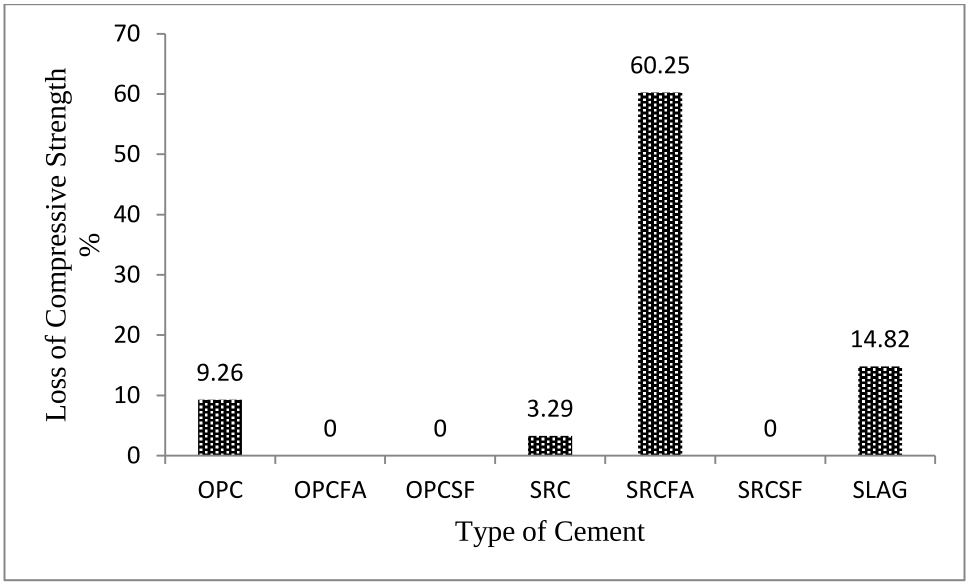

Figure 2: Loss of Compressive Strength at the exposure of 90 days

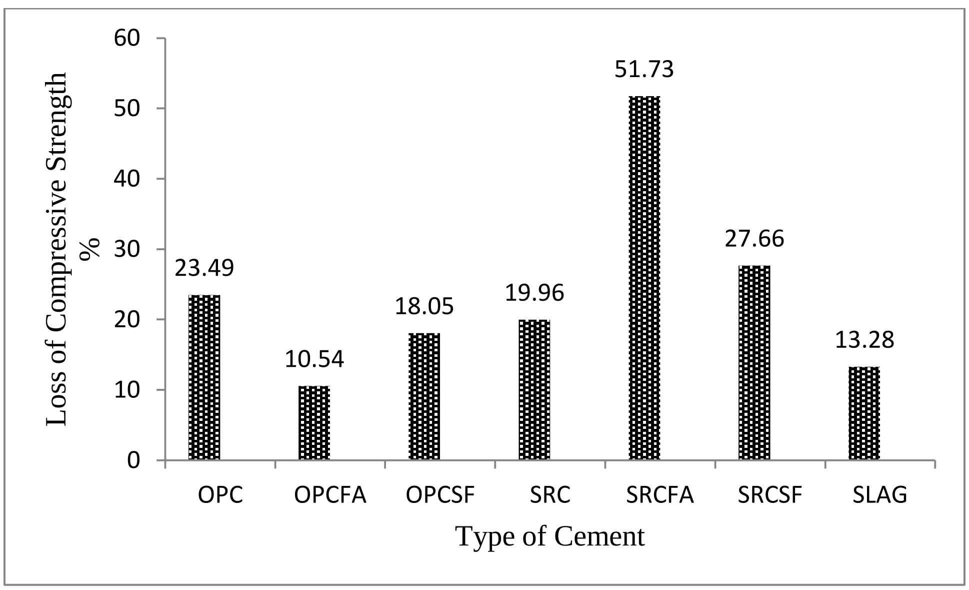

Figure 3: Loss of Compressive Strength at the exposure of 180 days

3.3 Change in pH of Concrete Cylinders

Change in pH of concrete samples was calculated as follows:

$$\Delta pH = |pH(initial) - pH(final)|$$

where, *pH(initial)* is the pH of the sample at the end of 28 days curing in tap water and *pH(final)* is the pH of the sample at the end of 28 days exposed to sea water.

Change in pH for all types of cements used in the study is shown in Figure 5. Minimum change (0.05) was found to be in OPCFA samples while maximum change (0.45) was noticed in OPCSF samples. It can be seen from the figure that SRC, SRCFA and SRCSF have performed better than OPC and Slag cement in terms of pH change. It can be noticed that almost all the blended cements have performed better or close to OPC except for OPCSF samples, where maximum change is observed, indicating that blended cements are a better option in marine environment.

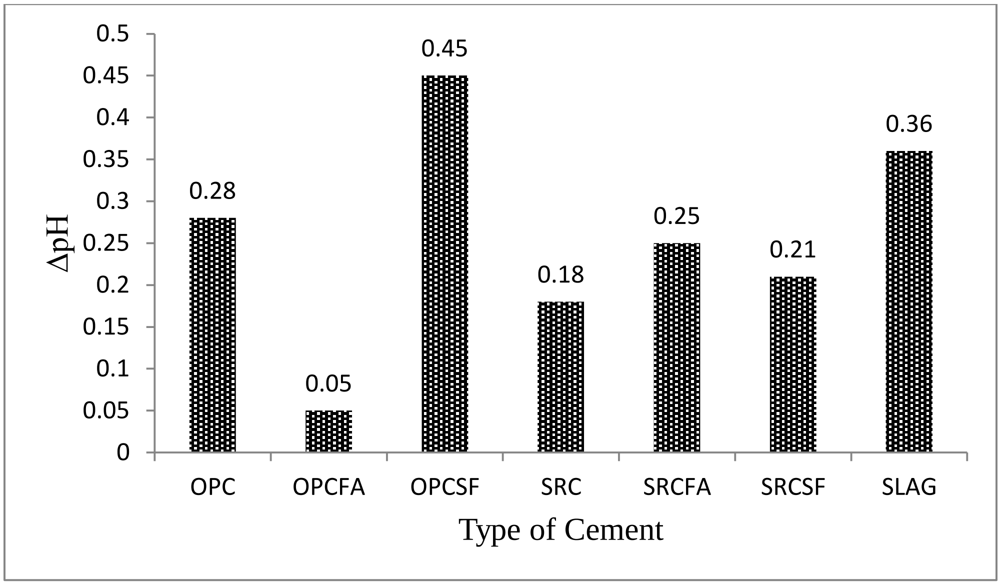

Figure 5: Change in pH values of Concrete Samples

4. Conclusions

Conclusions drawn from the study are as follows:

1. In terms of 28 days compressive strength, performance of OPC and slag cement and was found to be better than other cement types followed by SRCFA, OPCFA, OPCSF and SRCSF. Performance of SRCSF samples was found to be worst among all the cement types used.
2. 90 days of exposure to sea water resulted in strength gain in OPCFA, OPCSF and SRCSF only.
3. In terms of resistance to aggressive chemical attack, performance of OPCFA was found to be better than other types of cement used in the study followed by SC and OPCSF. Performance of SRCFA samples was found to be worst among all types of cement used.
4. OPCFA samples showed minimum change in pH followed by SRC, SRCSF and SRCFA. Performance of OPCSF samples was found to be worst among all types of cement used.
5. Overall performance of OPCFA was better than other types of cement used in the study.
6. It is further recommended that study be extended for longer exposure to marine environment and other durability related tests be included to have a better idea of performance of blended cements.

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5. References

ACI 357R-84 (reapproved in 1997), “Guide for the Design and Construction of Fixed Offshore Concrete Structures”, Committee 357, ACI.

Aguiar, J. B., Camoes, A. and Moreira, P. M. (2008), “Performance of concrete in aggressive environment”, *International Journal of Concrete Structures and Materials*, Vol. 2, No. 1, pp. 21-25.

Alexander, M., Bertron A. and Belie, N. D. (2013), Performance of Cement-Based Materials in Aggressive Aqueous Environments”, State-of-the-Art Report, RILEM TC 211 – PAE, Volume 10. ISBN: 978-94-007-5412-6 (Print) 978-94-007-5413-3 (Online)

British standard for maritime structures BS 6349-1:2000, “Maritime structures. Code of practice for general criteria”

Cao, H. T. and Liana, B. (2000). “Fly Ash Concrete In Marine Environments”, from CSIRO Research Report Bre No. 062. Fly Ash Reference Data Sheet No. 6(2000). Ash Development Association of Australia.

Ferreira, M., Liu, G., Nilsson, L. and Gjorv, O. E. (2004), “Blast Furnace Slag Cements for Concrete Durability in Marine Environment”, *Proceedings of Concrete under Severe Condition: Environment & Loading, CONSEC’04*, Seoul, Korea.

Khan, A. R. (2009), “Performance of different types of Pakistani cements exposed to aggressive environments”, Concrete Repair, Rehabilitation and Retrofitting II – Alexander et al (eds), Taylor & Francis Group, London, ISBN 978-0-415-46850.

Mehta, P. K. (1988), “Durability of Concrete Exposed to Marine Environment—a Fresh Look”, *Proceedings of Concrete in Marine Environment, SP-109, Second International Conference, St. Andrews by-the-Sea*, Editor: V. M. Malhotra, ACI, Canada.

Suprenant, B. A. (1991), “Designing concrete for exposure to sea water”, Publication # C910873, The Aberdeen Group.

Wee, T.H., Suryavanshi, A.K., Wong, S.F. & Rahman, A.K. (2000), “Sulfate resistance of concrete containing mineral admixtures”, *ACI Materials Journal*, Vol. 97, pp. 536–549.

Wegian, F. M. (2010). “Effect of seawater for mixing and curing on structural concrete”, *The IES Journal Part A: Civil & Structural Engineering*, Vol. 3, No. 4, pp. 235-243, DOI: 10.1080/19373260.2010.521048

Zacarias, P. S. (2007), “Alternative cements for durable concrete in offshore environments”, *Proceedings of The Offshore Mediterranean Conference and Exhibition*,Ravenna, Italy, March 28-30.

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The use of Building Information Modelling in disaster management

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Abstract
Around the world each year natural and man–made disasters pose a challenge to architects, civil engineers and builders that involves damage assessment and reconstruction of the affected areas. However, lack of proper management of existing technologies and failure to implement appropriate measures to manage reconstruction projects leads to disruption of communication between the parties involved and delay in the completion of projects. To overcome this situation the management of post-disaster reconstruction is proposed, using the Building Information Modelling (BIM) system as the main hub for consolidating, sharing and managing information construction between professionals. A housing prototype was modelled to explore the use of the BIM system in housing reconstruction after a disaster. The findings showed that BIM allows early and effective management of construction information, saving both time and money, since the housing prototype was easy to modify without the need to re-design. Future construction problems were identified through 3D views even before the real construction of housing. 3D views also enabled the creation of 4D (time) and 5D (estimation) views, thus managing all construction information in a single platform to enhance post-disaster management, which could facilitate housing reconstruction on a large scale, thus building disaster resilience.

Keywords
BIM, disasters management, disaster resilience, housing and reconstruction.

1. Introduction
After a disaster the role of the construction industry is significant in rebuilding the areas damaged. However, the magnitude of damage left by these types of catastrophe, lack of reconstruction plans (Nikbakhsh and Zanjiranim 2011) and experience to manage the reconstruction appropriately contribute to exacerbating the problem. In order to overcome such problems, the Building Information Modelling (BIM) system is proposed to implement measures that enable the teamwork and contribute to providing a solution to the restoration of affected areas as soon as possible. This paper is focused on the application of the BIM and the 3Dimensional-Lightweigth Panels construction (3D-LPs) systems for housing reconstruction post-disaster. BIM Revit 2013 from Autodesk was the platform to model a basic housing unit of 38.5 m^2 with 3D-LPs which are lightweight panels made of cores of polystyrene and steel wire mesh able to withstand earthquakes and hurricanes (Stevenson, 1986). The system involves panels (3D-LPs) acting as reinforced concrete walls and roof, which work as monolithic structures because the panels are covered by mortar or concrete layers on both faces

(Tecnopanel, 2002). A typical example of disasters that have occurred in recent decades, the 2004 Indian Ocean Tsunami is representative of a series of problems faced by stakeholders in charge of recovering housing and offers wide knowledge in matters of disaster management from which it is worth learning (Coles et al., 2012). After this disaster, construction firms were hired by Non-Governmental Organizations (NGOs) and International Agencies (IAs) to rebuild the housing damaged in fourteen countries (Da Silva and Batchelor, 2010) (Florian, 2007). The results were poor quality housing and delay in the completion of housing due to scaling of prices, scarcity of construction materials and lack of communication and understanding among construction firms, NGOs and IAs (Chang et. al., 2010). The housing suffered from cracks in the foundations and inappropriate architectural designs (Shaw, 2010). The shortage of construction materials increased the total cost of the housing and the lack of communication and understanding between stakeholders led to delay in delivery of houses (Nikbakhsh and Zanjiranim 2011). A computer simulation was conducted in the BIM system to explore how the BIM system allows the modelling of a housing prototype (HP). The findings were: first, an architectural design of the HP shows how the real building looks before being built, in order that NGOs, IAs and users can understand the stages of the construction, since the 3D views enable the visualization of the HP. Second, the construction information is accessible to construction professionals (engineers, architects, surveyors and designers) in a unique platform which can show the architectural and structural plans and the life cycle of construction of the HP. Third, the HP can be modified and all of the changes are available for all members of the team in order to save design time and have all information updates. The research aim was to reduce the construction cost and time of housing after a disaster by using the BIM and the 3D-LPs construction systems.

2. Methodology

The methodology developed by the University of Houston to conduct computer simulations was adapted to simulate the HP in the BIM system Revit 2013 developed by Autodesk. The methodology process was composed of nine steps. The first step was to establish the problem: how reduce the construction cost and time of housing after a disaster by using the BIM system. The second step was project planning: in this stage the 3Dimensional Lightweight Panels (3D-LPs) were chosen as the main construction material. An architectural design was the starting point in the third step: to model a HP, which can be adapted to build houses anywhere affected after a disaster. The fourth step was model formulation: in this step an architectural and structural prototype was proposed according to the specifications of the 3D-LPs construction system, based on the building design regulations for concrete and steel. Collection and analysis of data was the fifth step; it was decided that an interview with manufacturers of the 3D-LPs would be the appropriate means for data collection. The analysis was focused on practical feasibility of the models simulated. The sixth step was to establish the BIM system Revit 2013 developed by Autodesk as the system to model both architectural and structural HP models. Verification and validation were conducted in the seventh step by comparing the computer simulation to the real model built with the 3D-LPs construction system, and asking the representative of Panel W Company for technical support. Finally, steps eight and nine were to model the HP several times until the prototype behaved as planned and looked similar to real housing built using the 3D-LPs construction system, and to document the results (Houston, 2000).

3. Simulation

The housing prototype simulated in the BIM system Revit 2013 with the 3D-LPs construction systems is a basic housing unit on one level 5.50m wide x 7.00 m long, composed of two bedrooms of 2.50m x 2.50m and 2.50m x 3.00m; one lounge 3.00m x 4.50m; one kitchen 2.50 x 2.00m and one bathroom 2.50 x 2.25m. The HP was designed in accordance with the definition established for housing by the United Nations (UN), which states “The human right to adequate housing is more than just four walls and a roof. It is the right of every woman, man, youth and child to gain and sustain a safe and secure home and community in which to live in peace and dignity” (UN, 2006). The design also sought to meet the guiding principles for Housing Design Construction Technology (HDCTs) from the handbook for reconstruction after Natural Disaster by the World Bank, which indicates that universal housing should be coherent with construction materials, accessible and adaptable to all people to make life easier for users. In addition, it should have adequate size and be flexible to give comfort and efficiency. It should also be able to reduce hazards and damage caused by accidental actions (Jha, et al., 2010). Figure 1 shows the basic architectural model of a HP of 38.5 m^2 modeled in the BIM system with 3D-LPs (2D) taking into account the aforementioned requirements and construction design regulations for concrete and steel buildings.

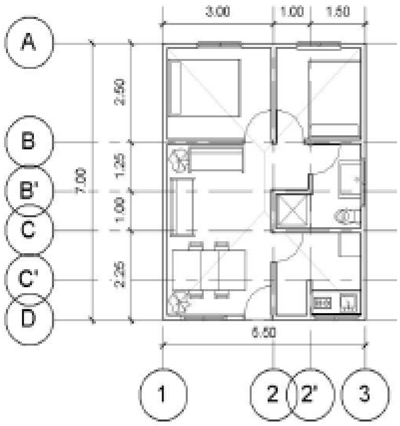
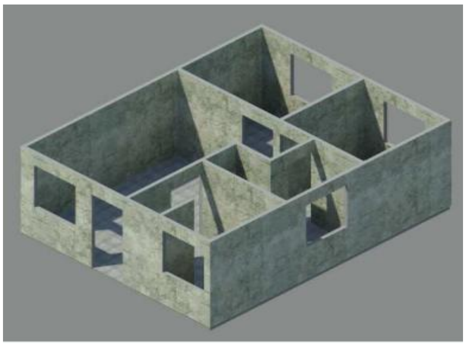


Figure 1 Housing Prototype in BIM (2D)

3.1 Architectural simulation

The computer simulation belonging to the architectural model of the HP involved several stages to explore the benefit of using the BIM Revit 2013. The modelling started by placing the HP in the geographic coordinates by using an internet map service integrated in the BIM. Subsequently, the plot was limited by using axes. An existing template BIM to model the walls was duplicated and the characteristics of the 3D-LPs (panels 2” thick, 1.22 m wide x 2.44 m long and 0.095 m thick) were loaded to start the modelling of the walls in the axes drawn. The 0.095 thickness of the panels was calculated by assuming a panel 2” thick and a layer of mortar and paint on both sides of the panels of 0.024m. After creating the 3D-LP walls in the BIM, the next step was to place square windows and doors. Subsequently, in order to make sure that the model was properly working, the first verification was conducted by activating the 3D view of the BIM system. The following step was to model the roof slab on the BIM system; as the BIM does not have the 3D-LPs construction system, a roof template was modified with the characteristics of 3D-LPs, this time the roof was made of 3D-LPs of 4” thickness and 1.22 m wide x 4.50 m long with 2 degrees of slope and a parapet at the top to facilitate future extensions and runoff of water, which can be used to capture rain water in order to have sustainable housing. The last steps were to place windows, doors and furniture. The BIM library was used to achieve these steps; however, the window types available were wider than the walls modelled with 3D-LPs. The windows were therefore modified and adapted to the HP. The simulation was completed with sanitary-hydraulic and electric installations; however it was decided to leave the HP without installations, to give the opportunity to modify and adapt the model to conditions and characteristics of the disaster location.

The architectural distribution was proposed using the minimal measures allowed by the Mexican and Chinese Building Codes, to suggest that the HP could be used anywhere post-disaster. Also it is suggested that the HP will be changed in accordance with the damaged site, to accommodate the suggestions of the HDCTs and the World Bank. The verification of the architectural model was conducted to check that the 2D plan shown in Figure 1 worked as planned. The architectural computer model behaves as was expected, since all walls appear aligned to axes and foundation and the flat roof slab is in the correct place. The validation of the HP was achieved by comparing the architectural computer model against real models obtained by the suppliers and by showing the model to the technical director of the W Panel Company, who agreed with the simulation on the BIM system and gave some suggestions. A back yard and a slight change in the facade were added to the HP to show how the same model can be modified without needing to model a new design. The simulation also shows that dimensions of the HP can be modified by moving the axes and height. Figures 2 to 6 show a compilation of the modelling stages of the HP with the 3D-LPs construction system in the BIM.



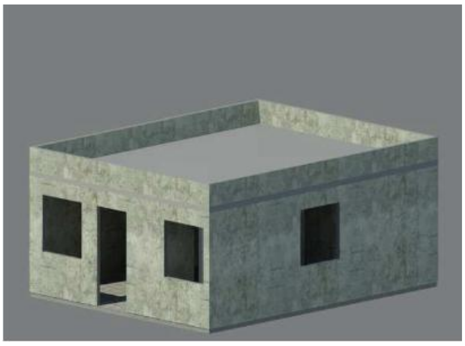


Figure 5 3D-LP walls and roof cover of mortar and concrete

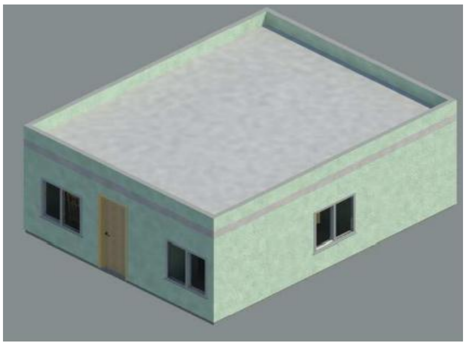


Figure 4 Housing Prototype with paint

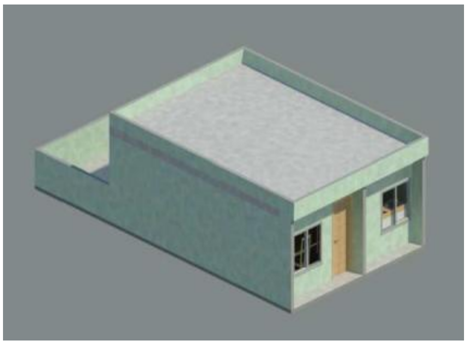


Figure 2 Housing prototype modified In

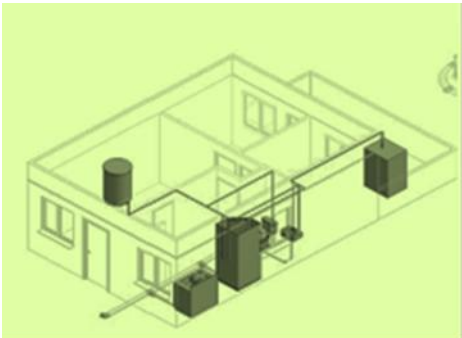


Figure 3 Installations

3.2 Structural simulation

The structural model was conducted in the BIM system Revit 2013 along with the architectural model, since in 2013 Autodesk launched the BIM Revit 2013 version to model a complete project. The structural housing prototype consisted of 3 stages. The first stage was to model a composite foundation based on a slab of 10 cm thickness and beams of 20 cm x 20 cm at a depth of -30 cm in relation to the level of the finished floor as shown in Figure 7. The 20 x 20 cm beams of the HP were modelled in the plot perimeter, and horizontal axes with stirrups/transverse reinforcements with 20 cm spacing and 4 longitudinal reinforcement steel bars with diameter 5/16” were added to simulate the construction of the foundation. Additionally, 60 cm steel bars bent in “L” shape to 90º with diameter 5/16” were anchored to the beams to simulate the placing of 3D-LPs on the foundation. The slab foundation was modelled at the top of the ground beams to complete the foundation simulation. Figure 8 shows the foundation cut belonging to the HP and Figure 9 shows the 3D view of the foundation.

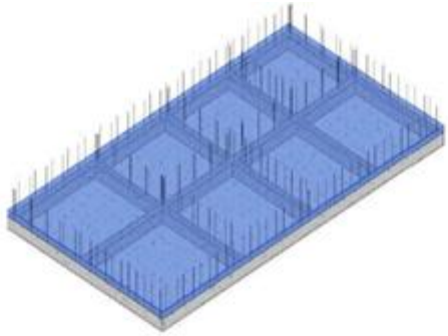


Figure 7 Foundation of housing Prototype in 3D

Figure 6 Cut foundation Housing Prototype (beams and slab)

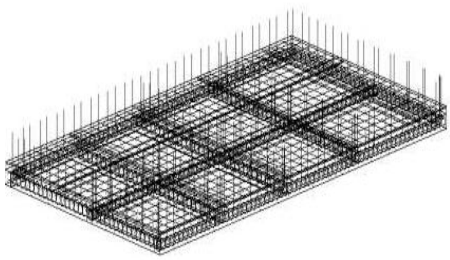


Figure 7 Foundation Housing Prototype in 3D

Subsequently, the second stage was to model the walls; two steps were necessary: connection of walls to foundation and connection of panels to roof. The connection simulation of walls to foundation was carried out by placing the panels in the steel bars placed in the foundation (Figure 9) and by connecting them to each other with meshes made of galvanized steel on both faces (interior and exterior) of the panels. Additionally, steel bars bent to 90º were placed at the corners; and steel bars bent in "U" shape were placed where three panels converged, as can be seen in Figures 10 and 11. The second step was to connect the walls to the roof; this stage was carried out along with the third stage, since the panels must be connected internally and externally. The third stage was to model the structural roof, which was achieved by placing panels 4" thick and 1.22 m wide x 4.50 m long at the top of the walls; they were also connected with galvanized steel mesh on both sides of the panels. The connection of the roof to the panels was carried out with "L" shaped mesh, and they were connected to each other with galvanized steel mesh. To provide continuity and ensure structural integrity, the process of connecting the panels is based on technical specifications of the manufacturers of the 3D-LPs construction system (CS&M, 1978) (Escrow, 2012).

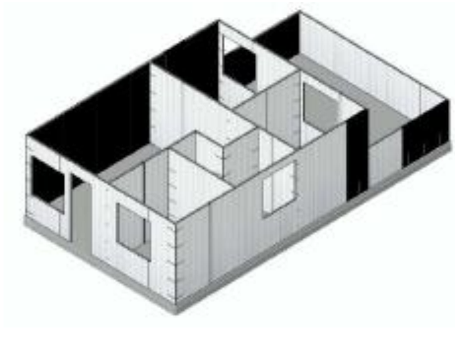


Figure 9 Modeling of the 3D-LPs construction system

Figure 8 3D view of the structural steel and galvanized mesh

4. Results and Discussion

The architectural model simulated in BIM with the 3D-LPs construction system shows that the housing reconstruction after a disaster could be managed in the BIM system if an architectural-structural design is modelled and documented in this system. It was shown that the BIM system is not only a system to model a building. BIM is a platform to create lists of materials, schedules of activities and phases of construction in order to manage the whole construction process. The management of housing reconstruction could be implemented through BIM to save design time and retain control over the reconstruction process. Moreover, the architectural housing prototype simulated in the BIM system shows that housing can be modelled with the 3D-LPs construction system under specifications established in housing design building codes. However, using the experience of construction professionals is important to optimize results. The most important finding is that the HP can be modified and adapted to different dimensions through modifying axis and height levels, thus avoiding waste of time in designing a new model. Therefore a housing prototype designed in accordance with the building regulations and needs of the affected people could be designed only once, then adapted and modified as many times as necessary. Similarly, it was found that all modifications made in the model are reflected in the take-off, which contributes to updating the list of construction materials. The architectural model was used to estimate the total cost of the basic housing prototype; it was found that listing quantities and materials contributed to reducing human error, since the BIM prevented the duplication of materials. Also, the constraints on modelling a building in BIM are useful to avoid placing structural or architectural elements outside the correct design.

The computer simulation of the HP modelled in the BIM allowed an economic estimation to be conducted; however, to achieve this it was necessary to export the data to a spreadsheet, because another system is required to develop the models towards 4D (time) and 5D (estimation). It is important to highlight that this paper is a part of an integral study which involved the study of using the 3D-LPs construction system, the participation of the affected people post-disaster and the use of the BIM system. Only the findings of the computer simulation of the housing prototype are highlighted here. However, it can be said that the 3D views obtained from the use of the BIM allowed guidelines for the provision of training to unskilled people affected by disasters to be developed, which is significant, because the 3D views enabled it to be determined that the reconstruction of housing damaged by disaster could be completed in 90 days (bringing the computer simulation of the BIM to 4D) and then calculating the schedule of the construction phases of the HP, allowing the total cost of the HP to be estimated as almost 37% cheaper than other traditional systems (bringing the computer simulation of the HP to 5D) (Flores, 2015).

5. Conclusions

A housing prototype was modelled in the BIM system by using the 3D-LPs construction system to rebuild (produce) housing post-disaster. The computer simulation of the housing prototype in the BIM system Revit 2013 allows the conclusion that BIM is more than a system for drawing, since the 3D views contribute to simplifying the understanding of a project, even if the stakeholder lacks construction experience and knowledge.

The computer simulation of the housing prototype in the BIM system Revit 2013 with the 3D-LPs construction system offers sufficient evidence to conclude that the 3D views enable the creation of schedules and economic estimations, giving control over the project and bringing the project toward 4D and 5D. However, two elements are essential to conduct projects in BIM appropriately: first, expertise in management of projects; and second, a platform to export data in order to estimate the total cost of a project.

As a result of the computer simulation of the housing prototype it can be concluded that there were additional benefits in modelling housing with the BIM system, such as the modification and creation of customized designs with different construction materials, which could be useful after a disaster since the places affected by disasters have individual needs and cultural, social and economic conditions, which should be catered for to build disaster resilience as soon as possible.

The computer simulation indicates that the use of the BIM system in housing reconstruction after a disaster could contribute to saving time and money, given that the simulation has shown that BIM prevents human error, and the creation of a template saves design time, translating into saving money. Furthermore, the housing prototype could be reproduced as many times as necessary to implement housing recovery on a large scale to build disaster resilience.

6. Implications and Recommendations

This study is limited to use of the 3D-LPs construction system, community participation and the BIM system post-disaster; therefore it is recommended to conduct a structural simulation in the BIM system to study the structural behaviour of the 3D-LPs and make a comparison between structural analysis developed with traditional methods and results obtained by using the analytic system from BIM Revit from Autodesk.

The implications of this study provide NGOs with a means to understand the stages of the construction of dwellings, in order to monitor construction firms' participation in housing reconstruction after a disaster. NGOs could obtain visual models before the real construction starts, in order to approve projects that really meet the needs of those affected post disaster to help to build disaster resilience in a short time. It is important to keep in mind that people who have been affected by a disaster spend a lot of time waiting for a home, while the construction professionals are addressing the problem.

Acknowledgements
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References

Chang, Y., Wilkinson, S., Potangaroa, R. & Seville, E. (2011). Donor-driven resource procurement for post-disaster reconstruction: Constraints and actions. *Habitat International,* 35**,** 199-205.

Coles, J. B., Zhuang, J. & Yates, J. (2012). Case study in disaster relief: A descriptive analysis of agency partnerships in the aftermath of the January 12th, 2010 Haitian earthquake. *Socio-Economic Planning Sciences,* 46**,** 67-77.

CS&M (1978). Structural Roof and walls panels for commercial and residential construction. *International Conference Building Officials*.

Da Silva, J. & Batchelor, V. (2010). Indonesia: Undersanding agency policy in a national context. *In:* LTD., P. A. P. (ed.) *Building Back Better Delivering people-centred housing reconstruction at scale*

Escrow. 2012. *3d wall panels* [Online]. Mainland China: Alibaba.com. Online at http://www.alibaba.com/trade/search?Country=&IndexArea=product_en&fsb=y&SearchText+panel+sandwich+polyurethane+with+mesh [Accessed 16/04/2012 2012].

Flores, A. 2015. Building Information Management and the provision of post natural disaster housing Ph.D Thesis, University of Manchester at the United Kingdom.

Florian, S. 2007. Housing reconstruction and rehabilitation in Aceh and Nias, Indonesia—Rebuilding lives. *Habitat International,* 31**,** 150-166.

Huston, U. O. 2000. *Simulation and Modeling Team* [Online]. Huston Texas. Online at http://www.uh.edu/~lcr3600/simulation/contents.html [Accessed 2012].

Jha, A., Barenstein, J., Phelps, P., Pittet, D. & Sena, S. 2010. "Safer homes, stronger communities: A handbook for reconstruction after natural disasters. . *The Word Bank. The International Bank for the reconstruction and Development.*

Nikbakhsh, E. & Zanjirani, F. R. 2011. 15 - Humanitarian Logistics Planning in Disaster Relief Operations. *In:* REZA, F., SHABNAM, R., LALEH KARDARA2 - REZA FARAHANI, S. R. & LALEH, K. (eds.) *Logistics Operations and Management.* London: Elsevier.

Shaw, J. 2010. Design and Delivery of Post-disaster Housing Resettlement Programs

Stevenson, D. 1986. Method of forming a reinforced structural building panel. Google Patents.

Tecnopanel, S. 2002. Application of sesimic-resistant building regulation (NCSE-2002). *In:* S.L., T. S. (ed.). Spain.

UN, U. N. H. R. 2006. The Right to Adequate Housing Toolkit. *Elements of the right to adequate housing.*

Investigation of Using Personal Protective Equipment at Construction Sites in Herat Province

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Abstract

This research has focused on the usage of PPE (Personal Protective Equipment) at construction project sites in Herat Province in order to find out the reasons of non-usage of PPE. In addition, the results of this research will help construction managers to increase safety performance in the construction sector of Herat province. A questionnaire survey accompanied by interview technique was conducted to collect data related to PPE usage in Herat province. The respondent society was composed of 64 labors, including project managers, site engineers, site supervisors, skilled and unskilled workers and also the officials of 7 governmental departments and 32 construction companies. Moreover, 18 active construction sites were visited to investigate the status of PPE usage accurately. Results of this study demonstrate that the percentages of PPE usage are as follows: hard hat (26%), safety shoes (43%), safety gloves (81%), glasses (58%), safety belt (64%), safety clothes (45%), face shield (91%), hearing protectors (8%), and safety mask (18%). The main reasons of not using PPE are weakness in emphasis and providing the equipment by owner, low interest of the labors, lack of consideration of a special budget for PPE and low safety culture. Hence, for increasing the safety knowledge and culture, it is needed to hold safety training workshops in different sections and periodically follow up this issue. More attention of donors to this issue can also be helpful.

Keywords

Construction safety, Personal Protective Equipment, Occupational accidents, Herat province, Afghanistan

1. Introduction

Occupational accidents are the origin of about 321,000 mortalities and 317 million injuries worldwide each year (International Labor Organization, 2013). This great number of cases has resulted in severe human and financial impacts in societies (Warch, 2002). Workers in various industries are exposed to occupational accidents differently (Dudarev et al., 2013). Construction is identified as one of the most dangerous industries all over the world (Cheng at al., 2010). Also construction works are one of the most employing activities in every country and so many people in every society are working in construction sites. Therefore, complying with safety rules and using PPE will protect the workers against different hazards. Low educational level of workers, lack of safety culture and communication are common characteristics of construction workers (Fung et al., 2010). Construction works have various occupational phases (Tam et al., 2004). These continuous changes associated with using different sources, weak work conditions, unstable employment, lack of training and rough work conditions are parts of this occupation (Pinto et al., 2011). Safety operation in construction is related to safety culture, methods of monitoring, work cycle, work pressure, competition of staff, safety meetings and safety budget (Lipscomb et al., 2014).

Safety is defined as an operation for protecting workers form hazards and using PPE plays an important role in decreasing frequency and severity of construction accidents (Tehran Chamber of Commerce, 2014).

Lack of required information and knowledge of owners and contractors, lack of monitoring, lack of legal necessities for technical skills in construction sites and lack of acquaintance about PPE are the most important causes of construction accidents (Edareye Kole Taavon, 2012).

In some researches, a relationship between unsafe acts and frequency of accidents in construction sites has been shown (Zwarenstein et al., 2008). Some researchers have concluded that there is a relationship between the availability of PPE and usage of them in construction sites (Mohammadfam and Fatemi, 2008).

Each country has special rules and regulations for health and safety in construction and industrial sites. Complying with these rules depends on the rate of development of that country (Shamsi et al., 2013).

There are no specific, detailed safety and health rules in Afghanistan. Only general rules exist in section ten of the official gazette of labor law as follows:

- Each agency is responsible for preparing proper safety and health conditions at work by using safety equipment and techniques. It should also prepare proper health circumstances for mitigating the risk of various occupational diseases.
- Manager of the agency is responsible to train all employees about safety and health rules, firefighting, first aid kids and other safety issues.
- All employees are responsible to apply safety rules and techniques, like using PPE in work operations.
- Agency must prepare specific shoes, masks, glasses, hard hats and any other required safety equipment for hazardous activities for free (Labor Law of Afghanistan, 2015).

After the collapse of the Taliban regime and entrance of western troops, which United States was in leadership of them, the reconstruction of Afghanistan entered into a new period. The reconstruction and renovation started under direct supervision and budget of them. Herein, each country had his own safety rules. Some countries like United State were very strict about complying with safety rules. A part of those strict rules were OSHA rules and regulations; for example section 10 of OSHA rules about PPE usage are as follows:

It is not necessary for contractors to become medical professionals, but it is necessary to know enough about the human body to anticipate hazardous conditions that could cause severe or even permanent injury. Each chemical hazard has its own set of characteristics that impact the human body. It is the understanding of these characteristics that is necessary to make an informed decision on personal protective equipment for each specific hazard.

Protective equipment, including personal protective equipment for eyes, face, head, and extremities, protective clothing, respiratory devices, and protective shields and barriers, shall be provided, used, and maintained in a sanitary and reliable condition wherever it is necessary by reason of hazards of processes or environment, chemical hazards, radiological hazards, or mechanical irritants encountered in a manner capable of causing injury or impairment in the function of any part of the body through absorption, inhalation, or physical contact (Reese and Eidson, 2006).

As mentioned above, US Army Corps of Engineers (USACE) was very strict in complying with safety rules in construction sites and they had forced contractors to comply with all safety rules on job sites, but recently, because of decreasing USACE projects in Afghanistan, safety situation in construction sites have got worse.

Moreover, in Afghanistan there is no agency or organization to record the occupational accidents and the regional hospital of Herat province is the only agency which generally records them. This agency records construction accident under the name of falling from high accidents and it is not clear that these accidents happened in construction sites or another place.

Government owners, construction companies and other related organizations do not supervise safety properly. Some construction companies apply safety rules in their projects owing to human reasons, but others do not have attention to safety rules.

2. Materials and Methods

A questionnaire was used for inspection of situation of using PPE, in this research. The questionnaire consisted of four sections; the first part included an interview with Labors, the second part included an interview with owners, the third part included an interview with government agencies and the fourth part included inspection of construction sites to know how many laborers used PPE.

In the first part, interviews with 64 persons, including project managers, site engineers, supervisors, workers and supervising officers were conducted. These persons were 20 to 65 years old and literacy levels of those persons were illiterate, diploma, bachelor, and master. In the second part, we interviewed with 32 private construction companies include big, middle and small companies. In the third part, the authors interviewed with 7 governmental agencies. These agencies were active in several construction sectors like road construction, irrigation, water supply projects, electrical projects and building construction projects. In the fourth part, we visited 25 construction sites in various sectors such as road construction, irrigation, water supply, electrical projects and building construction to know the status of PPE usage.

3. Results

In the interviews with governmental agencies like urban development directorate, Herat municipality, water supply directorate, rural rehabilitation and development directorate, water management directorate, public work directorate and work and social affairs directorate, the responsible unit for safety in the mentioned agencies expressed that the reason of non-usage of PPE was a lack of budget and attention of ministries.

Most of the interviewees expressed that the reason of non-usage of PPE include lack of interest, lack of information and not availability of PPE (For more information refer to Figure 1). Hence, in this case training will be a suitable solution.

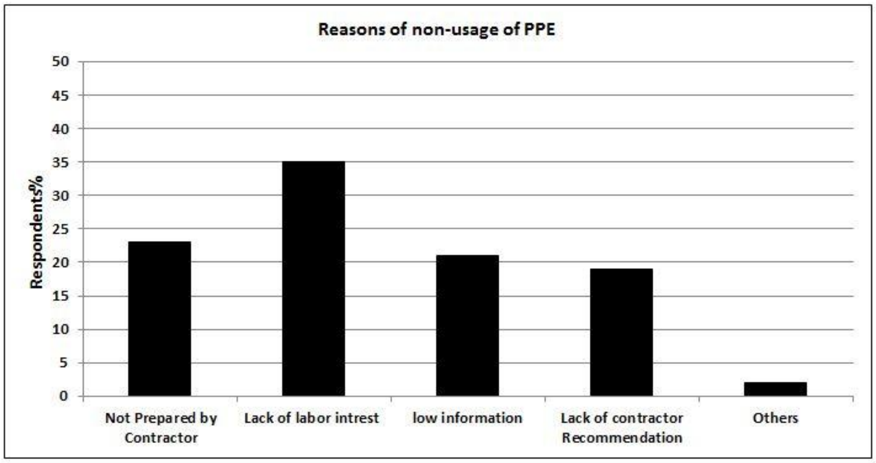

Figure 1: Reasons of non-usage of PPE

In this research, it was identified that the knowledge level of workers has a direct effect on accident frequency. It means that the people with high knowledge and experience are more careful. Since simple workers are mostly illiterate, the accident frequency is higher among them.

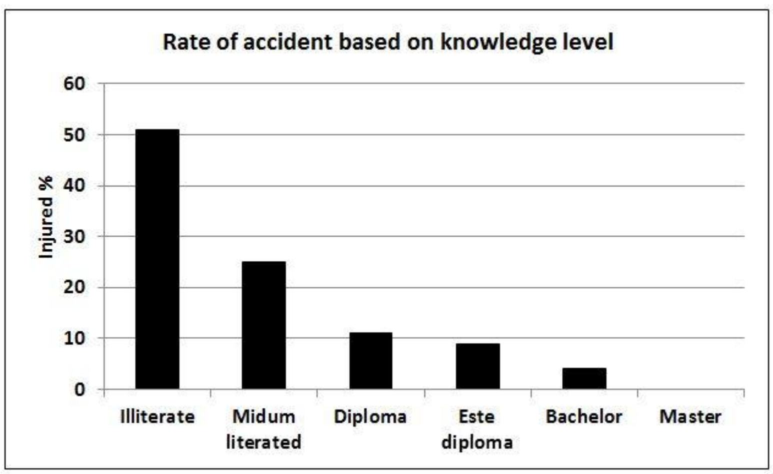

Figure 2: Frequency of accidents based on knowledge level

Statistics show that age of workers effects on their vulnerability. Younger workers experience more accidents, but older workers have fewer accidents. Moreover, the results show that most of injured workers are between 20-30 years old. Figure 3 demonstrates the percentage of injured workers based on their age.

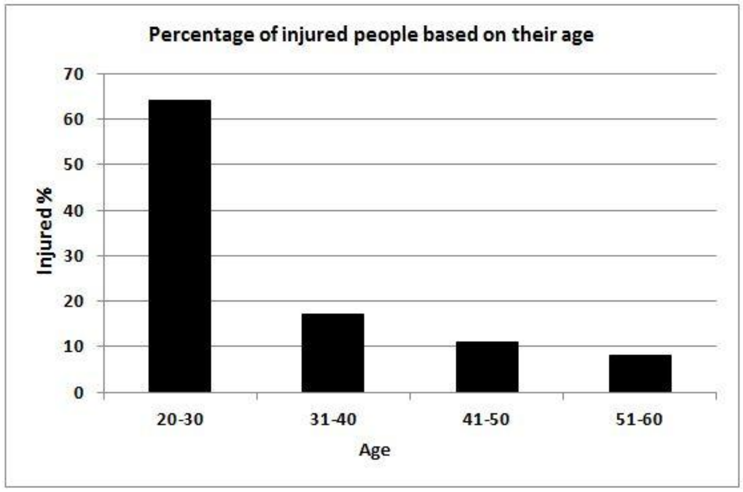

Figure 3: Percentage of injured people based on their age

Based on Figure 4, the most frequent reasons of accidents are falling from a height, non-compliance with safety rules and regulations and slipping. Other reasons causing accidents can be seen in Figure 4 in detail.

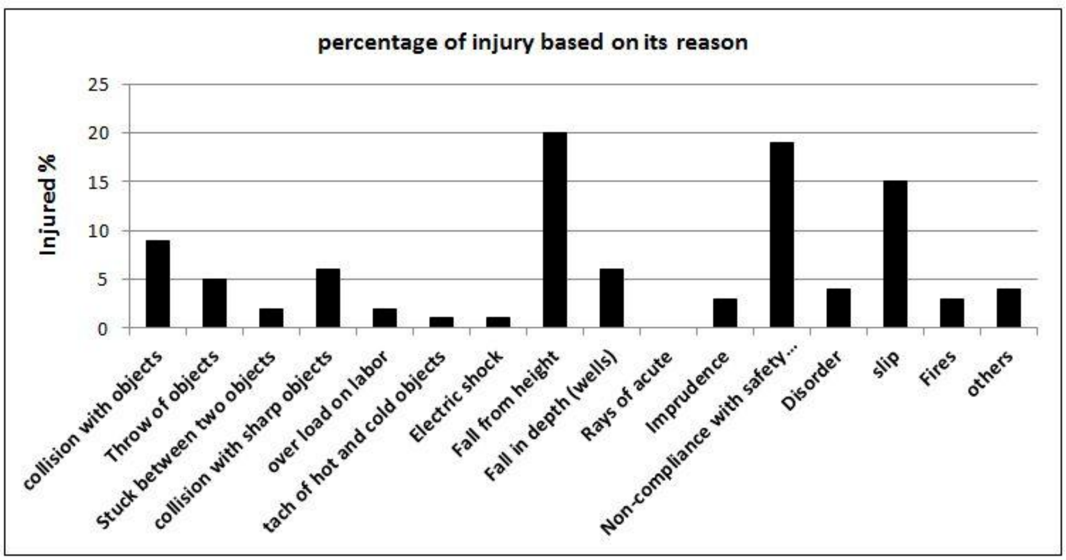

Figure 4: Percentage of injuries based on its reason

Herein, we conducted unannounced visits of some construction sites to evaluate safety situations and PPE usage. Unfortunately, the real conditions were disappointing. The results of this inspection are shown in Figure 5.

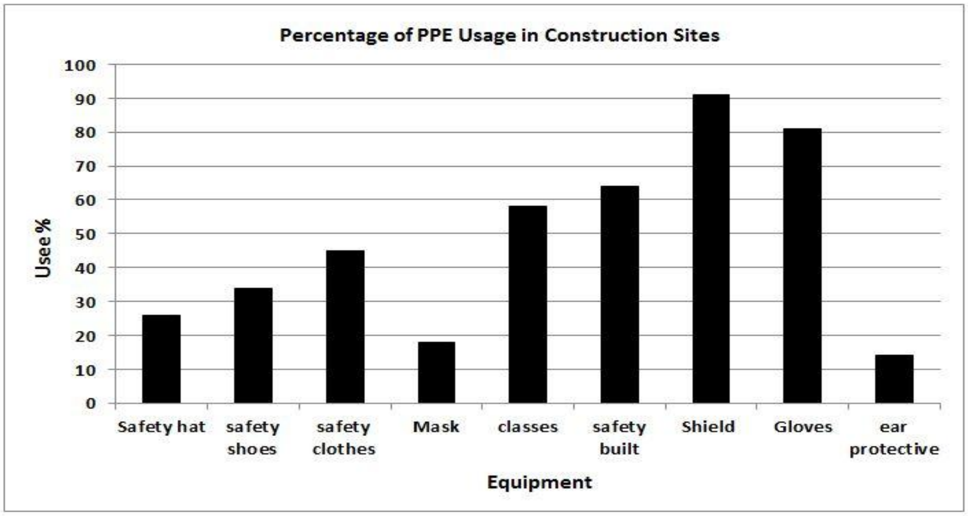

Figure 5: Percentage of PPE usage in construction sites.

Since, we were investigating PPE usage and we knew that PPE have an important role in protecting head, face, ears, eyes, hands and feet, we tried to inspect the injuries happened owing to PPE non-usage. The collected data from accident databases of 32 construction companies in the year 2014 based on injured organs are shown in Figure 6.

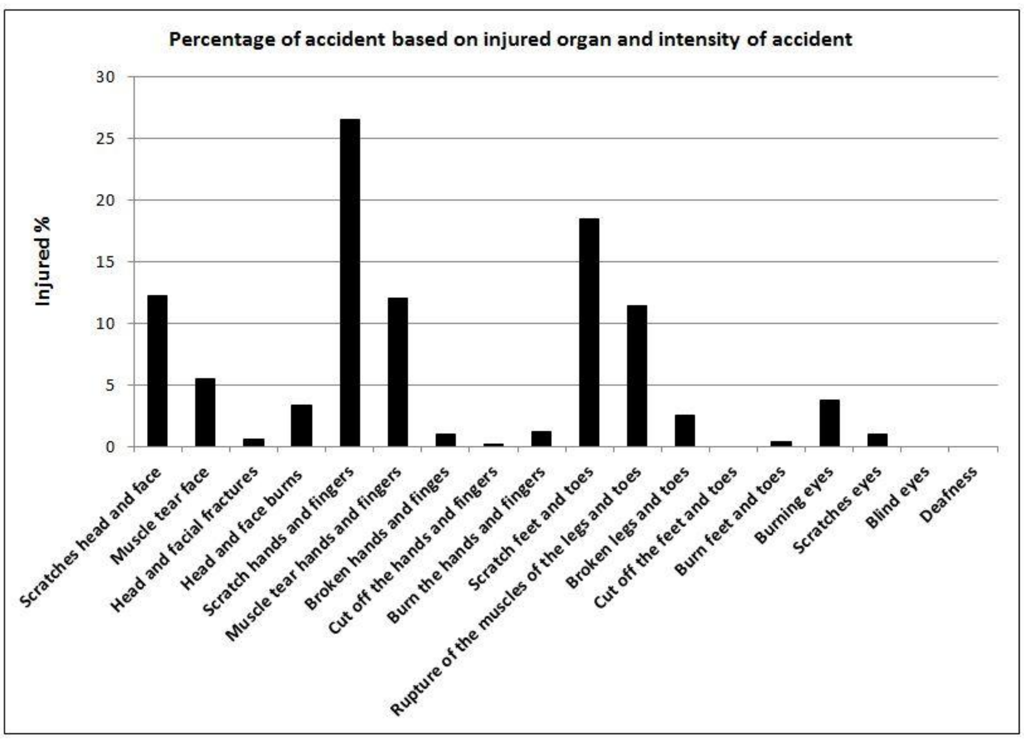

Figure 6: Percentage of accident based on injured organ and intensity of accident.

4. Discussion, Conclusion and Reccommendations

The results of this study are totally in line with previous research. Statistical investigation used in this research show that the reason of not using PPE is lack of information, low level of training by contractor, and low interest of the laborers. Some authors resulted that the reason of low level of safety in construction site are low level of safety knowledge of managers, lack of trainings, lack of required safety equipment and weak supervision (Moodie, 1992). Furthermore, similar results are presented about using PPE by welders in Kerman, Iran (Hashemi Nejad and Nikian, 1995).

Ling and his colleague have observed that the rate of serious accidents in old labors is higher than younger workers. They related the reason to repeating works and decrease of their awareness (Ling at al., 2009). In this research, we found out that the reason of accidents is mostly falling from height, slipping and not complying with safety rules. In the same study, falling from high has been known as the most important safety risk (Ardeshir et al., 2014). Some researchers expressed that" safety training is the affective factor for decreasing falling accidents" (Lipscomb et al., 2008).

After evaluating and analyzing the collected data and current safety situation in construction sites related to non-usage of PPE, we propose some recommendations in this regards as follows:

1. The responsible managers in ministry of labor and social affairs must offer and specific safety procedures and take acceptance of related agencies.

2. The responsible managers in ministry of labor and social affairs must try to hold safety trainings continuously and periodically for owner, contractors and labors.

3. Those governmental agencies that work in the construction sector must consider safety as one of the most required necessities in construction projects and allocate a special budget for that.

4. The owners of construction projects must ask their contractors to comply with safety rules and regulations and must seriously monitor the processes.

5. Supervising agencies must hire safety specialists for supervision of construction sites.

6. References

Ardeshir, A., Amiri, M., Mohajeri, M. (2014). "Safety risk assessment in mass housing projects using combination of fuzzy FMEA, fuzzy FTA and AHP-DEA". *Iran Occupational Health*, Vol. 10, No. 6, pp. 78-91.

Cheng, C.W., Lin, C.C., Leu, S.S. (2010). "Use of association rules to explore cause–effect relationships in occupational accidents in the Taiwan construction industry". *Safety Science*, Vol. 48, No. 4, pp. 436-444.

Dudarev, A.A., Karnachev, I.P., Odland, J.Ø. (2013). "Occupational accidents in Russia and the Russian Arctic". *International Journal of Circumpolar Health*, Vol. 72, pp. 20458-20458.

Edareye Kole Taavon, Kar va Refahe Ejtemaee, Ostane Esfahan. (2012). Online at http://isfahan.mcls.gov.ir/newsdetail-24694-fa.html. Accessed on June 20, 2012 [Persian].

Fung, I.W.H., Tam, V.W.Y., Lo, T.Y., Lu, L.L.H. (2010). "Developing a risk assessment model for construction safety". *International Journal of Project Management*, Vol. 28, pp. 593–600.

Hashemi Nejad, N., Nikian, Y. (1995). "Evaluation of knowledge and usage of personal protective equipments by welding workers in Kerman door shops". *Journal of Kerman University of Medical Sciences*, Vol. 2, No. 1, pp. 23-28.

International Labor Organization, Health and safety at work: facts and figures. (2015). Online at http: //www.ilo.org /safework/events/meetings/WCMS_204594/lang--en/index.htm. Accessed on April 1, 2014.

Labor Law of Afghanistan - Official Gazette No. 790, Chapter 10. (1999). Online at http://www.asianlii.org/af/legis/laws/lloaogn790p1999110114200722a443/. Accessed on May 20, 2015.

Ling, F.Y.Y, Liu, M., Woo, Y.C. (2009). "Construction fatalities in Singapore". *International Journal of Project Management*, Vol. 27, No. 7, pp. 717-726.

Lipscomb, H., Dale, A., Kaskutas, V., Sherman Voellinger, R., Evanoff, B. (2008). "Challenges in residential fall prevention: insight from apprentice carpenters". *American Journal of Industrial Medicine*, Vol. 51, pp. 60–68.

Lipscomb, H.J., Schoenfisch, A.L., Cameron, W., Kucera, K.L., Adams, D., Silverstein, B.A. (2014). "How well are we controlling falls from height in construction? Experiences of union carpenters in Washington State, 1989–2008". *American Journal of Industrial Medicine*, Vol. 57, No. 1, pp. 69-77.

Mohammadfam, I., Fatemi, F. (2008). "Evaluation of the relationship between unsafe acts and occupational accidents in a vehicle manufacturing". *Iran Occupational Health Journal*. Vol. 5, No. 3, pp. 44-50 [Persian].

Moodie, K. (1992). "The king's cross fire: damage assessment and overview of the technical investigation". *Fire Safety Journal*, Vol. 18, No. 1, pp.13-33.

Pinto, A., Nunes, I.L., Ribeiro, R.A. (2011). "Occupational risk assessment in construction industry – overview and reflection". *Safety Science*, Vol. 49, pp. 616–624.

Reese, C.D., Eidson, J.V. (2006). *Handbook of OSHA construction safety and health*, CRC Press.

Shamsi, M., Shams, M., Nilipour Tabatabae, A. (2013). "Study of attitude and behaviors related to using personal protective equipment in employees of constructing subway stations in Esfahan, Iran". *Iran Occupational Health*, Vol. 10, No. 3, pp. 20-28 [Persian].

Tam, C.M, Zeng, S.X, Deng, Z.M. (2004). "Identifying elements of poor construction safety management in China". *Safety Science*, Vol. 42, pp. 569–586.

Tehran Chamber of Commerce, Industries, Mines and Agriculture. (2014). Online at http://www.tccim.ir/images/Docs/Rules/kar.pdf. Accessed on March 1, 2014 [Persian].

Warch S.L. (2002). "Quantifying the financial impact of occupational injuries and illnesses, and the costs and benefits associated with an ergonomic risk control intervention within the uniprise business segment of united health group", Ph.D. Thesis, University of Wisconsin, USA.

Zwarenstein, M., Reeves, S., Barr, H., Hammick, M., Koppel, I., Atkins, J. (2008). "Inter professional education: effects on professional practice and health care outcome". *Cochrane Database of systematic reviews*, Issue 1.

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Factors Affecting BIM Use in Construction Organizations

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Abstract

A plethora of current literature on BIM talks about its effectiveness and potential uses however, organizational practices related to BIM use are still low. It has been observed that even those organizations (either architects or engineers) that are using this advanced process of building design, construction and management are limited to intra-organizational use. Information exchanges are still found to be heavily relied on 2D based document exchanges. Such practices results in losing the benefits that a 3D based BIM models can bring to building construction and facility management phases. There are many factors that derive this organizational behavior of BIM based use. This paper will analyze different organizational and inter- organizational factors related to BIM use. Preliminary analysis shows that these factors can be grouped into internal factors (technological, organizational factors) as well as external factors (i.e. Legal and regulatory, information exchange needs and contractual relationships between key stakeholders).

Keywords

Building Information Management, inter-organization, intra-organization, information exchange, and construction interfaces.

1. Introduction

Inter-organizational information exchange is the backbone of almost all the construction projects. Conventionally it comprises of frequent exchange of 2D drawings and documents. Even though, Computer-Aided Design (CAD) have been widely used in separate design and 3D models and applications for visualization and design development are commonly utilized, the collaboration practices have remained more or less 2D-based until recently. The prevalently increased use of object-oriented Computer-Aided Design (CAD) packages and increased constructability and level of automation in construction processes provide encouraging motives for the exchange of 3D data in the collaboration process (CURT 2005; AIA 2006). However, there are certain factors that inhibit the process. These factors can be grouped into several categories but their key characteristics. This categorization is important as it can lead to more focused and systematic approaches to improve information exchange bother intra-organizationally within several departments and inter-organizationally between several stakeholders of the construction project.

This paper aims at identifying different factors that inhibit use of BIM in organization, especially for information exchange purposes. Then the factors will be categorized in several categories so that focus

areas to remove roadblocks can be identified by the organizations individually as well as by the construction industry in general.
In the next section of this paper, literature review has been done to identify different factors. It is followed by analysis and discussion sections that creates and describes the systematic approach to group the factors into categories. Next section is related to conclusions and recommendations. Lastly some future research directions have been identified.

2. Literature Review

BIM was first espoused by the construction industry in mid 2000s. The main reason of this adoption was to overcome the low construction productivity and other problems related to the innovation of the AEC industry (Teicholz 2004). There is no single accepted definition of BIM. Eastman et al. (2008) perhaps gave the most complete definition "a modeling technology and associated set of processes to produce, communicate, and analyze building models". BIM components are represented with intelligent digital representations (of objects) that 'know' what they are, and can be associated with computable graphic and data attributes and parametric rules. These components include data that describe how they behave, as needed for analyses and work processes, e.g., takeoff, specification, and energy analysis. The data is consistent, non-redundant and well-coordinated; such that changes to component data are represented in all views of the component (Eastman et al. 2008)

Initial focus of BIM research was on general blockades, benefits, and limitations to BIM implementation (Won et. al 2013 Khemlani 2007a; Khanzode et al. 2008; Manning and Messner 2008). Most of this literature covered general considerations for BIM adoption in a qualitative manner (Lee et al. 2007; Dossick and Neff 2010; Gu and London 2010; Jung and Joo 2011). Factors for selecting appropriate BIM software applications (Khemlani 2007b; Gu and London 2010), organizational strategies related to BIM implementation (Eastman et al. 2008; Khanzode et al. 2008; Lee et al. 2007; Bernstein et al. 2010), barriers and limitations of successful BIM adoption (Young et al. 2008; Gilligan and Kunz 2007) were also remain under discussion. Only very few publications discussed success factors specifically for BIM adoption, Gu and London used expert focused group to identify factors for successful BIM adoption across disciplines (Gu and London 2010) and Lee et al. (2009) identified factors for selecting appropriate BIM software applications for a company. Won et.al. (2013) derived critical success factors from a detailed list of factors that can serve as metrics for evaluating and managing the level of BIM adoption and as a basis for developing BIM evaluation models in the future.

Lee (2007) proposed four phases of BIM adoption by level of organization involved in a BIM project, based on different levels of integration and collaboration involved beginning from personal adoption by a member without any collaboration; to adoption within a team of a company with several people within a company collaborating; to adoption across different types of teams within a company; and at the highest level adoption across companies with inter-organizational coordination and collaboration of BIM tools. The level option of BIM adoption varies by company and relates to organizational characteristics like early and aggressive adoption. Those who foresee the potentials are in advanced phase while others are still struggling with the first phase. With the passage of time however, the use of BIM by architects, engineers, contractors, owners, and others is rapidly becoming widespread within the design and construction industries. This is generally true for developed countries where major public and private owners, like federal General Services Administration (GSA) USA and the US Army Corps of Engineers, are requiring the use of BIM on all of their projects.(Wickersham 2009).

Based on the above discussion it can be observed that BIM and information exchange factors that causes successful implementation or barriers to BIM adoption can be classified as either internal (or organizational) and External (inter-organizational) factors. The following discussion highlights the major Internal and External factors related to BIM adoption.

3. Internal Factors of BIM adoption

Current body of knowledge presents both technical and non-technical internal factors that can influence the BIM adoption. While issues related to learning curve for BIM technologies are important factors as identified by Bernstein et al. (2012), Gilligan and Kunz (2007), Eastman et al. (2008), Yan and Damian (2008), D'Agostino et al. (2007), Young et al. (2009). Significant amount of impedance has been observed from non- technical factors like cost of investment. Many researchers, especially Eastman et al. (2008), Yan and Damian (2008) and Young et al. (2009) have highlighted the fact that major barrier to BIM use in an organization is related to the initial amount of investment required to support necessary infrastructure for BIM. Continuous investment (Won et al. (2013) is also required to maintain the BIM up and running. This cost increases with the number of users with in the organization. Additional difficulties are faced by investment decision makers within the organization in the absence of any mechanism for tangibly measuring impacts of BIM (D'Agostino et al. 2007). Thus middle management faces difficulties in getting buy-in from the top tier for such investment.

Lack of executive buy-in has also been identified as a barrier to adoption of BIM organizationally (Bernstein et al. 2012; Gilligan and Kunz 2007; and D'Agostino et al. 2007).It has been observed that the successful adoption of BIM depends more on how well a company "aligns BIM technology with their work process and vice versa" (Taylor and Levitt 2007). Information technology adoption in the construction industry relies on individual leadership to overcome organizational and technical challenges (Dossick and Neff 2010). Therefore, leadership of senior management is essential in this regard.

In addition to the above mentioned internal factors, there are also some factors that are common in internal and external factors of BIM adoption. These factors will be discussed after discussion on the external (inter-organizational) factors.

4. External factors of BIM adoption

The extent of use of BIM inter-organizationally is significantly lesser than that of internal use. Researchers have identified many reasons for this decline. The major one are discussed below.

Shift of liability among project participants is one major reason which shadows the use of BIM and BIM exchange (Eastman et al. 2008; D'Agostino et al. 2007). Typically in construction contracts roles and responsibilities of different project participants are clearly defined. In most contracts, designer is responsible for providing complete design to the constructors. A dynamic model as in case of BIM can results in conflicts as it is difficult to identify the changes made to original model after the consultants and contractors have worked on it for their portion of works. The issue of management of BIM master model should be well sorted out by establishing BIM protocols at the start of the project (Bernstein et al. 2012; (Eastman et al. 2008).

BIM use is more common in large organizations that can bear the expenses related to BIM adoption. Thus a lack of subcontractors who can use BIM technology is also a limitation in BIM crossing the organizational boundaries (Won et al. 2008; Young et al. 2009)

Poor collaboration among participants, which can also lead to liability issues discussed previously is one major factor on which BIM successful use relies deeply (Eastman et al. 2008; Won et al. (2008). Collaboration issues also get worse when there is lack of collaboration management tools (Gilligan and Kunz 2007;Won et al. 2008).

Compatibility of the system and ability of different BIM software to talk with each other can also create problems of poor interoperability among BIM software (D'Agostino et al. 2007; Young et al. 2009). Reluctance to openly share information has also been identified by many researchers as barrier to external use of BIM Gilligan and Kunz (2007), Won et al. (2008), Young et al. (2009). When all stakeholders are working on their parts, tracking of changes and thus Management problems with BIM master model are quite evident (Eastman et al. 2008, Won et al. 2008, Young et al. 2009).

Apart from the factors discussed above influencing the external use of BIM, there are certain factors that are common to BIM use in both internal and external use. Some of the key common problems are discussed below.

5. Common factors of BIM adoption

Apart from the factors mentioned above that are distint for internal and external use of BIM there are certain factors that are common to both internal and external use of BIM. These includes; Lack of expertise and absence of BIM Champions (Gilligan and Kunz 2007; Young et al. 2009). Limitation of current BIM applications also causes problems in creating a complete model (Gilligan and Kunz 2007; D'Agostino et al. 2007; Young et al. 2009). In addition to this, Lack of industry standards (D"Agostino et al. 2007; Eastman et al. 2008; Young et al. 2009) and shortage of BIM implementation data in construction phase (Eastman et al. 2008; Young et al. 2009) have been identified as significant factors affecting BIN use both intra-organizationally as well as inter-organizationally.

6. Conclusions and Recommendations

Power tussles and organizational changes occur as individuals, teams, and firms steer through changes to the legal risks associated with standards of practice, apprehensions over intellectual property, financial risks associated with capital investments in hardware and software, and the investment needed to train and maintain technologically skilled staff (Allen et al. 2005; Dossick and Neff 2010). This paper provided categorization of internal and external issues related to BIM use and highlighted technical as well as non-technical issues related its use on projects.
It is important to create a balance between technical as well as non-technical issues related to BIM use. Several recommendations have been made based on the review of issues highlighted in this research. These recommendations and way forward are discussed below.

There is a need of devising means and methods to determine BIM readiness of an organization. Mechanisms should be devised to provide better measurement of return on investment of BIM investments. Technical issues can be dealt with training of professionals however, buy-ins from the leadership is also required at the same time.

External barriers can be reduced by strategies such as changing contracts/delivery methods. Current forms of contracts should be revisited in order to incorporate BIM friendly clause. This will also include changing the defined roles of different project stakeholders. Shifting towards more collaborative delivery methods like Integrated Project Delivery (IPD) is also suggested to promote BIM-based collaboration in most efficient manner (Azhar et al. 2014). Public sector should also encourage the use of BIM in government led projects.

References

American Institute of Architects - Committee on Integrated Practice. (2006). Report on integrated practice, American Institute of Architects, Washington, DC.

Azhar, N., Kang, Y., & Ahmad, I. (2014). Critical look into the relationship between information and communication technology and integrated project delivery in public sector construction. *Journal of Management in Engineering,* , 04014091. doi:10.1061/(ASCE)ME.1943-5479.0000334

Bernstein, H. M., Jones, S. A., and Russo, M. A. (2012). The business value of BIM in North America: Multi-year trend analysis and user rating (2007–2012), McGraw-Hill Construction, Bedford, MA.

Construction Users Roundtable (CURT). (2005). Optimizing the construction process: An implementation strategy, CURT, Cincinnati, OH.

D'Agostino, B., Mikulis, M., and Bridgers, M. (2007). FMI/CMAA Eighth Annual Survey of Owners: The perfect storm—construction style, FMI Corp./Construction Management Association of America, Raleigh, NC.

Dossick, C. S., and Neff, G. (2010). "Organizational divisions in BIM enabled commercial construction." J. Constr. Eng. Manage., 136(4), 459–467.

Eastman, C. M., Teicholz, P., Sacks, R., and Liston, K. (2008). *BIM handbook: A guide to building information modeling for owners, managers, architects, engineers, contractors, and fabricators.* Wiley, Hoboken, N.J.3,

Gilligan, B., and Kunz, J. (2007). "VDC use in 2007: Significant value, dramatic growth, and apparent business opportunity." Construction Users Roundtable (CURT) National Meeting, Center for Integrated Facility Engineering (CIFE), Stanford Univ., Stanford, CA.

Gu, N., and London, K. (2010). "Understanding and facilitating BIM adoption in the AEC industry." Autom. Constr., 19(8), 988–999.

Jung, Y., and Joo, M. (2011). "Building information modelling (BIM) framework for practical implementation." Autom. Constr., 20(2), 126–133.

Khanzode, A., Fischer, M., & Reed, D. (2008). Benefits and lessons learned of implementing building virtual design and construction (VDC) technologies for coordination of mechanical, electrical, and plumbing (MEP) systems on a large healthcare project.

Khemlani, L. (2007a). "2007 3rd annual BIM awards." AECBytes, ⟨http://www.aecbytes.com/buildingthefuture/2007/BIM_Awards_Part1.html⟩

Khemlani, L. (2007b). Top criteria for BIM solutions: AECbytes survey results, AECbytes Special Report, ⟨http://www.aecbytes.com/feature/ 2007/BIMSurveyReport.html⟩ (Aug. 1, 2012).

Lee, C.-J., Lee, G., and Won, J.-S. (2009). "An analysis of the BIM software selection factors." J. Archit. Inst. Korea, 25(7), 153–163.

Lee, G. (2007). "BIM collaboration methods for improving the efficiency of BIM." BIM Workshop, Construction Association of Korea, Seoul, Korea.

Manning, R., & Messner, J. (2008). Case studies in BIM implementation for programming of healthcare facilities.

Taylor, J. E., and Levitt, R. (2007). "Innovation alignment and project network dynamics: An integrative model for change." Project Manage. J.,38(3), 22–35

Teicholz, P. (2004). Labor Productivity Declines in the Construction Industry: Causes and Remedies. AECbytes 4 Web. Mar. 2010. <aecbytes.com>.

Wickersham, J. (2009). Legal and Business Implications of Building Information Modeling (BIM) and Integrated Project Delivery (IPD).

Won, J., Lee, G., Dossick, C., & Messner, J. (2013). Where to focus for successful adoption of building information modeling within organization.*Journal of Construction Engineering and Management*, *139*(11), 04013014.

Won, J., Lee, J., and Lee, G. (2008). "A case study on BIM collaboration and information management method." J. Arch. Inst. Korea, 24(8), 25–32.

Young, N. W., Jr., Jones, S. A., Bernstein, H. M., and Gudgel, J. E. (2009).The business value of BIM, McGraw-Hill Construction, Bedford, MA.

Young, N. W., Jr., Jones, S. A., Bernstein, H. M., and Gudgel, J. E. (2009). The business value of BIM, McGraw-Hill Construction, Bedford, MA.

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AN OVERVIEW OF CLAIMS PREVENTION STRATIGIES IN CONSTRUCTION PROJECTS OF PAKISTAN

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Abstract
A construction claim is a request of compensation for damages or extra work performed during the construction project. In construction industry of Pakistan claim is considered as one of the retarding factor in project success. Thus, construction companies intend to reduce or prevent generation of claims in order to avoid such retardation. The sole aim of the study is to provide basic understanding of the contributing factors and practices that generate claims in construction projects in Pakistan. The paper generally discusses the role of project stakeholders mainly that of the A/E firms (normally project administrators) in avoiding the factors leading towards claims. The findings presented have been collected through detailed structured interviews of experienced contract management professionals working with A/E, and construction firms regarding ten projects administered by them. It was found that having realistic expectations, documentation, proper budgeting, timely decisions, contractors input during design and well-designed plans and specifications can significantly reduce the chances of claims. Recommendations based on the study can be used by the stakeholders in construction industry for claims prevention.

Keywords
Causes of claims, claims anticipation, documentation, personnel participation, claims prevention

1. Introduction A proactive approach in claim reduction is much more effective in claim reduction than a reactive approach. Early in the project lifecycle, at the point when the design is substantially completed to allow qualified bidders to submit offers for the construction work, the careful arrangement of appropriately considered contract documents offers the most prominent open door for claims anticipation. On the other hand, when contracts are executed and construction starts, the prevention of claims gets more difficult. Thus a mechanism that determines arrangements and proposes plans to mitigate, counteract and oversee claims is highly desirable. In this study, such plan is proposed for the local industry of Pakistan, and more specifically Karachi, based on expert interviews conducted. The proposed plan covers the subjects of (1) Quality Contract Documents(2) Administration of Outside Design

Experts(3) Constructability and Bid ability Audits (4) Site Examination (5)Audit and Regard of Point by point As-Arranged Schedules (6) Task Audits and (7) Owner’s Rules. Additionally Contractor's Project Audit and Contractor's Risk Analysis included are also the accompanying agendas.

The major objectives of the study are to:

- Determine the reasons of construction claims during different phases of the project,
- Identify the common problems which cause claims through the project,
- Scrutinize the measures taken to avoid claims, and

The rest of the paper is arranged as follows. First the literature review has been discussed followed by the brief methodology of the study. Analysis of the experts interviews is presented next. Recommendations and conclusions based on the study are presented at the end.

2. Literature Review

A Construction Claims Dictionary" published by the Contract Management Corporation in Camden, New Jersey defines and describes the categories of construction claims. According to this source, most common types are those which are associated with the following items or conditions presented in Table 1.

Table 1: Most Common Construction Claims Conditions

1. Acceleration	18. Errors & omissions	36. Nonpayment
2. Agency conflicts	19. Excessive inspection	37. Over-inspection
3. Ambiguity	20. Excessive management	38. Owner furnished material
4. Bankruptcy	2l. Excessive testing	39. Performance
5. Bidding errors	22. Failure to coordinate	40. Personal injury
6. Breach of contract	23. Failure to perform	41. Quality considerations
7. Cardinal changes	24. Failure to provide access	42. Reasonable profit
8. Changed conditions	25. Fast track projects	43. Refusal of change orders
9. Changes in dimension	26. Hold harmless clauses	44. Substantial completion
10. Changes in quality or details	27. Impossibility	45. Substitution problems
11. Codes & conflicts	28. Improper rejection	46. Subsurface conditions
12. Constructive changes	29. Improper retainage	47. Supervision by others
13. Defaults	30. Interference	48. Trade practices
14. Defective specifications	31. Latent conditions	49. Warranty provisions
15. Delay	32. Liquidated damages	50. Weather
16. Differing site conditions	33. Misinterpretation	51. Winter construction
17. Disruption	34. Misrepresentation	
	35. Negligence	

Analyzing this non exhaustive list of factors, Acharya and Lee (2006) categorized the critical causes of conflicts into six following categories i.e.

- Differing site condition
- Local people obstruction
- Difference in change order evaluation
- Errors and omission in design
- Excessive quantity of works
- Double meaning in specification

From the construction claim body of knowledge certain principles and theories have evolved from the construction contractor's point of view, as well as from the designer's and the owner's viewpoints.
The following criteria are typical of all except catastrophic claims

Bosche (1978) explains the main the three causes of claims as greed, communication and integrity. In addition to this, the following six criteria establish the ground rules for the necessity of equitable contract adjustments and thus can be regarded as the criteria for claims.

1) Claims occur after contract signing.
2) They are unanticipated by reasonable parties involved in a contract.
3) They affect costs, methods, performance, procedures and/or materials, as well as the schedule of completion.
4) They are damaging parties.
5) They are caused by ambiguity.
6) Errors and/or omissions are frequently involved.

When equitable contract adjustments are allowed during the course of a contract, they are called change orders. When equitable contract adjustments are not requested, or are in fact disallowed, a decision tree comes into play. In fact, participants or contracting parties are headed for litigation in some form if the claim is ever to be resolved.
Since this paper deals with claim preparation and prevention, rather than the litigation of claims, some possibilities for claim prevention are discussed next.

To be successful, a claim prevention program must defuse the three causes of claims discussed above thus the main aim of prevention exercise is to improve communication between the project participants throughout the construction lifecycle. This can be achieve through strategies like early involvement of key participants and selecting contracting strategies that motivates the project participants to communicate and coordinate frequently (Azhar et al. 2014).

Increasing the integrity of the project stake holders and satisfying the greed can also be achieved by aligning the interests of the project stakeholders (AIA 2007).

Some of the other things that must be included:

- Rethink the entire bidding process (Azari-Najafabadi 2011; Khalil 2002).
- Develop equitable specifications and contracts
- Have architects and engineers accept responsibility for their design
- truly provides incentives to contractors and subcontractors, as well as designers (AIA and AGC 2011)
- Time extensions granted in full and on time (Bosche 1978)
- All change order requests acted on impartially and fairly

3. Research Methodology

Following is the brief methodology of the study conducted. Base on the literature review, the first step was to develop an interview questionnaire. The goal of this instrument was to gauge the significance of every claim, cause from the diverse perspectives of project gatherings (builder, manager and consultant) and to determine the most proficient method to maintain a strategic distance from the reasons for claims. The resulted questionnaire had three major sections. Section I was aimed to document the respondent's personal information, position, and work information. Section II, contained areas for reasons identified by the client / consultant, builder, and outside conditions. In every segment the respondent is solicited to assess every reason from claims as per the likelihood of an event and energy to deliver a claim on a Likert scale in reactions of: - Not important, low important, Moderately Important, Important, Very important; and dependably, for the likelihood of events and reactions of: high; medium; low; and exceptionally solid, for energy to create a claim. In Section III, respondents were solicited to organize causes from claims as indicated by their significance from their perspectives, and looked for input on the best way to dodge such causes.

Before conducting the experts' interviews, the questionnaire was examined by four specialists who checked it for clarity, equivocalness and reasonableness. Improvements were made to the questionnaire based on the feedback given by the specialist.

Structured interviews were than conducted in face to face meetings with the selected experts which were selected on the basis of their availability and experience in the subject matter.

4. Analysis

The respondents who participated in these interviews were experts from construction industry having vast experience in the field. The respondents can be divided into 3 major categories based on the type of projects as shown in Table 2.

Table 2: Categories of Experts

Category-1	A/E Firm
Category-2	Contracting & Managing Firm
Category-3	Contracting Firm

4.1 Primary Causes of Claims in Pakistan

The results of the interviews reveal several primary causes of claims in construction industry of Pakistan as indicated in Figure 1. The *Changed Site Conditions* is remarked to be the largest cause of construction claims. This can be reduced, however, not wiped out by better site examinations and more exact as-builds - both Geotechnical examinations (counting audit of verifiable records and dialog with neighbors and past builders) and detailed examinations of building conditions (as opposed to depending on old as-builds).

Next, the respondents indicated that the Client *Coordinated Extension Changes* causes problems. This can be generally executed by including client gatherings (and operations and support) in predesign and design, setting clear goals, and by getting 'close down' by client groups. Other "stakeholders" ought to likewise be included, if their utilization of the office is essential and particularly on the off chance that they be able to "wreck" the project. Open contribution is generally extremely advantageous, even when it is not required. On the off chance that legitimately oversaw, it won't take significant additional time and can spare time and cash, notwithstanding better serving the citizens.

Architect Blunders and Oversights can be decreased by additional time and money for design, additionally by choice of better managed experts. Different arrangements are: Clearly composed extent of work, better plan schedules, tighter managerial oversight of the design procedure, value engineering, constructability surveys, and so on.

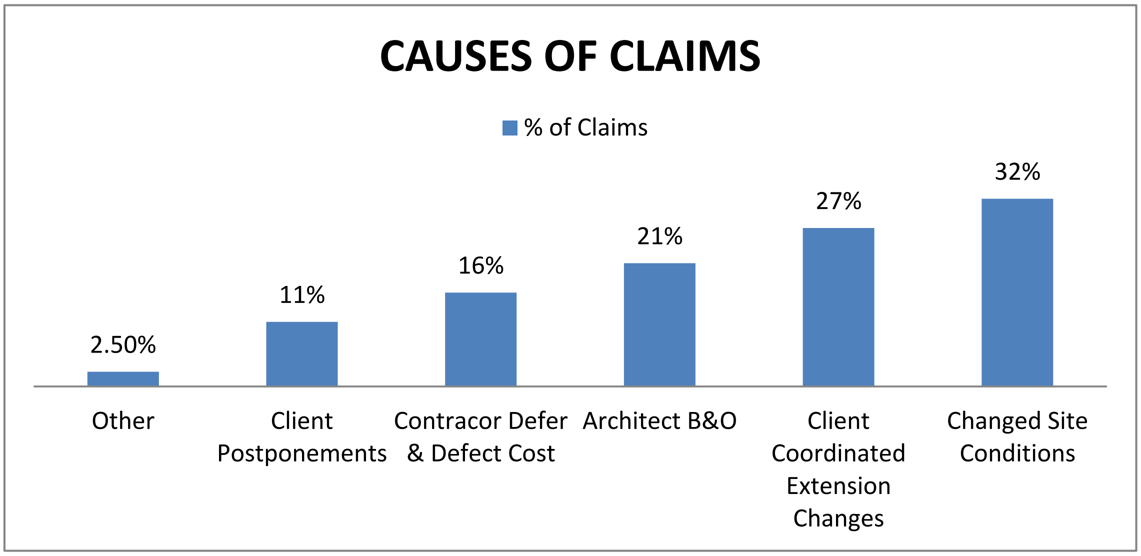

Figure 1: Causes of Claims

Contractor defers can be altogether diminished by: (1) better planning specifications, (2) application of those specifications, (3) cooperating workshops and endeavors at team building, and (4) reasonable, auspicious and firm determination of changes and claims.

Client Postponements_has maintained a strategic distance from by more intensive site examinations to abstain from varying site conditions, an unmistakably composed extent of work, client gathering and O&M data amid design, and firmer control of construction plans.

4.2. Projects with Claims (Perceptive of Architect/Engineer/Contractor)

Experts that were Architect/Engineer professionals were asked about the solution to problems faced by them and their organizations if contractors are at blame, the experts come up with the following solutions/suggestions:

1) Better plans and contract jargon.

2) Extra preparing of organization staff in contract organization and field oversight.

3) Enhanced contractor plans by means of tighter booking detail, implementation of those determinations, and enhanced following and recordkeeping practices.

4) Assessment and conceivable upgrading of company's reputation for being a reasonable and sensible manager.

5) Enhanced promoting of the org's projects to the construction group. Changing contracting systems from focusing low offer (design bid built) to CM or design/fabricate may help, yet has different weaknesses and still won't wipe out the greater part of the issues.

Same approach was adopted for the contractor and it was asked that if the designers are at blame what are the aspects they should improve which could lead to smooth completion of project, they responded with suggestions including the following.

1) Selection process of consultant needs improvements, alongside changes to organization of A/E contracts,

2) well-defined scope,

3) Satisfactory design and construction plans, timely award of contract, and

4) Feedback on selection process of consultant future determination strategies.

5. Recommendations

The following recommendations are made generally in light of researchers' knowledge. Extra reviews are expected to affirm, re dress, and organize these suggestions.

Well planned plans and specification
This is considerably more critical that the general conditions, as design slips and sudden changes can wreck devastation with the contractor's financial plan, prompting claims for additional time and cash, clash over qualification and expenses, and construction claims. Sometimes, particularly if one of the party is not reasonable or uninformed about contract law, claims will result and joining forces endeavors will come up short.

Adequate financial plan and right time to proceed
In the event that the financial backing is too tight or the time too short, the administering body needs to give a bigger budget, extra assets, and more administration consideration.

The right logic and society
To be fruitful, an association needs the right winning theory and society. Ideally, this is in light of joining forces and team building. It ought to include: (1) sensible expectation, (2) backing of the administering body, (3) great administration and experienced and trained staff, and (4) firm yet reasonable and opportune determination of claims.

Clear goals and design criteria/building project
Clearly recorded goals and a well-composed scope of work (building system, designing design criteria, and so on.) is vital if the designer is going to plan the venture you truly require.

User (and operations and support) support during design
Include the client in pre-design (architectural designing, setting design criteria) and design. Train them in how to audit plans and help them sort out with the goal that they distinguish their needs amid design as opposed to amid development or later. Now and again, utilize design charettes to get an expansive scope of info. Be sure to get a 'close down' by key client groups. Use life cycle costing to maintain a strategic distance from operational plan issues later on.

Construction skill' in design phase

This ought to incorporate constructability audits, value engineering, cost estimation of every design stage, and Expense and Scope Administration all through the design process.

Change administration - recordkeeping

Keeping up complete and precise records is vital to minimize claims. This incorporates, (1) RFIs and RFI logs, (2) structures and logs for notification of progress, ASI, change requests, change request recommendations, field approvals, and so on structure, techniques, and log (with classifications), (3) power record recordkeeping, photos that are date stamped and explained, (4) administrator and subcontractor day by day field reports, (5) correspondence logs and numbered serial letters, (6) phone discussion records, (7) messages and reminders, (8) minutes of gatherings, (9) and

Good contract general conditions

Elegantly composed contract conditions give the Owner's Representative the apparatuses implement proper conduct by the contractor. They include: (1) updated planning particulars, (2) a sensible changes clause, (3) a powerful dispute clause, and (4) the majority of the other contract clause influencing the schedule and resolution of disputes.

Bid-Stage: promoting your business to the industry

In a competitive bid (design-bid-build) circumstance, it is fundamental that a public works organization builds up notoriety for firm, however reasonable contract organization, with a specific end goal to guarantee sufficient rivalry and that the better contractor will bid your projects, while the 'claim specialists' will evade them. Furthermore, public works managers ought to caution the bidders that you need them to bid your project - through contractor associations in addition to exclusively to those contractors that you especially need to offer your tasks. Careful assigning of the date of bid opening that the date of bid opening of your project not conflict with the other project bid opening.

Effective preconstruction meeting and partnering

The preconstruction meeting and partnering will help with team building, so that the parties altogether (owner's representative, designer, general contractor, subcontractors, and so forth.) are cooperating with each other.

The preconstruction meeting is the point at which you ought to review the schedule (at least a preparatory schedule), set the 'guidelines', make sensible expectation, and clarify imperative issues.

Joint schedule audit, schedule updates, and time expansions

This is a crucial component of calendar administration.

Timely award and notice to proceed

Timely award and issuance of notification to continue will help stay away from postponements/delays.

Submittal schedule, log, and charrette

Late material conveyance is a regular reason for delay. To stay away from the likelihood: (1) run down the key submittals in the offer records and require the builder to present a submittal calendar, (2) keeps up a submittal log and overhaul it frequently to guarantee against delays, (3) attach key submittals to the CPM schedule, and (4) utilization charrettes when suitable for key exchanges and materials.

6. References:

Acharya, N. K., & Lee, Y. D. (2006). Conflicting factors in construction projects: Korean perspective. Construction and Architectural Management, 13 (6), 543–566.

American Institute of Architects (AIA) and Associated General Contractors of America (AGC). (2011). "Primer on project delivery."
〈http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab093116.pdf〉 (April 4, 2015).

American Institute of Architects (AIA). (2007). "Integrated project delivery: A guide." 〈 http://www.aia.org/groups/aia/documents/pdf/aiab083423.pdf〉 (May 4, 2015).

Azari-Najafabadi, R. , Ballard, G. , Cho, S. , and Kim, Y. (2011). "A dream of ideal project delivery system." AEI 2011, ASCE, Oakland, CA, 427–436.

Azhar, N., Kang, Y., & Ahmad, I. (2014). Critical look into the relationship between information and communication technology and integrated project delivery in public sector construction. *Journal of Management in Engineering*, , 04014091. doi:10.1061/(ASCE)ME.1943-5479.0000334
http://dx.doi.org/10.1108/09699980610712364

Khalil, M. I. (2002). "Selecting the appropriate project delivery method using AHP." Int. J. Project Manage., 20, 469–474.

Richard P. Vanden Bosche, CCE, CVS, President, Contract Management Corporation, Camden, New Jersey, The Value Engineer's Role In Construction Claims And Claims Prevention

Calculating Quantity of Steel Bar Placed In Mesh Form in a Circular Slab or Dome

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Abstract

When steel reinforcement is placed in mesh form in circular concrete slab at base or domes at top in case of over head service reservoir or any other structure, it is difficult to estimate/measure the total quantity of steel that would be needed or placed. For the purpose of calculating the total length of the steel bars, at present, the practice is – the length of each bar is measured and then added up. This is tiresome and time consuming process. I have derived a mathematics formula with the help of which we can calculate in one line the quantity of total steel that will be needed. This will not only make it easy and time saving but also avoids any error in making entries and calculations.

Keywords

Steel, Estimation, Mesh, Slab, Spacing

1. INTRODUCTION

It very easy to calculate steel quantity in rectangular or square concrete slab of a building. We multiply number of bars in one direction by length of one bar. But in case of circular slab at base or circular dome at top of a structure like Over Head Service Reservoir, it is difficult to estimate/measure the total quantity of steel that would be needed or placed. For the purpose of calculating the total length of the steel bars, at present, the practice is – the length of each bar is measured and then added up. For example in Fig.1 the total length of steel bars is taken as equal to ab + cd + ef + gh and so on. This is tiresome and time consuming process. Error can also occur in long calculations. I have derived a formula with the help of which we can calculate in one line the quantity of total steel that will be needed or used in mesh of circular slab dome.

2. FORMULA

$$L = \pi D^2/2s$$

Where L = Total length of steel bar in m
D = Diameter of the circular slab/mesh in m
s = Spacing of steel on both directions in m

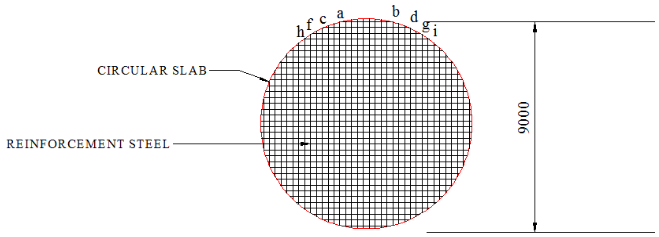

Figure 1: Steel Mesh

3. DERIVATION OF FORMULA

Suppose there is a circular slab having steel in mesh form within diameter D. Diameter of mesh is approximately equal to the diameter of the slab. But we will take in calculation the diameter of the mesh only. Spacing of the steel in both direction is 's'. Steel bars have divided the whole area of slab in to many squares with side 's'.

Total area of circular mesh = $\pi D^2 / 4$

Area of one square with side 's' = s^2

Number of squares in the circular mesh = Area of circular mesh/Area of one square = $(\pi D^2 / 4)/ s^2$

Total length of steel bar in one square = 4 s

As each side 's' is shared by two squares, the length of steel bar in each square will be = 4 s / 2 = 2 s

Therefore total length of the steel in circular slab

= Number of squares x 2 s

= $(\pi D^2 / 4 s^2) \times 2 s$

= $\pi D^2 / 2 s$

4. PRACTICAL ASPECTS

To check up the correctness of the formula either the length of each bar will be measured in the drawing or the length of each bar will be calculated geometrically with the formula and then add up so as to know the total steel and the result can be compared with the one calculate with the formula.

$$2\sqrt{h\,(D-h)}$$

(Where h is distance of steel bar from edge of mesh)

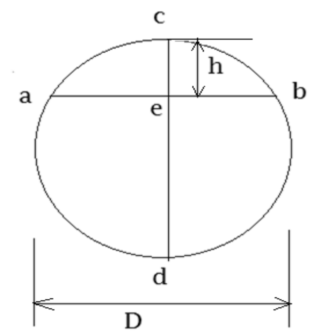

Figure 2

Suppose steel is provided at spacing 250 mm centre to centre in mesh having diameter 9 m. The lengths of steel bars in both directions will be as under:-

Table 1: Length Calculations

Length of steel bars going from top to bottom of the mesh	Length of steel bars going from left to right of the mesh
2.11	2.11
3.60	3.60
4.58	4.58
5.33	5.33
5.95	5.95
6.48	6.48
6.92	6.92
7.31	7.31
7.64	7.64
7.93	7.93
8.18	8.18
8.39	8.39
8.57	8.57
8.71	8.71
8.83	8.83
8.91	8.91
8.97	8.97
9.00	9.00
9.00	9.00
8.97	8.97
8.91	8.91
8.83	8.83
8.71	8.71
8.57	8.57
8.39	8.39
8.18	8.18
7.93	7.93
7.64	7.64
7.31	7.31
6.92	6.92
6.48	6.48
5.95	5.95
5.33	5.33
4.58	4.58
3.60	3.60
2.11	2.11
Total 254.83 m	Total 254.83 m
Total steel bar in mesh	= 509.66 m

Total length of steel bar with the formula

$= \pi D^2 / 2s$

$= \pi 9^2 / 2 \times 0.25$

$= 508.94$ m

which is approximately equal to the length actually calculated above. Thus exact quantity of steel can be worked out and neither waste will be there nor short quantity of steel has been arranged.

In case where spacing of steel bars is not same in both directions, then length of steel bar

$$L = \pi D^2 (S_1 + S_2) / 4 S_1 S_2$$

where S_1 is spacing of steel in one direction and S_2 in other direction.

In case of a spherical dome where spacing in both directions is same, then length of steel bar

$$L = 4 \pi r h / s$$

Where r is radius of dome
h is height of dome
s is spacing of steel in both direction

In case where the spacing of steel bar in both directions in the dome is not same, then length of steel bar

$$L = 2 \pi r h (S_1 + S_2) / S_1 S_2$$

where S_1 is spacing of steel in one direction and S_2 in other direction.

For an irregular shaped figure just as bed slab of a lake, the length of steel will be

$$L = \frac{A}{s/2}$$

where A is area of bed slab of lake which can be calculated with the planimeter of the drawing and ‘s’ is spacing of the steel in both direction

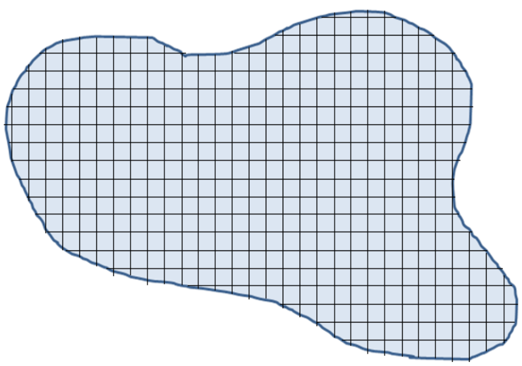

Figure 3: Bed Slab of Lake

5. CONCLUSION

With the help of this formula we can calculate the exact quantity of steel to be provided in mesh form in circular slab or dome in one line. If this formula is adopted, a field engineer will be able to do the calculations in very easy way and chances of error are very less. It will also save the lengthy paper work while estimating the steel for circular slab or dome.

6. REFERENCES

[1] Document No PWSSB-93/Q.C., Punjab Water Supply and Sewerage Board Chandigarh.
[2] D.S. Chan, Theory and implementation of multidimensional discrete systems for signal processing, doctoral diss., Massachusetts Institute of Technology, Cambridge, MA, 1978. (8)

[3] M Ozaki, Y. Adachi, Y. Iwahori, and N. Ishii, Application of fuzzy theory to writer recognition of Chinese characters, International Journal of Modelling and Simulation, 18(2), 1998, 112-116. (8).
[4] Manual of Instructions for Water Supply and Sewerage Works Silver Jubilee 1977-2002 Chandigarh Page 102 Steel in Mesh.
[5] SSRG International Journal of Engineering Trends and Technology Part-1 Civil Engineering April 2015 Page 120.
[6] S. L. Loney, The Elements of Coordinate Geometry (Scholarly Publishing Office, University of Michigan Library, 978-1418184148)
[7] The Tribune dated January 19, 1989 Page 6 'For Engineers'
[8] W.J. Book, Modelling design and control of flexible manipulator arms: A tutorial review, Proc. 29th IEEE Conf. on Decision and Control, San Francisco, CA, 1990, 500-506 (8)

Microbial Contamination in Drinking Water and Incidence of Waterborne Diseases in Mega City of a Developing Country- Karachi, Pakistan

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Abstract
It is not uncommon for cities of developing countries that drinking water is generally contaminated microbially because of poor infrastructure management and cross-contamination from leaking sewers. The contaminated water becomes one of the major sources for various diseases. The main objective of the study was to evaluate the microbial quality of potable water and relate the quality of water to the diseases to the residents of Karachi, Pakistan. A total of 238 drinking water samples were collected from 18 areas of Karachi from March-October, 2012. A questionnaire was also designed with the help of public health professionals to find out the occurrence of different waterborne diseases for the study area. In addition, the data for different waterborne diseases were collected from 42 government and private hospitals to correlate with water quality data for different localities. The results show that 87% of the total samples were found contaminated with total coliforms while 26% of the samples were found contaminated with fecal coliforms. The study reveals that typhoid, hepatitis A, gastro-intestinal tract disorder, dysentery, and cholera are common among the residents of the area where drinking water was contaminated with coliform bacteria. Overall, children and senior citizens were the most susceptible groups as they were the dominant group of patients who were admitted to hospitals due to waterborne diseases. It is concluded from the study that regular monitoring of water supplies and application of point-of-use water treatment technologies would help reduce the risk of waterborne diseases for the residents of Karachi.

Keywords
Waterborne diseases; Drinking water, Coliforms, Hospitals

1. Introduction
The developing countries face major water problems including a huge gap between supply and demand. Moreover, the treated water supplied through the distribution system is contaminated before it reaches the

users because of ageing infrastructure and contamination from leaking sewers. Many other factors also contribute in the contamination of water supply system which include lines construction and repair, microbial re-growth in distribution system and their colonization and entrance of inadequately treated water in distribution system especially after rainfall. Such water has high turbidity, bad taste and objectionable odor and rejected by the consumer and not used for drinking purpose (Langah et al. 2008). Clean drinking water which is a basic necessity is not available for most of the population of Pakistan (Rasheed et al. 2009). Karachi which a mega city and hub of industries, is also suffering from the shortage of safe drinking water. In Karachi water supply to households is intermittent through a distribution system that is notable for cross contamination with groundwater and the sewage system and this situation leads to high risk for waterborne diseases (Karachi Development Plan 2000). Luby et al., 2000 conducted a drinking water quality study in a squatter settlement of Karachi and found that 85% of the water samples were contaminated with coliform bacteria. In another study conducted in Karachi it was found that the water used by the people of Karachi especially in the town of Landhi, Korangi and Malir is highly contaminated with coliforms bacteria and has high turbidity and TDS value (Langah et al. 2008).

The infant mortality rate is 12.6% in Pakistan which is a high value and indicates the poor health status of Pakistani population. According to United Nations Children's Fund (UNICEF), 20% to 40% beds in the hospitals of Pakistan are occupied by patients suffering from water related diseases. The hospital data shows that most of the diseases treated in the hospitals are due to the water borne microorganisms confirming that the use of polluted water causes a high morbidity rate. Gastrointestinal infections with diarrhea have very high frequency among children as well as in adults (Ali et al. 2011). The aims of this study were to examine the quality of drinking water which is supplied to the residents of the various areas of a mega city and to find relevance with outbreaks of waterborne diseases.

2. Materials and Methods

238 random drinking water samples were collected from eighteen areas of Karachi during the period of March-October 2012. Representative samples were collected in pre-sterile glass bottles from the residential areas of different localities. Physical, chemical and microbiological analyses were carried out according to the procedures described in Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Multiple tube fermentation method (MPN) was used to detect the presence of total coliforms (TC) and fecal coliforms (FC), and the results were interpreted in MPN/100mL. Data for the incidence of different waterborne illnesses were collected from 42 government and private hospitals of Karachi during the same period. A questionnaire was designed with the help of medical professionals to find out the incidences of different waterborne diseases. These questionnaires were filled in by qualified medical staff and doctors. The questionnaire was designed to collect detailed information with respect to the age group of the reported patients, period of hospitalization, gender and major waterborne diseases. The obtained data was correlated to find the relationship between the use of contaminated water and the occurrence of infections in different localities of Karachi. Another questionnaire was distributed among the residents of different areas to find the source of drinking water (municipal water supply or tap water, bottled water, well water and water tankers) and point-of-use treatment processes (boiling, filtration, UV, chemical) used by the general public of these areas.

3. Results and Discussion

Out of 238 samples, 208 (87.4%) samples were found contaminated with total coliforms (TC) while 62 (26%) samples were contaminated with fecal coliforms (FC). This study revealed that typhoid, hepatitis A, gastro-intestinal tract disorder (GIT), dysentery and cholera are common among the residents of the area where drinking water was contaminated with coliform bacteria. With regard to physical and chemical parameters all values were under the limits as described by WHO drinking-quality guidelines. Figure 1 shows percentage of microbial contamination in water samples collected from different areas of Karachi.

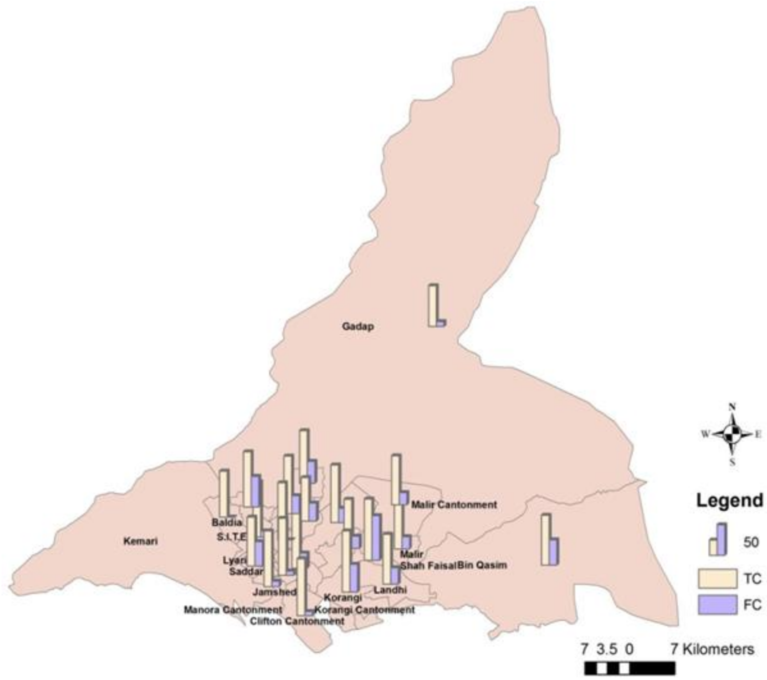

Figure 1: Map Showing Different Areas of Karachi and Microbial Contamination in Samples

Patients of typhoid, hepatitis A and GIT were treated in all hospitals while the patients suffering from dysentery and cholera were reported in 80.9% and 73.8% of the hospitals, respectively. Most alarming situation was observed in Shah Faisal and Korangi areas where 100% samples were contaminated with TC while the percentage of samples with FC was 72.7% and45.5% for the two areas, respectively. Hospital data also supported our results as GIT and typhoid were the common ailments in the inhabitants of these areas. 90-99% of the samples collected from eight other areas were contaminated with TC which includes Gulshan and North Nazimabad (94.1%), Liaquatabad and Defence (92.3%), Jamshed (91.7%), Saddar (90.9%), Orangi and Site (90%). Fecal coliforms were present in water samples of all areas except Liaquatabad. They were detected in 23.5% (Gulshan), 29.4% (North Nazimabad), 7.7% (Defence), 25% (Jamshed), 9% (Saddar), 50% (Orangi) and 10% (S.I.T.E.) of the samples collected from these areas. Other areas where high numbers of TC and FC were detected in water samples were Malir (86.7% and 20%), North Karachi (85.7% and35.7%), Bin Qasim (81.8% and 45.5%), Landhi (81.8% and 27.3%) and Lyari (80% and 40%), respectively. Table 1 presents the percentage of waterborne diseases reported in different areas of Karachi. Typhoid, dysentery, cholera and GIT disorder were prominent waterborne diseases reported in the occupants of these areas. GIT disorder was major reported ailment in 33.3% of the hospitals while typhoid was dominant in 19% of the hospitals. Together they were reported as major ailments in 16.7% of the hospitals.

Hospital data analysis further indicates that the patients from all age groups were suffering from water related illnesses. Aged people and children were the most susceptible groups as in 47.5% and 37.5% hospitals. They were the dominant group of patients who were admitted due to waterborne diseases. Overall, men were more susceptible to waterborne infections as compared to women. Figure 2 presents drinking water sources used by residents of Karachi. Residential questionnaire data analysis indicates that three fourth of the respondents (74.5%) depend on municipal water supply whereas 17.6% use bottled water for drinking purpose. The remaining 4.4% of the respondents use groundwater while 3.5% use water supplied by tankers. 74.9% of the respondents said that they treat drinking water before use. 57% of the respondents said that they boil the water while 31.2% said they filter it.

Table1: Percentage of Waterborne Diseases Reported in Different Areas of Karachi

S. No.	Name of area	GIT	Typhoid	Hepatitis	Cholera	Dysentery
1	Baldia	Data not collected				
2	Bin Qasim	44.0	30.0	12.0	4.0	10.0
3	Gulberg	59.33	17.0	16.33	5.67	1.67
4	Gulshan-e- Iqbal	52.62	22.88	13.75	3.25	7.5
5	Jamshed	61.2	23.8	8.4	4.0	2.6
6	Korangi	70.0	14.0	8.0	8.0	0.0
7	Landhi	Data not collected				
8	Liaquatabad	51.67	21.67	11.67	6.33	8.66
9	Lyari	65.5	17.5	4.5	7.5	5.0
10	Malir	71.5	16.0	7.5	1.0	4.0
11	North Karachi	51.33	29.0	12.33	4.0	3.33
12	North Nazimabad	53.2	25.0	14.8	2.4	4.6
13	Orangi	80.0	15.0	5.0	0.0	0.0
14	Saddar	54.5	22.0	13.5	5.5	4.5
15	Shahfaisal	40.0	30.0	20.0	3.0	7.0
16	Defence	55.0	25.0	10.0	1.0	9.0
17	Malir Cantonment	54.5	25.0	9.5	5.0	6.0
18	S.I.T.E.	55.0	20.0	15.0	0.0	4.0

GIT: Gastro-intestinal tract disorder

The present study is based on the water quality evaluation of the municipal water supplied to eighteen areas of Karachi city. This study provides a broad based and reliable data regarding the presence of infectious microorganisms in drinking water supplied to the mega city of Karachi and will be helpful to agencies responsible for maintaining drinking water quality. Inspite of the fact that water treatment plants treat water and then supply it to consumers still the drinking water is contaminated microbially because of poor infrastructure management and cross-contamination from leaking sewers. The main reasons for microbial contamination suspected include aged infrastructure, cross-contamination and leakages in the water supply and sewer systems. Moreover, the change in building pattern, only ground plus four constructions were allowed by the building control authority until the last decade, in residential areas. However the pattern has changed after alteration in laws and now residential buildings up to ground plus fifteen and more are prevailing. The sewer systems have not been upgraded and they have to cater for high flows resulting in overflow of sewage from manholes and thus contaminating the public water supplies.

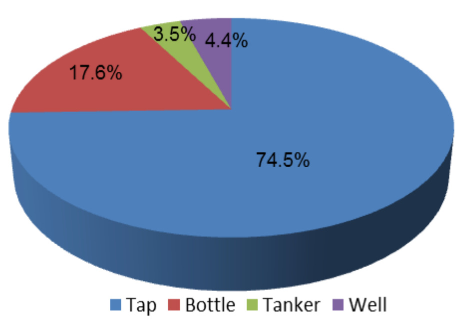

Figure 2: Drinking Water Sources Used by Residents of Karachi

The study shows that the people of Karachi are using drinking water which is not fulfilling the WHO drinking-quality guidelines and microbial contamination of water leads to outbreaks of waterborne diseases. This is an alarming situation and contamination of drinking water supplies should be controlled to protect public health. Water quality should be monitored regularly at the user end and results be made public on the water agency's website so that measures can be taken to reduce the waterborne diseases. Possible measures that can be adopted by residents include application of point-of-use treatment technologies like solar disinfection, biosand filter, ceramic filter and chlorination. This research could serve as a foundation for better management of water quality for the occupants of the mega city of Karachi.

4. Conclusions

Our results signal an alarming situation in many areas of the city and indicate that public health is mostly neglected by the regulatory and management authorities. Consumer education regarding the use of drinking water, continuous and periodic monitoring of water supply system and its improvement, and appropriate treatment of household water before use is strongly recommended for residents of the mega city for prevention of water borne diseases.

References

Ali, J., Hussain, A., Abid, H. and Rahman, Z. (2011). "Bacteriological quality assessment of drinking water from Khyber agency and its impacts on public health". *Pakistan Journal of Biochemistry and Molecular Biology,* Vol. 44, No. 2, pp. 73-76.

APHA (2005). Standard Methods for the Examination of Water and Wastewater, AWWA, WEF (21st edition) American Public Health Association, Washington, DC.

Karachi Development Plan (2000). KDA master plan and environmental control development 1991.

Langah, A. A., Khalid, M. K., Haq, Q., Perveen, S. & Ullah, Z. (2008). "Physical and bacteriological analysis of drinking water of Korangi, Landhi and Malir towns of Karachi". *Journal of Chemical Society of Pakistan*, Vol. 30, No. 2, pp. 315-322.

Luby, S. P., Syed, A. H., Atiullah, N., Faizan, M. K. & Fisher-Hoch, S. (2000). "Limited effectiveness of home drinking water purification efforts in Karachi, Pakistan". *International Journal of Infectious Diseases*, Vol. 4, No. 1, pp. 3-7.

Rasheed, F., Khan, A. & Kazmi, S. U. (2009). "Bacteriological analysis, antimicrobial susceptibility and detection of 16S rRNA gene of Helicobacter pylori by PCR in drinking water samples of earthquake affected areas and other parts of Pakistan". *Malaysian Journal of Microbiology*, Vol. 5, No. 2, pp. 123-127.

Yousuf, F. A., Siddiqui, R., Subhani, F. & Khan, N. A. (2013). "Status of free-living amoebae (Acanthamoeba spp., Naegleria fowleri, Balamuthia mandrillaris) in drinking water supplies in Karachi, Pakistan". *Journal of Water and Health*, Vol. 11, No. 2, pp. 371-375.

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MHD Maxwell Fluid with Non Linear Velocity over the Boundary

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Abstract

This work concerned with the analysis of the effects of MHD on the unsteady motion of a viscoelastic Maxwell fluid moving over the plane. The exact solutions for velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ corresponding to the motion of MHD Maxwell fluid moving over the plane are obtained. The general solutions are determined with the help of Laplace and Fourier Sine Transforms and represented in terms of elementary functions, simple integral and the convolution product of Laplace transforms. These solutions satisfy both the governing equations and all imposed initial and boundary conditions. The similar solutions corresponding to Maxwell, MHD Newtonian and Newtonian fluids are obtained as the particular cases of the present results. Finally, the solutions that have been obtained are compared by graphical illustrations and the influence of the pertinent parameters on the fluid motion is also analyzed. The comparison of four models MHD Maxwell, Maxwell, MHD Newtonian and Newtonian fluids for two different magnetic parameters are also presented. Such type of flows have many applications related to civil engineering like in structure engineering, fluid mechanics, hydraulics and traffic flow problems etc.

Keywords

Magnetohydrodynamics (MHD), Maxwell fluid, Integral transforms, Exact solutions, Graphical analysis.

Introduction

Nonlinear relationship in stress and the rate of deformation in different fluids have been observed in several industries and modern technological applications. Such types of fluids are called non-Newtonian fluids. To achieve the best result forms these industries (oils and greases, ketchup, cosmetic products, drilling muds, polymer and chemical industry and bio-engineering) and technologies, it is necessary to understand the phenomenon of these non-Newtonian fluids. The best way to predict the nature of these fluids is to find their exact solution for different geometric situations. For this reason, the analysis of flows of non-Newtonian fluids has received potential attention of the mathematicians, physicists, engineers and computer scientists [2]. There are three different types of non-Newtonian fluids: rate, differential and integral types. Exact solutions for rate/viscoelastic type fluids have been studied by many researchers for different boundary value problems [3, 4, 5, 6, 7, 8, 9]. The rate type fluids have one very simple subclass of fluid known as Maxwell model. We are living in the era of nanotechnology or even smaller. Scientific calculations do not want to ignore or approximate very small contributions. MHD (magnetohydrodynamics) have significant impact in the modern scientific world and play very important role in MHD generators, plasma, aerodynamics, nuclear engineering control, MHD energy systems, mechanical and manufacturing process engineering and so forth [10]. Some of the interesting studies for finding exact solutions for non-Newtonian fluids where MHD effect is considered are given in [11, 12, 13, 14]. Very few investigations were found when the Maxwell fluid flows in the presence of MHD influence [15, 16, 17, 18, 19].

In the present analysis, we study the effects of MHD on the unsteady motion of a viscoelastic Maxwell fluid moving over the plane. Our aim is to find the exact solutions for velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ corresponding to the motion of MHD Maxwell fluid moving over the plane. The general solutions are obtained with the help of Laplace and Fourier Sine Transforms and represented in terms of elementary functions, simple integral and the convolution product of Laplace transforms. These solutions satisfy both the governing equations and all imposed initial and boundary conditions. Such exact solutions, which are not common in the literature, provide an important check for numerical methods that are used to study flows of such fluids in a complex domain. The similar solutions corresponding to Maxwell, MHD Newtonian and Newtonian fluids are obtained as the particular cases of the present results. Finally, the solutions that have been obtained are compared by graphical illustrations and the influence of the pertinent parameters on the fluid motion is also analyzed by graphs. The comparison of four models MHD Maxwell, Maxwell, MHD Newtonian and Newtonian fluids for two different magnetic parameters are also presented.

Basic Governing Equations

The equations governing the MHD flow of an incompressible fluid include the continuity equation and the momentum equation. In the absence of body forces, they are

$$\nabla.\boldsymbol{V} = 0, \nabla.\boldsymbol{T} = \rho\frac{\partial \boldsymbol{V}}{\partial t} + \rho(\boldsymbol{V}.\nabla)\boldsymbol{V} + \sigma B_0^2\boldsymbol{V}, \tag{1}$$

where the body forces are absent, ρ is the fluid density, **V** is the velocity field, σ is the electrical conductivity of the fluid, $\boldsymbol{B_0}$ is the applied magnetic field, t is the time and $\boldsymbol{\nabla}$ represents the dell operator. Note that the fluid is electrically conducting in the presence of a uniform magnetic field and the induced magnetic field is neglected for small magnetic Reynolds number assumption. No electric field is applied. The Cauchy stress $\boldsymbol{T}$ in an incompressible Maxwell fluid is given by

$$\boldsymbol{T} = -\boldsymbol{p}\,\boldsymbol{I} + \boldsymbol{S}, \quad \boldsymbol{S} + \lambda\left(\dot{\boldsymbol{S}} - \boldsymbol{LS} - \boldsymbol{SL}^T\right) = \mu\boldsymbol{A}, \tag{2}$$

where $-p\mathbf{I}$ denotes the indeterminate spherical stress due to the constraint of incompressibility, $\boldsymbol{S}$ is extra-stress tensor, **L** is the velocity gradient, $\boldsymbol{A} = \boldsymbol{L} + \boldsymbol{L}^T$ is the first Rivlin Ericksen tensor, μ is the dynamic viscosity of the fluid, λ is relaxation time, the superscript T indicates the transpose operation and the superposed dot indicates the material time derivative. The model characterized by the constitutive equations (2) contains as special case the Newtonian fluid model for $\lambda \rightarrow 0$. For the problem under consideration we assume a velocity field **V** and an extra-stress tensor **S** of the form

$$\boldsymbol{V} = \boldsymbol{V}(y,t) = u(y,t)\boldsymbol{i}\,, \qquad \boldsymbol{S} = \boldsymbol{S}(y,t), \tag{3}$$

where $\boldsymbol{i}$ is the unit vector along the x-coordinate direction. For these flows the constraint of incompressibility is automatically satisfied. If the fluid is at rest up to the moment $t = 0$, then

$$\boldsymbol{V} = (y,0) = 0\,, \qquad \boldsymbol{S} = (y,0) = 0, \tag{4}$$

and equations. (2)-(4) imply $S_{yy} = S_{yz} = S_{zz} = S_{xz} = 0$, and

$$\left(1 + \lambda\frac{\partial}{\partial t}\right)\tau(y,t) = \mu\frac{\partial u(y,t)}{\partial y}\,, \tag{5}$$

where $\tau(y,t) = S_{xy}(y,t)$ are the non-zero shear stresses. In the absence of body forces, the balance of linear momentum reduces to

$$\begin{aligned}\frac{\partial \tau(y,t)}{\partial t} - \frac{\partial p}{\partial x} &= \rho\frac{\partial u(y,t)}{\partial t} + \sigma B_0^2 u(y,t),\\ -\frac{\partial p}{\partial y} = \sigma B_0^2 v(y,t), &-\frac{\partial p}{\partial z} = \sigma B_0^2 w(y,t).\end{aligned} \tag{6}$$

Eliminating τ between Equations (5) and $(6)_1$, we find the governing equation under the form

$$\left(1+\lambda\frac{\partial}{\partial t}\right)\frac{\partial u(y,t)}{\partial y}=-\frac{1}{\rho}\left(1+\lambda\frac{\partial}{\partial t}\right)\frac{\partial p}{\partial x}+\nu\frac{\partial^2 u(y,t)}{\partial^2 t},$$
$$-\frac{\sigma B_0^2}{\rho}\left(1+\lambda\frac{\partial}{\partial t}\right)u(y,t);\qquad y,t>0. \tag{7}$$

Where $\nu = {}^{\mu}/_{\rho}$ is the kinematic viscosity of the fluid. The governing equations corresponding to an incompressible MHD Maxwell fluid performing the same motion in the absence of pressure gradient are

$$\left(1+\lambda\frac{\partial}{\partial t}\right)\frac{\partial u(y,t)}{\partial t}=\nu\frac{\partial^2 u(y,t)}{\partial^2 t}-B\left(1+\lambda\frac{\partial}{\partial t}\right)u(y,t), \tag{8}$$

$$\left(1+\lambda\frac{\partial}{\partial t}\right)\tau(y,t)=\mu\frac{\partial u(y,t)}{\partial y}, \tag{9}$$

where $B=\frac{\sigma B_0}{\rho}$. The system of partial differential equations can be solved in principle by several methods, their effectiveness strictly depending on the domain of definition. Here, we shall use the Laplace and Fourier sine transforms.

Statement of the Problem

Consider an incompressible MHD Maxwell fluid occupying the space lying over an infinitely extended plane which is situated in the *xz* plane and perpendicular to the *y*-axis. Initially, the fluid is at rest and at the moment $t=0^+$ the plane is impulsively brought to the constant velocity U in its own plane. Due to the shear, the fluid above the plane is gradually moved. Its velocity is of the form $(3)_1$ while the governing equations are given by equations (8) and (9). The appropriate initial and boundary conditions are [20]

$$u(y,0)=\frac{\partial u(y,0)}{\partial t}=0,\quad \tau(y,0)=0,\qquad y>0, \tag{10}$$
$$u(0,t)=UH(t)t^n,\qquad t\geq 0, \tag{11}$$

where $H(t)$ is the Heaviside function. Moreover, the natural conditions

$$u(y,t),\qquad \frac{\partial u(y,t)}{\partial t}\to 0\ as\ y\to\infty\qquad and\quad t>0, \tag{12}$$

have to be also satisfied. They are consequences of the fact that the fluid is at rest at infinity and there is no shear in the free stream.

Solution of the Problem

The solution of the problem lies in the calculation of velocity field i.e. $u(y,t)$ and the adequate shear stress $\tau(y,t)$ associated with the velocity obtained. Hence, for the exact solutions, we are going to first calculate the velocity field for the problem.

Calculation of Velocity Field

Multiplying both sides of (8) $\sqrt{2/\pi}\ \sin(y\xi)$, integrating the result with respect to y from 0 to infinity, and taking into account the boundary conditions (10) and (11), we attain that

$$\left\{\frac{\partial u_s(\xi,t)}{\partial t}+\lambda\frac{\partial^2 u_s(\xi,t)}{\partial^2 t}\right\}=\left\{-\nu\xi^2 u_s(\xi,t)+\sqrt{\frac{2}{\pi}}\nu\xi\, UH(t)t^n - B\left(1+\lambda\frac{\partial}{\partial t}\right)u_s(\xi,t)\right\}, \quad (13)$$

where $H(t)$ is the Heaviside function and $u_s(\xi,t)$ is the Fourier sine transform defined by

$$u_s(\xi,t)=\sqrt{\frac{2}{\pi}}\int_0^\infty u(y,t)Sin(y\xi)dy, \quad (14)$$

has to satisfy the initial conditions

$$u_s(\xi,0)=\frac{\partial u_s(\xi,0)}{\partial t}=0, \quad \xi>0\,, \quad (15)$$

By applying the Laplace transform to (13) and having in mind the initial and boundary conditions (7) and (8), we find that

$$\overline{u_s}\,(\xi,q)=\sqrt{\frac{2}{\pi}}\;\frac{U\,n!\,\nu\,\xi}{q^{n+1}[\lambda q^2+(1+\lambda B)q+B+\nu\xi^2]}. \quad (16)$$

Now, for a more suitable presentation of the final results, we rewrite (16) in the following equivalent form

$$\overline{u_s}\,(\xi,q)=\frac{U\,n!\;\nu\,\xi}{(B+\nu\xi^2)}\sqrt{\frac{2}{\pi}}\;\left[\frac{1}{q^{n+1}}-\frac{1+q\lambda+\lambda B}{q^n[\lambda q^2+(1+\lambda B)q+B+\nu\xi^2]}\right], \quad (17)$$

Inverting (17) by means of the Fourier sine formula, we can write $\overline{u_s}\,(y,q)$ as

$$\bar{u}(y,q)=\frac{2\,n!\,U\,\nu}{\pi}\int_0^\infty\frac{\xi\;\sin(y\xi)}{(B+\nu\xi^2)}\left[\frac{1}{q^{n+1}}-\frac{(1+q\lambda)}{\lambda q^n(q-q_1)(q-q_2)}+\frac{\lambda B}{\lambda q^n(q-q_1)(q-q_2)}\right]d\xi, \quad (18)$$

Finally in order to obtain the expression for velocity field $u(y,t)=\mathcal{L}^{-1}\{\bar{u}(y,q)\}$, we apply the inverse Laplace transform to (18) having convolution theorem, and using the fact

$$\int_0^\infty\frac{\xi\,\sin\,(y\xi)}{a^2+\xi^2}d\xi=\frac{\pi}{2}e^{-ay},\;\; a>0. \quad (19)$$

We find for the velocity field in integral form,

$$u(y,t)=U\,H(t)\,t^n\;\;e^{-\sqrt{\frac{B}{\nu}}y}-\frac{2\,n\,U\,H(t)\nu}{\pi\,\lambda\,(q_1-q_2)}\int_0^\infty\int_0^t\frac{\xi\,\sin(y\xi)}{(\mathrm{B}+\nu\xi^2)}\,(t-u)^{n-1}\,\{(1+\lambda q_1)e^{q_1u}$$
$$-(1+\lambda q_2)e^{q_2u}\}\,d\xi\,du+\frac{2B\,n\,U\,H(t)\,\nu}{\pi(q_1-q_2)}\int_0^\infty\int_0^t\frac{\xi\,\sin(y\xi)}{(\mathrm{B}+\nu\xi^2)}\,(t-u)^{n-1}(e^{q_1u}-e^{q_2u})\,d\xi\,du. \quad (20)$$

Where

$$q_1,q_2=\frac{-(1+\lambda B)\pm\sqrt{(1+\lambda B)^2-4\lambda(B+\nu\xi^2)}}{2\lambda},$$

are the roots of the algebraic equation $\lambda q^2+(1+\lambda B)q+B+\nu\xi^2=0$.

Calculation of Shear Stress

Applying Laplace transform to equation (9), we find that

$$\bar{\tau}(y,q)=\frac{\mu}{(1+\lambda q)}\;\;\frac{\partial\bar{u}(y,q)}{\partial y}, \quad (21)$$

where $\bar{\tau}(y,q)$ is the Laplace transform of $\tau(y,t)$, on differentiating partially equation (18) with respect to y, we get

$$\frac{\partial \bar{u}(y,q)}{\partial y} = \frac{2\,n!\,U\,\nu}{\pi}\int_0^\infty \frac{\xi^2\cos(y\xi)}{(B+\nu\xi^2)}\left[\frac{1}{q^{n+1}} - \frac{1+q\lambda+\lambda B}{q^n[\lambda q^2+(1+\lambda B)q+B+\nu\xi^2]}\right]d\xi, \tag{22}$$

Substituting equation (22) in (21), we have

$$\bar{\tau}(y,q) = \frac{\mu}{(1+\lambda q)}\left[\frac{2\,n!\,U\,\nu}{\pi}\int_0^\infty \frac{\xi^2\cos(y\xi)}{(B+\nu\xi^2)}\left\{\frac{1}{q^{n+1}} - \frac{1}{q^n}\frac{1+q\lambda+\lambda B}{[\lambda q^2+(1+\lambda B)q+B+\nu\xi^2]}\right\}d\xi\right], \tag{23}$$

Simplifying (23), we obtain an expression for shear stress as

$$\bar{\tau}(y,q) = -\frac{U\,\mu}{(1+\lambda q)}\sqrt{\frac{B}{\nu}}\,\frac{n!}{q^{n+1}}\,e^{-\sqrt{\frac{B}{\nu}}y} - \frac{2\,n!\,U\,\nu\,\mu}{\pi\,\lambda}\int_0^\infty \frac{\xi^2\cos(y\xi)}{(B+\nu\xi^2)}\left\{\frac{1}{q^n(q-q_1)(q-q_2)}\right\}d\xi$$
$$+\frac{2\,U\,B\,n!\,\nu\,\mu}{\pi(q_1-q_2)}\int_0^\infty \frac{\xi^2\cos(y\xi)}{(B+\nu\xi^2)}\,\frac{1}{q^n}\,\frac{1}{(1+\lambda q)}\left\{\frac{1}{q-q_1} - \frac{1}{q-q_2}\right\}d\xi, \tag{24}$$

we can also write (24) as

$$\bar{\tau}(y,q) = -\frac{U\,\mu}{(1+\lambda q)}\sqrt{\frac{B}{\nu}}\frac{n!}{q^{n+1}}e^{-\sqrt{\frac{B}{\nu}}y} - \frac{2\,U\,n!\,\nu}{\pi\,\lambda\,(q_1-q_2)}\,\frac{\mu}{(1+\lambda q)}\int_0^\infty \frac{\xi^2\cos(y\xi)}{(B+\nu\xi^2)}\,\frac{1}{q^n}\left\{\frac{1+\lambda q_1}{q-q_1}\right.$$
$$\left. -\frac{1+\lambda q_2}{q-q_2}\right\}d\xi + \frac{2\,U\,B\,n!\,\mu\,\nu}{\pi(q_1-q_2)}\int_0^\infty \frac{\xi^2\cos(y\xi)}{(B+\nu\xi^2)}\left\{\frac{1}{q^n(q-q_1)(1+q_1\lambda)} - \frac{1}{(q-q_2)(1+q_2\lambda)}\right.$$
$$\left. +\frac{\lambda^2(q_1-q_2)}{(1+q_1\lambda)(1+q_2\lambda)(1+q\lambda)}\right\}d\xi. \tag{25}$$

Finally, applying inverse Laplace transform on equation (25),

$$\tau(y,t) = -U\,H(t)\,\frac{\mu}{\lambda}\sqrt{\frac{B}{\nu}}\;e^{-\sqrt{\frac{B}{\nu}}y}\int_0^t (t-u)^n\,e^{u/\lambda}du - \frac{2\,n\,U\,H(t)\,\nu\,\mu}{\pi\,\lambda\,(q_1-q_2)}\int_0^\infty\int_0^t \frac{\xi^2\cos(y\xi)}{(B+\nu\xi^2)}(t-u)^{n-1}$$
$$\times(e^{q_1u}-e^{q_2u})\,d\xi\,du + \frac{2\,B\,n\,U\,H(t)\,\nu\,\mu}{\pi(q_1-q_2)}\int_0^\infty\int_0^t \frac{\xi^2\cos(y\xi)}{(B+\nu\xi^2)}(t-u)^{n-1}\left\{\frac{e^{q_1u}}{(1+q_1\lambda)} - \frac{e^{q_2u}}{(1+q_2\lambda)}\right.$$
$$\left.+\frac{\lambda(q_1-q_2)e^{-u/\lambda}}{(1+q_1\lambda)(1+q_2\lambda)}\right\}d\xi\,du. \tag{26}$$

we get shear stress in integral form.

Particular Cases

Maxwell Fluid $B \to 0$

Taking the limit $B \to 0$ into equations (20) and (26), the velocity field and shear stress are

$$u_M(y,t) = U\,H(t)\,t^n - \frac{2\,n\,U\,H(t)}{\pi\,\lambda\,(q_1-q_2)}\int_0^\infty\int_0^t \frac{\sin(y\xi)}{\xi}(t-u)^{n-1}$$
$$\times\{(1+\lambda q_1)e^{q_1u} - (1+\lambda q_2)e^{q_2u}\}\,d\xi\,du, \tag{27}$$

$$\tau_M(y,q) = -\frac{2\,n\,U\,H(t)\,\mu}{\pi\,\lambda\,(q_1-q_2)}\int_0^\infty\int_0^t \cos(y\xi)\;(t-u)^{n-1}(e^{q_1u}-e^{q_2u})\,\partial\xi\,du\,. \tag{28}$$

corresponding to Maxwell fluid in the absence of magnetic field are obtained.

MHD Newtonian Fluid $\lambda \to 0$

Taking the limit $\lambda \to 0$ into equations (20) and (26) and using following facts

$$\lim_{\lambda\to 0} q_1 = -(B+\nu\xi^2)\ , \quad \lim_{\lambda\to 0} q_2 = -\infty\ , \quad and \quad \lim_{\lambda\to 0} \lambda(q_1-q_2) = 1\ ,$$

the solutions for MHD Newtonian fluid for the velocity field and the shear stress

$$u_{MN}(y,t) = U\,H(t)t^n e^{-\sqrt{\frac{B}{\nu}}y} - \frac{2\,n\,U\,H(t)\,\nu}{\pi}\int_0^\infty\int_0^t \frac{\xi^2\sin(y\xi)}{(B+\nu\xi^2)}(t-u)^{n-1}e^{-(B+\nu\xi^2)u}\,d\xi\,du, \quad (29)$$

$$\tau_{MN}(y,t) = -UH(t)\mu\sqrt{\frac{B}{\nu}}t^n e^{-\sqrt{\frac{B}{\nu}}y} - \frac{2nUH(t)\nu\mu}{\pi}\int_0^\infty\int_0^t \frac{\xi^2\cos(y\xi)}{(B+\nu\xi^2)}(t-u)^{n-1}e^{-(B+\nu\xi^2)u}\,d\xi du. \quad (30)$$

are achieved.

Newtonian Fluid $\lambda \to 0$ and $B \to 0$

Letting the limit $\lambda \to 0$ *and* $B \to 0$ into equations (20) and (26) or using $B \to 0$ in equations (29) and (30) then solutions for velocity field and the shear stress for Newtonian fluid in the absence of magnetic field

$$u_N(y,t) = UH(t)t^n - \frac{2\,U\,H(t)\,n}{\pi}\int_0^\infty\int_0^t \sin(y\xi)\ \left\{(t-u)^{n-1}\,e^{-\nu\xi^2 u}\right\}d\xi\,du\ , \quad (31)$$

$$\tau_N(y,t) = -\frac{2\,n\,U\,H(t)\,\mu}{\pi}\int_0^\infty\int_0^t \cos(y\xi)\ \left\{(t-u)^{n-1}\,e^{-\nu\xi^2 u}\right\}d\xi\,du\ . \quad (32)$$

are achieved.

Numerical Results and Discussion

In this section our main emphasis is to discuss the influence of physical parameter on the flow of MHD Maxwell fluid induced by a moving plane. More precisely our aim is to sketch the graphs of the velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ for the flow parameter relaxation time λ, kinematic viscosity ν and specially the magnetic parameter *B*. The diagrams of the velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ have been drawn against y for different values of time t and the material parameters λ, ν, the power n and magnetic parameter B. For the sake of simplicity, all graphs are plotted by taking $U = 1$, $\nu = 0.63$, $\mu = 1.52$, $\lambda = 2$, $B = 0.5$. Figure 1, is the diagrams of the velocity field and the shear stress at four different times for MHD Maxwell fluid induced by a moving plane. Both the velocity field and the shear stress as expected are increasing functions with respect to time t and decreasing ones with respect to the height y. To observe the influence of the relaxation time on the fluid motion the figure 2 is sketched. It is noted that both quantities the velocity field $u(y,t)$ the shear stress $\tau(y,t)$ are decreasing functions of the relaxation time λ. In figure 3, we have plotted the velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ for different values of kinematic viscosity ν. It is obvious that both entities are increased with the increasing values of ν. As we are considering Maxwell fluid in the presence of magnetic field, the impact of magnetic parameter is much impotent for us. For this purpose figures 4 are depicted for different values of magnetic parameter *B*. The increasing values of the magnetic parameter *B* slow down the fluid motion and weakened the shear stress. Figure 5 represent the variation of the power *n* on the fluid motion. As we look forward that the effect of the power *n* accelerate the velocity field $u(y,t)$ as well as the shear stress $\tau(y,t)$. The natural phenomena that the velocity field $u(y,t)$ the shear stress $\tau(y,t)$ will be decreased are clear from figure 6.

At the end, the comparison, for the profiles of the velocity field and the shear stress corresponding to the four models (MHD Maxwell, Maxwell, MHD Newtonian and Newtonian) are together presented in figures 7 and 8 for two different values of the magnetic parameter $B = 0.2,\ 0.8$ and of the common material parameters. It is clearly seen from these diagram that, that the Newtonian fluid is swiftest and the MHD Maxwell fluid is slowest whether magnetic effect is small or large. The shear stress corresponding to the Newtonian fluid have largest values for both values of the magnetic parameter. The units of the material parameters in all figures are SI units.

Concluding Remarks

In the present analysis we study the effects of MHD on the unsteady motion of a viscoelastic Maxwell fluid moving over the plane. Our objectives are to determine the exact solutions for velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ corresponding to the motion of MHD Maxwell fluid moving over the plane with velocity $U\ H(t)t^n$. The general solutions are obtained with the help of Laplace and Fourier sine transforms and represent in terms of elementary functions, simple integral and the convolution product of Laplace transforms. These solutions satisfy both the governing equations and all imposed initial and boundary conditions. The similar solutions corresponding to Maxwell, MHD Newtonian and Newtonian fluids are obtained as the limiting cases of the present results. At the end, the solutions that have been obtained are compared by graphical illustrations and the influence of the pertinent parameters on the fluid motion is also analyzed by graphs. A comparison among the velocities and shear stresses of several fluid models are also included. The main outcomes are given below.

- The general solutions (20) and (26) are presented in very simple form in term of elementary functions, simple integral and the convolution product of Laplace transforms. In the limiting cases the general solutions can be easily particularized to give the similar solutions Maxwell, MHD Newtonian and Newtonian fluids.
- Both velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ are increasing functions with respect to the time and kinematic viscosity.
- The velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ are decreasing functions with respect to the relaxation time.
- The magnetic parameter B has significant effects on fluid motion and slows down the motion of the fluid.
- As expected, the increasing values of n and the height y increases and decreases the fluid motion respectively. It is also observed that all parameters of interest have clear effects near the moving plane.
- The Newtonian fluid moves fastest in comparison to MHD Maxwell, Maxwell and MHD Newtonian.

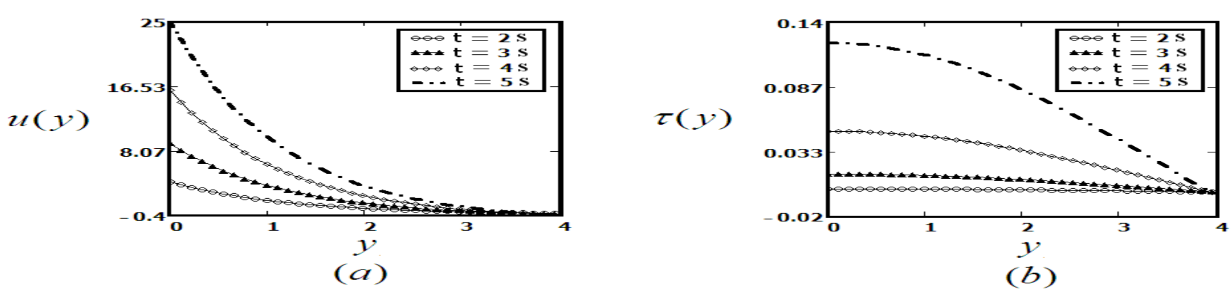

Figure 1: Profiles of the velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ for MHD Maxwell fluid given by Equations (20) and (26) for $U = 1,\ \nu = 0.63,\ \mu = 1.52,\ \lambda = 2,\ B = 0.5,\ n = 2$ and different values of t.

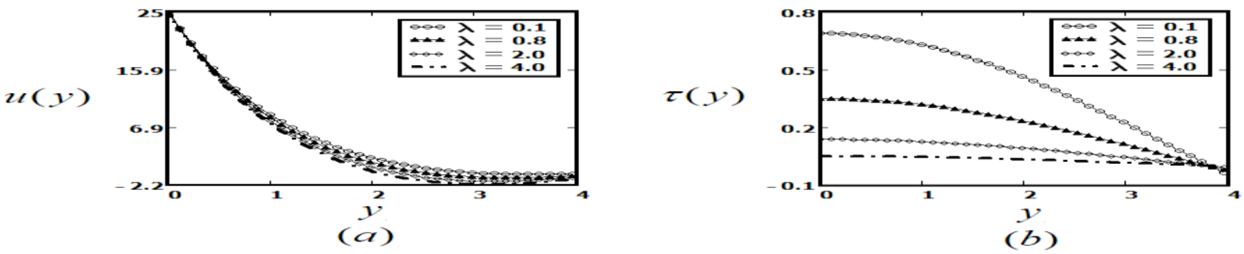

Figure 2: Profiles of the velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ for MHD Maxwell fluid given by Equations. (20) and (26), for $U = 1,\ \nu = 0.63,\ \mu = 1.52,\ t = 5\ s,\ B = 0.5,\ n = 2$ and different values of λ.

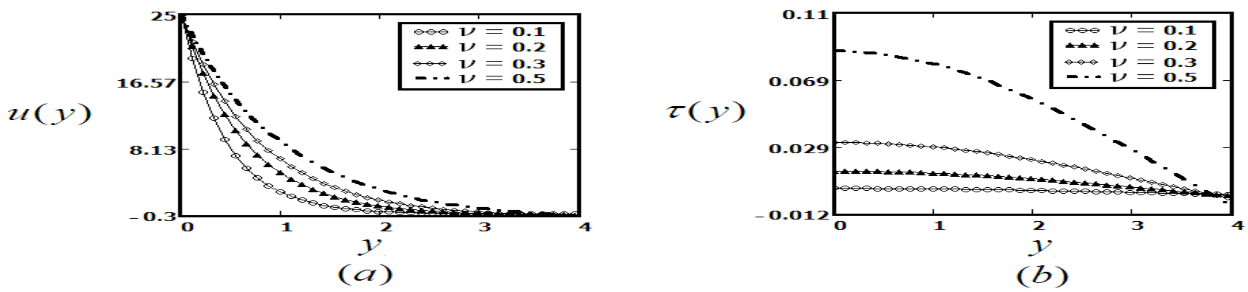

Figure 3: Profiles of the velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ for MHD Maxwell fluid given by Equations. (20) and (26), for $U = 1,\ \rho = 2.413,\ t = 5\ s,\ \lambda = 2,\ B = 0.5,\ n = 2$ and different values of ν.

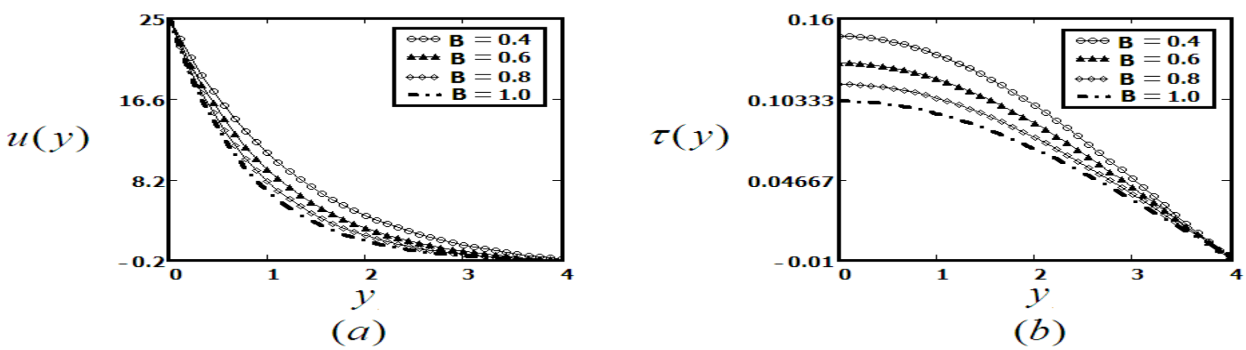

Figure 4: Profiles of the velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ for MHD Maxwell fluid given by Equations. (20) and (26), for $U = 1,\ \nu = 0.63,\ \mu = 1.52,\ \lambda = 2,\ t = 5\ s,\ n = 2$ and different values of B.

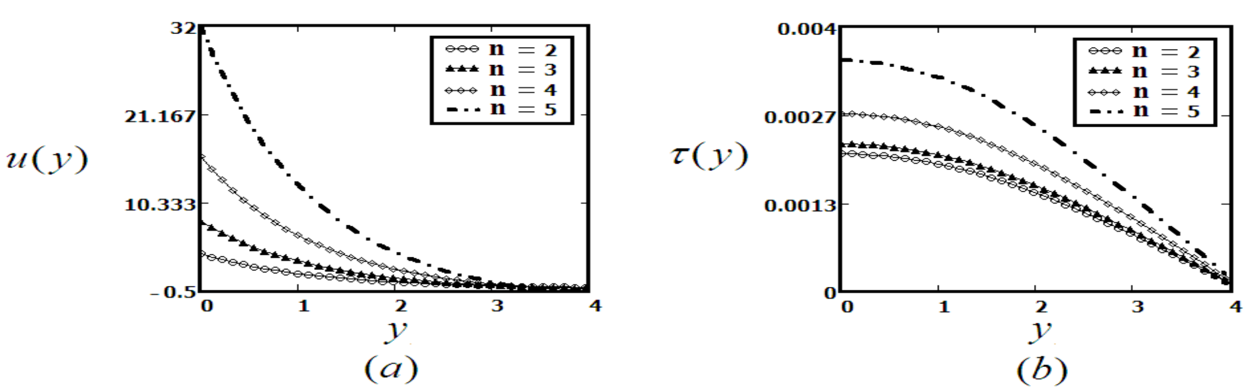

Figure 5: Profiles of the velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ for MHD Maxwell fluid given by Equations. (20) and (26), for $U=1,\ \nu=0.63,\ \mu=1.52,\ \lambda=2,\ B=0.5,\ t=2$ s and different values of n.

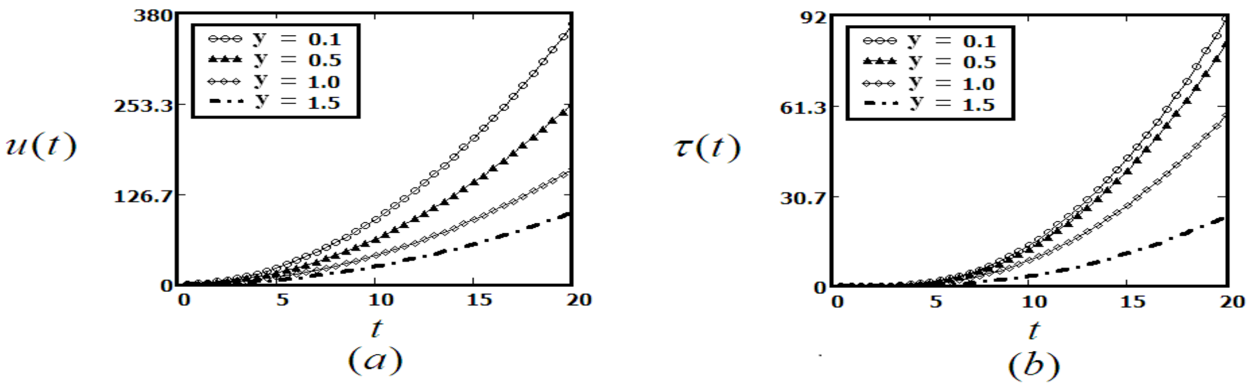

Figure 6: Profiles of the velocity field $u(y,t)$ and the shear stress $\tau(y,t)$ for MHD Maxwell fluid given by Equations (20) and (26), for $U=1,\ \nu=0.63,\ \mu=1.52,\ \lambda=2,\ B=0.5,\ n=2$ and different values of y.

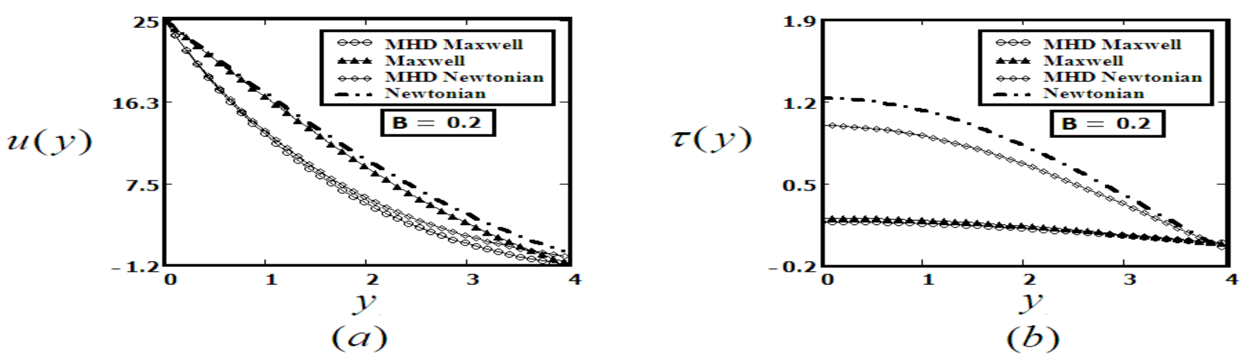

Figure 7: Profiles of the velocity fields $u(y,t)$ and the shear stresses $\tau(y,t)$ for MHD Maxwell, Maxwell, MHD Newtonian, Newtonian fluids given by equations (20), (27) , (29) , (31) , (26), (28) , (30) and (32) for $U=1,\ \nu=0.63,\ \mu=1.52,\ t=5\,s,\ B=0.5,\ n=2$ and different values of $B=0.2$.

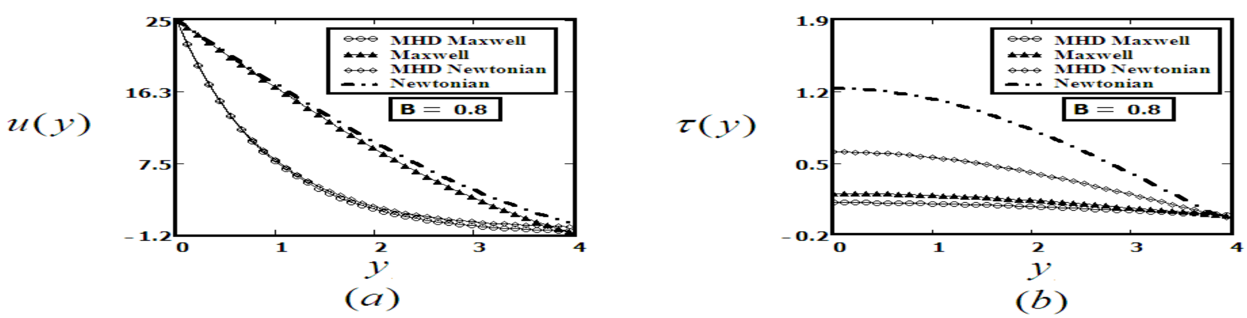

Figure 8: Profiles of the velocity fields $u(y,t)$ and the shear stresses $\tau(y,t)$ for MHD Maxwell, Maxwell, MHD Newtonian, Newtonian fluids given by equations (20), (27) , (29) , (31) , (26), (28) , (30) and (32) for $U=1,\ \nu=0.63,\ \mu=1.52,\ t=5\,s,\ B=0.5,\ n=2$ and different values of $B=0.8$.

References

[1] T. Hayat, S. Zaib, S. Asghar, K. Bhattacharyya, S. A. Shehzad, Transient flows of Maxwell fluid with slip conditions, Appl. Math. Mech. Engl. Ed., 34 (2013) 153 - 166.

[2] M. Jamil, N. A. Khan: Helical flows of fractionalized Burgers' fluids, AIP Advances, 2 (2012) Article ID 012167.

[3] M. Jamil, First problem of Stokes' for generalized Burgers' fluids, ISRN Mathematical Physics, (2012) Article ID 831063.

[4] M. Jamil, A. A. Zafar, C. Fetecau, N. A. Khan, Exact analytic solutions for the flow of a generalized Burgers fluid induced by an accelerated shear stress , Chem Engg Comm, 199 (2012) 17 - 39.

[5] M. Jamil, A. Rauf, A. A. Zafar, N. A. Khan, New exact analytical solutions for first Stoke's problem of Maxwell fluid with fractional derivative approach, Comp. and Math with Appl., 62 (2011) 1013 - 1023.

[6] Khan, S. Asghar, T. Hayat, Hall effect on the pipe flow of a Burgers' fluid, Nonlinear Anal.: Real World Appl., 10 (2009) 974 - 979.

[7] M. Khan, R. Malik, Fetecau Corina, C. Fetecau, Exact solutions for the unsteady flow of a Burgers' fluid between two sidewalls perpendicular to the plate, Chem Eng Commun, 197 (2010) 1367 - 86.

[8] L. Zheng, F. Zhao, X. Zhang, Exact solutions for generalized Maxwell fluid flow due to oscillatory and constantly accelerating plate, Nonlinear Anal.: Real World Appl., 11 (2010) 3744 - 3751.

[9] M. Khan, M. Arshad, A. Anjum, On exact solutions of Stokes second problem for MHD Oldroyd-B fluid, Nucl Eng Des, 243 (2012) 20 - 32.

[10] M. Jamil, N. A. Khan, N. Shahid, Fractional MHD Oldroyd-B fluid over an oscillating plate, Thermal Science, 17 (2013) 997 - 1011.

[11] N. A. Khan, A. Ara, M. Jamil, A. Yildirim, Traveling wave solutions for MHD Aligned flow of a second grade fluid, A symmetry independent approach, J King Saud Uni Sc., 24 (2011) 63 - 67.

[12] L. Zheng, Y. Liu, X. Zhang, Exact solutions for MHD flow of generalized Oldroyd-B fluid due to an infinite accelerating plate, Mathematical and Computer Modelling, 54 (2011) 780 - 788.

[13] M. Khan, M. Arshad, A. Anjum, On exact solutions of Stokes second problem for MHD Oldroyd-B fluid, Nucl Eng Des, 243 (2012) 20 - 32.

[14] T. Hayat, S. Hina, The influence of wall properties on the MHD peristaltic flow of a Maxwell fluid with heat and mass transfer, Nonlinear Anal.: Real World Appl., 11 (2010) 3155 - 3169.

[15] T. Hayat, R. Sajjad, Z. Abbas, M. Sajid, A. A. Hendi, Radiation effects on MHD flow of Maxwell fluid in a channel with porous medium, Int. J. Heat and Mass Transfer, 54 (2011) 854 - 862.

[16] T. Hayat, C. Fetecau, Z. Abbas, N. Ali, Flow of a Maxwell fluid between two side walls due to a suddenly moved plate, Nonlinear Anal.: Real World Appl., 9 (2008) 2288 - 2295.

[17] V. Singh, S. Agarwal, MHD flow and Heat transfer for Maxwell fluid over an exponentially stretching sheet with variable thermal conductivity in porous medium, Thermal science, 18 (2014) 599 - 615.

[18] S. Shateyi , A new numerical approach to MHD flow of a Maxwell fluid past a vertical stretching sheet in the presence of thermophoresis and chemical reaction, Boundary Value Problems, (2013) 2013 - 196.

[19] M. Jamil, C. Fetecau, Starting solutions for the motion of a generalized Burgers' fluid between coaxial cylinders, Boundary Value Problem, 14 (2012) 1 - 15.

[20] L. Debnath, D. Bhatta, Integral Transforms and Their Applications, (Second Edition) (2007) Chapman & Hall/CRC.

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Bio-crude oil from microalgal biomass to produce environmentally friendly higher value fuels and chemical compounds

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Abstract
The importance of microalgae as the third generation biofuel feedstock has been realised in recent years due to its potentially high oil yield (20 times higher than that from land crops). It is an alternative to fossil fuels and will reduce CO_2 emissions helping to tackle global warming. Autotrophic microalgae species such as *Chlorella vulgaris*, can be cultivated in municipal wastewater on 350,000 acres of marginal lands in Pakistan with favourable climatic conditions; making this land useable to produce biofuels without competing with arable land. The wastewaters are rich in nutrients and these can be consumed for algal growth, improving the wastewater quality. The treated wastewater can be used for irrigational and industrial purposes, conserving the fresh water demand, while the algal biomass can be used as a feedstock to produce bio-energy. The potential of using *Chlorella vulgaris* wet biomass as a feedstock for hydrothermal liquefaction (HTL) was investigated. Processing was done in a sealed batch reactor at two temperatures, 200 and 350^{o}C in liquefaction water conditions at two holding times, 30 min and 60 min for each temperature. The highest bio-crude oil yields obtained were 0.064±0.007 and 0.273±0.015 (g/g of biomass) on a dry basis, measured at both reaction times, respectively, at a maximum temperature of 350^{o}C. The energy efficiency of the process at both experimental conditions were found to be 8.23% and 40.22% respectively. The measured nutrients in the aqueous phase were total nitrogen and total phosphorous of 4.58 mg/L and 333.07 mg/L for 30min reaction, while 2.28 mg/L and 795.80 mg/L were measured for 60 min treatment at the same temperature. The bio-oil had long chain fatty acids (C14-C18) which can be readily used in boilers and heavy engines and can be thermally upgraded to obtain gasoline, diesel and jet fuels.

Keywords
biofuels, microalgae, hydrothermal liquefaction, nutrients, energy recovery, *Chlorella vulgaris*
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1. Introduction

Due to the depletion of fossil fuel reserves and to comply with environmental degradation issues (Ali and Shaikh 2012) related to climate change and global warming (Xu *et al.* 2011), the importance of microalgae as a third generation biofuel feedstock has been realised. It has high oil productivity yield, up to 20 times the oil per area than vegetable seed crops, and they do not displace land for food crops. Microalgae are unicellular microscopic plants, heterotrophic or autotrophic photosynthesizing organisms (Bi and He 2013), with advantages over traditional feedstock in that many species are able to grow in salt (saline/coastal water) or wastewater (domestic/municipal /industrial wastewater) streams (Chen *et al.* 2013) and they are compatible for production of biofuels and co-products within bio-refineries. Ahmad *et al.*(2012) utilized the nutrients available in wastewater to grow microalgae as a feedstock for biodiesel production. Eutrophication of water bodies due to the discharge of wastewater rich in nutrients causes degradation of marine and aquatic ecosystems. Mixed algal species were investigated to uptake nutrients from wastewater, showing promising results. It was found that the maximum uptake of nitrate was 97% and phosphate was 93%. The potential of microalgae cultivation on uncultivated 350,000 acres of land with wastewater can make biofuel production commercially viable in Pakistan. Pakistan has suitable climatic conditions such as sunlight intensity (which is between 5.1-6.2 kWhr/square meter/day) which compares favourably for the requirements of microalgal growth via photosynthesis, which is 4.52 kWhr/square meter/day for its optimum growth conditions (Ali 2014). Furthermore, carbon dioxide emissions can be sequestrated to enhance microalgal growth and to meet the international commitments for global warning and climate change.

The fatty acid profile of microalgae lipids are similar to soybean vegetable oil and found to be a good candidate for biofuels production. The major challenges faced by the biofuel production facilities is the extraction of oil from wet microalgal paste with an economically viable method (Biller and Ross 2011). This issue can be addressed with thermochemical hydrothermal liquefaction treatment that can be applied to extract bio-oil and gaseous products directly from the wet algal paste with a high moisture content, a main advantage of this process is that it does not require feedstock drying. The process is important from the energy point of view as the energy consumption required by hydrothermal liquefaction (HTL) is very low compared to other processes (Shuping *et al.* 2010). The reaction involves obtaining low molecular weight liquid fuels from high molecular weight organic compounds, present in the biomass, at elevated temperatures and pressures, with or without a catalyst at different treatment times (Brown *et al.* 2010).

The resulting bio-crude oil with heating values varies between 30-40MJ/kg can be used as a burning fuel in boilers or upgraded and refined into higher value fuel products (Illinois 2014). Hydrothermal liquefaction can be conducted at subcritical and supercritical water conditions, however, it has been observed that the extraction of bio-crude oil from algae at supercritical conditions is less effective and its quality is poorer than that extracted at subcritical water conditions (Toor *et al.* 2013). As the reaction temperature increases the unstable fatty acids undergo various reactions to form a wide range of useful chemicals. The major chemical obtained in the bio-crude oil is glycerol, derived from the rapid hydrolysis of less stable fatty acids. Increased amounts of alkanes were detected in bio-crude oil samples above the reaction temperature of 310^{o}C and further increase in temperature decomposed the alkanes into gaseous products such as: carbon dioxide, carbon monoxide and methane. The bio-crude oil and the gaseous products from liquefaction capture as much as 90% energy content of the microalgal feedstock. An additional benefit of hydrothermal liquefaction routes is the potential to recycle process water which can be fed back into the algal cultivation system because it is rich in essential nutrients such as nitrogen, phosphorous and potassium required for microalgal growth (Biller *et al.* 2012). It is interesting to note that the rigid wall of microalgae might play an important role in protecting the protein present during hydrothermal liquefaction. This results in the highly nutritional solid residue, rich in nitrogen and minerals but low in carbon, can be utilised as an animal feed (Toor *et al.* 2013), fertilizer or bio-char (Biller *et al.* 2012). The extracted lipids (fats) fatty acids profile is an indicator of the physical and chemical properties of the microalgae derived biofuel (Ali and Watson 2015). The bio-crude oil from microalgae showed a fatty acids profile mainly constituents

(44.9% GC-MS peak area) long chain fatty acids (C14-C18), which can be easily converted into hydrocarbon fuels (Du *et al.* 2012).

This research investigation provides information about using microalgae biomass under different hydrothermal conditions to extract bio-crude oil as a source of alternative fuels. The hydrothermal liquefaction reactions were conducted at two different temperatures (200 and 350^oC) with two treatment holding times 30min and 60min to investigate its bio-crude oil yields and its compositional fatty acids properties to convert it into hydrocarbon fuels. The aqueous phase and the solid phase after the reaction were also analysed in terms of recovery of valuable products. The energy recovery of the process was calculated to look for its energy viability at the two holding times at 350^oC.

2. Materials and methods

C*hlorella vulgaris* was procured from a commercial source (Wholefoods, UK) with a bio-chemical composition of protein 57.20%, carbohydrates 11.20% and lipids 8.70%. All the experiments were conducted at a room temperature of 24 ± 1^oC and at a relative humidity of 50%, measured with a humidity temperature meter (Model: 1365, RS Components, UK). The experimental work was conducted at the School of Engineering, University of Glasgow, Glasgow, UK.

2.1 Moisture content measurement of biomass and algal slurry

The initial moisture content (on % dry basis) of dried powdered microalgae biomass and prepared algal slurry for HTL experiments were measured by weighing the initial and the final weight of 1g samples after heating at 110^oC for 1hr in an oven (Model: KWS-1525R-F2U, Cook Works Signature, UK) and weighing with analytical scales (Model: AS120, Ohaus Corp., USA).

2.2. Hydrothermal liquefaction protocol

Hydrothermal liquefaction was carried out in an unstirred batch reactor (25mL, Parr, USA) and charged with 1g of powdered microalgae sample and 9 mL of distilled water (Biller and Ross 2011) at a pressure ~ 200bar in water. An algal slurry was prepared by mixing vigorously. Then the algal slurry was sealed in the reactor chamber and introduced into a muffle furnace (Model: 1294, Pyro-Therm Furnace Manufacturers, UK), until the desired treatment temperature was reached. The furnace heating rate was measured as 15^oC/min. Following the liquefaction reaction, the reactor was taken out from the furnace and allowed to cool down at room temperature for 3hrs. Then the reactor vessel was opened and the reaction mixture was transferred into a 50mL centrifuge tube (Eppendorf, UK). The reactor was rinsed with dichloromethane (DCM) to clean its surfaces because most of the oil was stuck to the reactor walls. Then it was washed with distilled water and cleaned. Both DCM and distilled water (1:1) each with a volume 16.66 mL, were added to the reaction mixture. The centrifuge tube was shaken vigorously for 30s by hand and then centrifuged with a lab centrifuge (Model: 5810, Effendorf, UK) for 3min at 3000rpm (1811G). The lower layer with bio-crude oil with DCM was pipetted out and the DCM was evaporated at its boiling point, 40^oC in a Techne sample concentrator (Model: DB-3, Bibby Scientific Ltd, UK) for 1 hr and then the bio-crude oil weight was determined. The bio-crude oil yield (g/ g dry microalgae biomass) was measured (on % dry basis) with the following equation:

Bio-crude oil yield = Mass of bio-crude oil with the container – Mass of an empty container **(Eq.1)**

Where the mass of the bio-oil recovered and mass of the empty container were measured in grams. The upper aqueous layer and the residue solids were collected separately for further analysis. The residue solid recovered was dried in an incubator (Model: PIN-120, Carbolite Ltd., UK) for 3 hrs and then the difference between the weights of the solid biomass before and after drying operation gave its % dry weight.

2.3. Bio-oil GC-MS compositional analysis

The GC-MS analysis of the extracted bio-crude oil was conducted at the School of Geographical and Earth Sciences, University of Glasgow, UK. The GC-MS analyser (QP 2010 Plus, Shimadzu, Japan) was used to identify compounds at different treatment temperatures with two treatment times.

2.4. Higher heating value (HHV) of bio-oil

The higher heating value of the extracted bio-crude oil at 350^{o}C for 30min and 60min samples were measured with an oxygen bomb calorimeter (Model 1341, Parr, USA) according to ASTM D2015, as per previous research work (Ali and Watson 2014).

2.5. Determination of total nitrogen and total phosphorus in a reaction water

The aqueous phase after reaction was collected and centrifuged again for 3 min at 3000 rpm to remove any solid matter present in it for the determination of total nitrogen (TN) and total phosphorus (TP). The total nitrogen (TN) and total phosphorus (TP) detection was conducted at the Civil and Environmental Engineering Laboratory, University of Strathclyde, Glasgow, UK with an Ion chromatography system (Metrohm 850/858, Cheshire, UK) as per the protocol (De Borba *et al.* 2014).

2.6. Elemental analysis and higher heating value (HHV) of bio-char

The elemental compositional analysis was conducted with an analytical elemental analyser (CE-440, Exeter Limited, UK) at the School of Chemistry, University of Glasgow, UK. The % content of carbon, hydrogen and nitrogen was used to calculate the HHV (MJ/kg) of the bio-char obtained at different experimental conditions with the help of the equation (Friedl *et al.* 2005):

$$HHV = 3.55\,C^2 - 232\,C - 2230\,H + 51.2\,(C \times H) + 131\,N + 20600 \qquad \textbf{(Eq. 2)}$$

2.7 Energy recovery of the process

The energy balance of the hydrothermal liquefaction process was calculated at two treatment times with maximum bio-crude oil yield at 350^{o}C for comparisons with the following equation (Biller and Ross 2011):

$$\text{Energy recovery (\%)} = (\text{HHV of bio-crude} \times \text{mass of bio-crude} / \text{HHV of feed} \times \text{mass of feed}) \times 100\% \qquad \textbf{(Eq. 3)}$$

Where the HHV values of bio-crude and feed are in MJ/kg and the mass of bio-crude oil and feed are in grams.

3. Results and discussions

3.1 Bio-crude oil yields and its higher heating values

The moisture content of the dried microalgae powder was found to be 8.528 ± 0.552 (mean ± standard deviation, n=3), while the algal slurry moisture content was 90.196%. The reaction products are depicted in **Figure 1**, the recovered bio-char, bio-crude oil with DCM solvent and the light yellow aqueous phase can be compared to the original algal slurry, dark green colour.

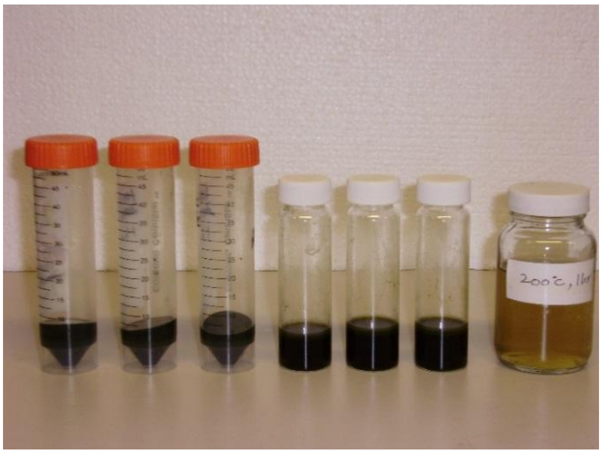

Figure 1: showing (from left to right) the bio-char (3 samples), bio-crude oil (3 samples) and the aqueous reaction phase (extreme right).

Table 1, shows the bio-crude oil extraction yields presented as mean ± standard deviation (n=3), it was found that the highest yields were 0.064 ± 0.007 and 0.273 ± 0.015 g/g biomass at 350^{o}C with both treatment times, 30 and 60 mins respectively. In contrast to the lipid yields of 0.014 ± 0.001 and 0.037 ± 0.002 g/g biomass at 200^{o}C at 30 and 60 respectively. The extracted bio-crude oil had a high viscosity and was like tar. The retention time is also an important factor in bio-crude oil yield, which allows complete reaction with higher bio-crude oil yields. According to previous research (Biller *et al.* 2012), the bio-crude yield was low at 350^{o}C (35.8% by weight) as compared to 330^{o}C reaction temperature (46.6% by weight), here forced cooling of the reactor was achieved via compressed air, blowing at approximately 20^{o}C/min. But in the present case, the reactor was allowed to cool down to room temperature in 3hrs. The improved yield with treatment time is due to more time for the reaction mixture to interact, converting the organic matter into more bio-crude. Similarly, the increase in temperature results in higher pressure, which improves the solvent density and solubility of the target biomass, allowing the solvent to diffuse (following Fick's Law) more efficiently into the biomass molecular structure, thus enhancing the extent of biomass decomposition and fragmentation (Chan *et al.* 2015). The higher heating values (HHV) of the extracted bio-crude oil were found to be 26.40 MJ/kg and 30.24 MJ/kg at 350^{o}C for retention times 30 min and 60 min respectively. The HHV obtained at 350^{o}C for 60min holding time was found similar with previous literature (Shuping *et al.* 2010).

Table 1: Bio-crude oil yield with respect to HTL

Time (min)	Temperature (^{o}C)	Bio-crude oil yield (g/g)	Bio-char yield (g/g)
30	200	0.014 ± 0.010	0.751 ± 0.015
	350	0.064 ± 0.007	0.559 ± 0.062
60	200	0.030 ± 0.002	0.724 ± 0.035
	350	0.273 ± 0.015	0.130 ± 0.002

3.2 GC-MS analysis

Figures 2 and **Figure 3** show the comparison of GC-MS chromatographs of the bio-crude oil extracted with hydrothermal liquefaction processing at 350^{o}C with 30min and 60min holding times. The results showed the presence of octanoic acid, decanoic acid, tetradecanoic acid (myristic acid), palmitic acid, linolenic acid and octadecanoic acid (stearic acid) in both samples. The composition of the bio-crude includes fatty acids (C14 - C18) which can be readily converted into hydrocarbon fuels (Du *et al.* 2012).

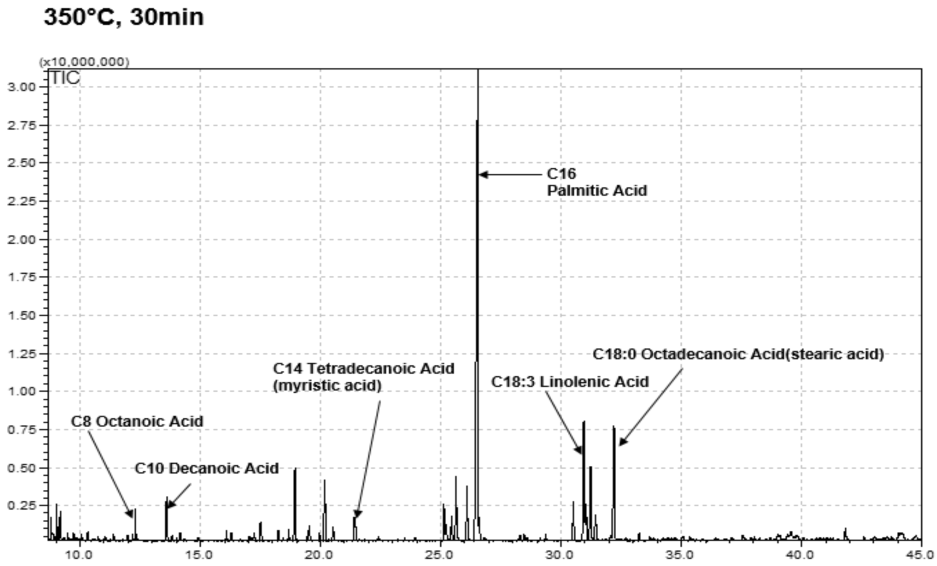

Figure 2: GC-MS chromatogram of bio-crude oil at 350°C with 30min retention time.

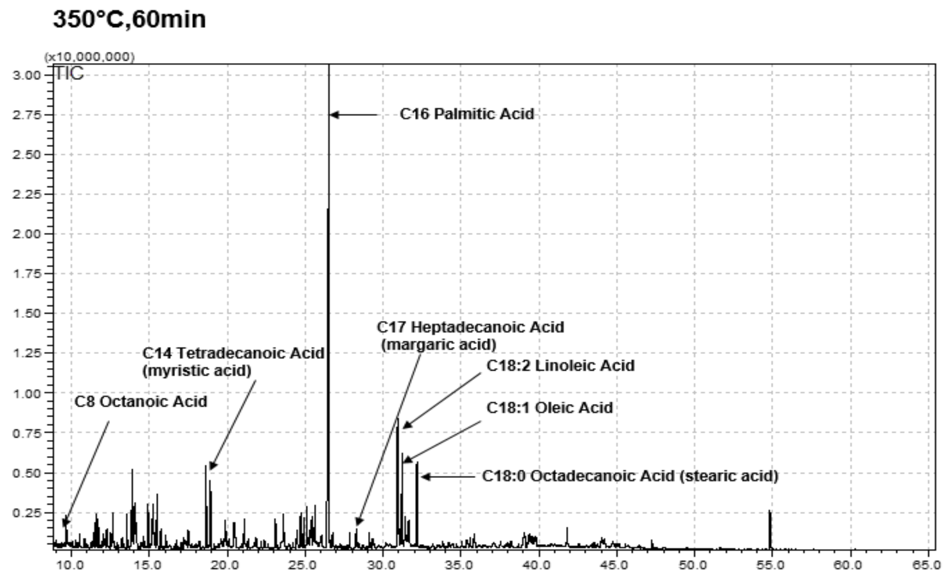

Figure 3: GC-MS chromatogram of bio-crude oil at 350°C with 60min retention time.

3.3 Results of total nitrogen and total phosphorus

Table 2, shows the total nitrogen and total phosphorus results at both holding times (30min and 60min) with two temperature conditions. The presence of nitrogen and phosphorus compounds might be in the form of K, NH_4^+, acetate, PO_4^{3-} and it looks promising that nutrients can be recycled for microalgae growth, lack of nutrients is one of the main economic constraints for microalgal biofuel production. All algae strains that are able to grow in recycled process water show heavy dilution of the water phase is necessary to avoid the effects of growth inhibitors such as phenol, fatty acids and nickel (Biller *et al.* 2012).

Table 2: HTL aqueous phase analysis results.

Time (min)	Temperature (°C)	TN (mg/L)	TP (mg/L)
30	200	3.68	431.21
	350	4.58	333.07
60	200	4.58	362.44

	350	2.28	795.80

3.4 Bio-char analysis

Chlorella vulgaris feedstock compositional analysis was 48.19% carbon, 6.88% hydrogen and 9.42% nitrogen, its higher heating value was calculated as 20.53 MJ/kg. The bio-char elemental composition and the HHV results are presented in **Table 3.** The results showed decreases in the carbon and hydrogen content with respect to increasing treatment temperature at both holding times due to the recovery of bio-crude oil from the biomass. The amount of carbon and hydrogen reduces with increasing temperatures in HTL processing and the results are in accordance with the literature (Toor *et al.* 2013). This results in a decrease in the HHV values with corresponding increase in temperature (Toor *et al.* 2013).

Table 3: Bio-char elemental composition and its calculated HHV values

Time (min)	Temperature (^{o}C)	Elemental composition (%)			HHV
		C	H	N	(MJ/kg)
30	200	46.2	5.94	9.53	19.512
	350	42.5	4.06	9.83	18.221
60	200	45.95	5.79	9.62	18.841
	350	42.32	3.35	8.40	17.825

3.5 Energy balance

The energy balance of the HTL processing at 350^{o}C for both treatment times was calculated with Equation 3 and compared. The equation takes into account the amount of bio-crude oil and the feedstock with their respective HHV values and the results were 8.23% and 40.22% respectively. The results show a higher energy ratio with 60min treatment at 350^{o}C as compared to the 30min treatment at the same temperature.

4. Conclusions

This work indicates that the bio-crude oil yield was higher with 60min treatment as compared to 30min. The extracted bio-crude oil has free fatty acids that are desirable for production of hydrocarbon fuels with further bio-refining. The bio-crude oil HHV was 30.248MJ/kg, showing a 28.5% lower value as compared to petroleum crude oil HHV value 42MJ/kg. The total nitrogen and total phosphorus showed promising results for recycling the aqueous phase for cultivating microalgae. The residue bio-char from HTL processing can be used to produce biogas by anaerobic digestion, with HHV values comparable to the bio-char from wood (25MJ/kg). It can also be used as a soil conditioner or a building material with low thermal conductivity properties. Microalgal biomass can be converted into bio-crude oil for multiple fuel production such as: jet fuels, biodiesel, bioethanol, and hydrogen gas.

5. References

Ahmad, F., A. U. Khan and A. Yasar (2012). " Uptake of Nutrients from Municipal Wastewater and Biodiesel Production by Mixed Algae Culture." Pakistan Journal of Nutrition **11**(7): 648-652.
Ali, M. (2014). "Microalgae magic: Small wonder." from

http://tribune.com.pk/story/717814/microalgae-magic-small-wonder/.
Ali, M. and A. A. Shaikh (2012). "Emission Testing of Jatropha and Pongamia Mixed Biodiesel Fuel in a Diesel Engine." NED University Journal of Research Thematic Issue on Energy: 43-52
Ali, M. and I. A. Watson (2014). "Comparison of oil extraction methods, energy analysis and biodiesel production from flax seeds." International Journal of Energy Research **38**(5): 614-625.
Ali, M. and I. A. Watson (2015). "Microwave treatment of wet algal paste for enhanced solvent extraction of lipids for biodiesel production." Renewable Energy **76**(0): 470-477.
Bi, Z. and B. He (2013). "Characterization of microalgae for the purpose of biofuel production." Trans. ASABE **56**(4): 1529-1539.
Biller, P. and A. B. Ross (2011). "Potential yields and properties of oil from the hydrothermal liquefaction of microalgae with different biochemical content." Bioresource Technology **102**(1): 215-225.
Biller, P., A. B. Ross, S. C. Skill, A. Lea-Langton, B. Balasundaram, C. Hall, R. Riley and C. A. Llewellyn (2012). "Nutrient recycling of aqueous phase for microalgae cultivation from the hydrothermal liquefaction process." Algal Research **1**(1): 70-76.
Brown, T. M., P. Duan and P. E. Savage (2010). "Hydrothermal Liquefaction and Gasification of Nannochloropsis sp." Energy Fuels **24**: 3439-3646.
Chan, Y. H., S. Yusup, A. T. Quitain, R. R. Tan, M. Sasaki, H. L. Lam and Y. Uemura (2015). "Effect of process parameters on hydrothermal liquefaction of oil palm biomass for bio-oil production and its life cycle assessment." Energy Conversion and Management(0).
Chen, C.-Y., X.-Q. Zhao, H.-W. Yen, S.-H. Ho, C.-L. Cheng, D.-J. Lee, F.-W. Bai and J.-S. Chang (2013). "Microalgae-based carbohydrates for biofuel production." Biochemical Engineering Journal **78**(0): 1-10.
De Borba, B. M., R. F. Jack, J. S. Rohrer, J. Wirt and D. Wang (2014). "Simultaneous determination of total nitrogen and total phosphorus in environmental waters using alkaline persulfate digestion and ion chromatography." Journal of Chromatography A **1369**(0): 131-137.
Du, Z., Michael Mohr, Xiaochen Ma, Yanling Cheng, Xiangyang Lin, Yuhuan Liu, Wenguang Zhou, Paul Chen and R. Ruan (2012). "Hydrothermal pretreatment of microalgae for production of pyrolytic bio-oil with a low nitrogen content." Bioresource Technology **120**(0): 13-18.
Du, Z., M. Mohr, X. Ma, Y. Cheng, X. Lin, Y. Liu, W. Zhou, P. Chen and R. Ruan (2012). "Hydrothermal pretreatment of microalgae for production of pyrolytic bio-oil with a low nitrogen content." Bioresource Technology **120**(0): 13-18.
Friedl, A., E. Padouvas, H. Rotter and K. Varmuza (2005). "Prediction of heating values of biomass fuel from elemental composition." Analytica Chimica Acta **544**(1–2): 191-198.
Illinois, U. O. (2014). "Illini Algae- hydrothermal liquefaction (waste biomass to bioenergy conversion)." June 2014, from http://algae.illinois.edu/projects/Hydrothermal.html.
Shuping, Z., W. Yulong, Y. Mingde, I. Kaleem, L. Chun and J. Tong (2010). "Production and characterization of bio-oil from hydrothermal liquefaction of microalgae Dunaliella tertiolecta cake." Energy **35**(12): 5406-5411.
Toor, S. S., H. Reddy, S. Deng, J. Hoffmann, D. Spangsmark, L. B. Madsen, J. B. Holm-Nielsen and L. A. Rosendahl (2013). "Hydrothermal liquefaction of Spirulina and Nannochloropsis salina subcritical and supercritical water conditions." Bioresource Technology **131**(0): 413-419.
Xu, Y., X. Hu, W. Li and Y. Shi (2011). Preparation and Characterization of Bio-oil from Biomass, 1st edition, InTech, Croatia.

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Hydrological Trends and Variability in the Mangla Watershed

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Abstract

Pakistan's economy is based on agriculture that is highly dependent on water resources originating in the mountain sources of the Upper Indus. The aims of this study are to detect trends, variability analysis and assessment of changes in minimum (low), mean and maximum (high) flows in Mangla Basin, Pakistan. Trend analyses are performed by applying Mann-Kendall, non-parametric test. Sen's method was applied to estimate slope time series that indicates changes in river flows. The influence of serial correlation was eliminated from time series by applying the trend-free pre-whitening (TFPW) method prior to the trend analysis. Results of this study revealed that trends were more common in mean and low flows compared to high flows. Statistically significant increasing and decreasing trends are noticed in different parts of Mangla watershed. The annual minimum flow at the outlet of Mangla watershed has decreased whereas mean and maximum flow has increased.

Keyword: Upper Indus Basin; climate change; trends; streamflows

1 Introduction

Pakistan's economy is based on agriculture that is highly dependent on Indus Basin Irrigation system (IBIS). The Indus Basin Irrigation System serves an area of 22.2 million hectares and irrigated land accounts for 85% of all crop/food production (Khan et al., 2002). Pakistan has three major reservoirs (Tarbela, Mangla and Chasma), which have original storage capacity of 19.43 BM^3. The Mangla reservoir has original storage capacity 6.6 BM^3 (34% of total storage) and installed capacity of 1000 MW (WRM, 2008). Its command area is about 6 million hectares (60 BM^2). The total population of Pakistan is about 180 million having a growth rate 2 % annually (PCO, 2012). Being an agricultural country with heavy population growth, there is a great stress on water resources to meet the food and fiber requirement for the people. The per capita water availability is declining over time due to combined impact of rising population, falling water flow and reduction in the storage reservoirs capacities in Pakistan. The per capita water availability is declining from 5650 m^3 in 1951, 1700 m^3 in 1992, 1400 m^3 in 2000 and 1000 m^3 in 2012 (GOP, 2007).

According to Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2008), the global average surface temperature has increased by 0.074°C (± 0.018°C) and 0.13°C (± 0.03°C) per decade over the past 100 years (1906–2005) and 50 (1956-2005) years respectively. Since 1981, the rate of warming is faster, with a value of approximately 0.177 °C (±0.052°C) per decade. The linear trend for the global average precipitation from Global Historical Climatology Network (GHCN) during 1901–2005 observed that precipitation over land generally has increased over the 20th century between 30°N and 85°N. From 10°N to 30°N, precipitation has increased markedly from 1900 to the 1950s, but has declined after about 1970. Parker and Horton, (1999); IPCC (2001) and Jones and Moberg (2003) indicate large-scale warming of the Earth's surface over the last hundred years or so. Such warming affects global circulation patterns as often simulated and predicted by use of general circulation models (GCM) but also directly affects local climatic settings with changes in distribution and characteristics of precipitation and temperature. Hydrological impacts by climate change may significant affect water resources and may cause changes in the hydrological cycle (Bates et al., 2008). The frequency and severity of drought events could increase as a result of changes in both precipitation and evapotranspiration. Changes in hydrologic regime that do occur are not expected to be equally distributed throughout the year. For example, increased temperatures in the winter are expected to lead to earlier snowmelt events and a shift in runoff from the spring to late winter with a corresponding decrease in runoff in the summer period. Changes in climate and related hydrological impacts vary in space and time domains as affected by local climatological and topographic settings. In this study we explore hydrological trends and variability for the Mangla basin resulting from climate variability.

Streamflow (also called river flow) varies over space and time. The temporal scale ranges from minutes (e.g. in the case of flash floods) to decades (e.g. in the case of water resource assessments). River flow regimes describe the temporal patterns of flow variability. Knowledge about changing river flow regimes is vital for assessing climate change risks related to freshwater. Estimation of changes in seasonality, inter-annual variability, statistical low, mean and high flows, and floods and droughts is required to understand the impact of climate change on humans and freshwater ecosystems. River flow regime alterations affect humans with respect to water supply, navigation, hydropower generation and flooding, and they affect ecosystems with respect to habitat suitability for freshwater-dependent biota.

Most studies in the UIB (i.e. the Northern part of Indus basin) are performed for very high elevated catchments such as the Chitral, Hunza and Shyok with focus on aspects of glacier melt. In lower areas on the southern Himalayan slopes a warm monsoon climate exists with much precipitation in the form of rainfall in the summer season (Archer, 2004). Therefore the hydrological regime differs from the higher elevated areas but also changes in the climate are dissimilar to changes at high elevated areas (Khattak et

al., 2010). Assessments on hydrological impacts in the southern slopes of the Himalayas are not frequent although these slope areas cover a major part of the Indus River runoff source area. This aspect is one of the main reasons why we selected Mangla basin with elevation range between 300 and 6500 m.a.s.l. We note that Mangla basin is one of the major source areas of the Indus Basin Irrigation System (IBIS). Runoff from the watershed serves hydro power generation at Mangla reservoir and agricultural production, industry and urban development in the downstream area of Upper Indus River (UIR).
Therefore, quantitative estimates of hydrologic effects of climate change are essential for understanding and analyzing the potential water resources issues associated with water supply for domestic and industrial water use, power generation, and agriculture as well as for future water resource planning, reservoir design and management, and protection of the natural environment. The results of this study will also be helpful for decision makers to develop the strategies for planning and development of water resources under different climatic scenarios to overcome their adverse impact.
In Sections 2 and 3 we describe the study area and all data available for this study, respectively. Section 4 describes the methodology and statistical analysis performed. Results of this study are presented and discussed in Section 5. In Section 6 conclusions are drawn.

2 Study Area

Mangla basin is located between latitudes 33° 00 to $35^{\circ}12'$ N and longitudes 73° $07'$ to $75^{\circ}40'$ E with elevation ranging from 300 m to 6260 m above mean sea level (a.m.s.l.). The basin is located on the southern slope of the Himalayas and has basin area of 33425 km^2 at Mangla dam. This dam serves hydropower generation and regulates the flow from Mangla reservoir at 300m a.m.s.l. About 55% of the area lies in Indian held Kashmir and 45% lies in Pakistan including Azad Kashmir. There are five subbasins i.e. Jhelum, Poonch, Kanshi, Neelum/Kishan Ganga and Kunhar which all drain water to Mangla reservoir (Fig 1.). The river Jhelum originates from Verinag Spring situated in southern slopes of the Himalaya mountain ranges and in foot of the Pir Panjal Ranges in Jammu and Kashmir. Large tributaries to Jhelum River are Neelum River and Kunhar River that join the main stream at Muzaffarabad and Kohala Bridge, respectively (Fig. 1). The flow of Jhelum River enters Mangla reservoir in the district of Mirpur. Flows from Poonch and Kanshi Rivers also enter into Mangla reservoir. In the South-East, Mangla basin borders India and Pakistan. Although monsoon precipitation affects the lower part of the basin, runoff by melt water from glaciers and winter snowfall makes a significant contribution to river flow during the summer season.

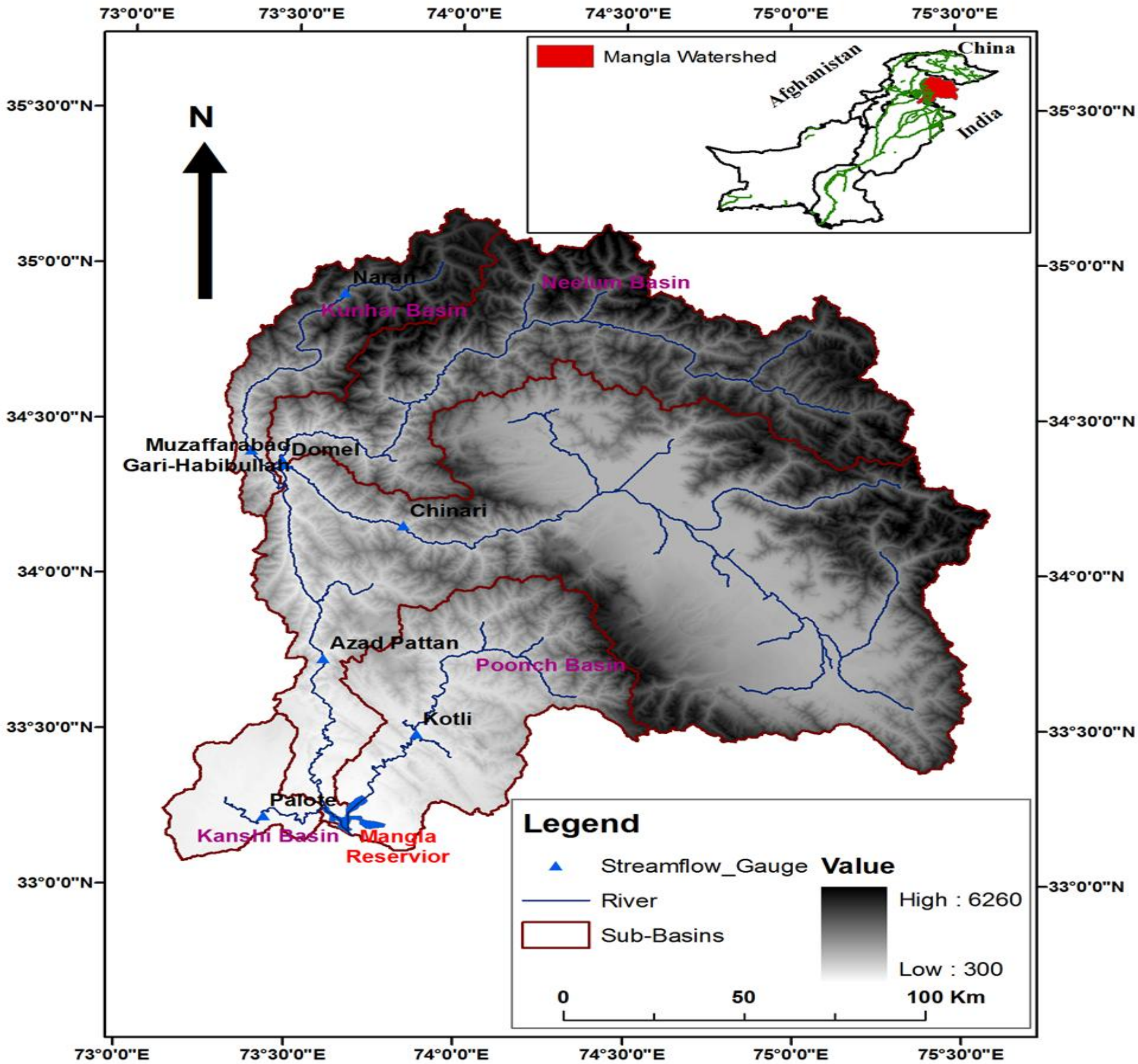

Figure 1: Digital elevation model of Mangla basin showing major subbasins, and streamflow gauges (Table 1).

3 Data Availability

Streamflow measurements (Q_{st}) at daily base for 9 gauging stations were made available by the Water and Power Development Authority Surface Water Hydrology Project (WAPDA-SWHP) with earliest records dating back to 1960. Streamflow gauges are installed in all five subbasins. From these gauges, we selected nine gauges that are Naran and Garhi-Habibullah (now Talhata Bridge) in Kunhar River, Chinari (Now Hattian Bala), Domel, Kohala and Azad Pattan in Jhelum River that cover largest areas in Mangla basin (Fig 1) in Pakistan but also in India.

Streamflow discharges of the relatively small subbasins Neelum, Kanshi and Poonch are measured at Muzaffarabad, Palote and Kotli respectively. Characteristics of selected gauging sites are given in Table 1. The annual runoff at Azad Pattan just upstream of Mangla reservoir is 1014 mm (833 cumec) and varies between 680 and 720 mm (296 and 327cumec) for Jhelum above the Neelum confluence. The annual runoff for Neelum and Kunhar varies from 1422 to 1760 mm (260 to 333 cumec) and 1320 to 1340 mm (47 to 102 cumec) before joining the River Jhelum. The annual percentage contribution of three tributaries to total flow before their confluence at Kohala is 45%, 43% and 13% for Jhelum, Neelum and Kunhar respectively. The total annual runoff of all four tributaries (Kunhar, Neelum, Pooch and Kanshi) and main River Jhelum at reservoir is 967 cumec. The percentage of flows at dam site is 10%, 34%, 13%, 1% and 41% for River Kunhar, Neelum, Poonch, Kanshi and Jhelum respectively. The river Kunhar, Neelum and Jhelum (at Azad Pattan) has the peak flows in June whereas other Rivers Kanshi and Poonch have in August.

Table 1: List of stream gauges used in the present study and their characteristics.

Sr.No.	Stream Gauges	Lat	Lon	River	Area	Mean Annual		
		dd	dd		km^2	Min.	Mean	Max.
1	Naran	34.9	73.7	Kunhar	1085	6.1	47	233
2	G-Habibullah	34.4	73.4	Kunhar	2379	19	103	445
3	Muzaffarabad	34.4	73.5	Neelum	7412	47	333	1394
4	Chinari	34.2	73.8	Jhelum	13652	51	297	942
5	Domel	34.4	73.5	Jhelum	14396	58	328	1172
6	Kohala	34.1	73.5	Jhelum	24464	145	785	2737
7	Azad Pattan	33.7	73.6	Jhelum	25967	155	1231	3041
8	Kotli	33.5	73.9	Poonch	3210	19	126	1760
9	Palote	33.2	73.4	Kanshi	1078	0.2	5.8	318

4 Tests for Trend Detection and Estimation of Slope

The purpose of trend testing is to determine if the values of a random variable generally increase or decrease over some period of time in statistical terms (Haan, 1977). Parametric or Non-parametric statistical tests can be used to decide whether there is a statistically significant trend.

The analysis was carried out for the time series of the regional averages; these steps essentially involve: (i) testing the serial correlation effect; (ii) Trend detection by applying the Mann–Kendall test, spearman test and linear trend methods; (iii) Estimate the trend value by applying Sen's estimator

Non-parametric tests are widely used in trend analysis of climatic and hydrological data, which are robust with respect to missing values. The times series of all the meteorological variables were analysed using the Mann-Kendall non-parametric test for trend. Mann originally used this test and Kendall subsequently derived the test statistic distribution (Kendall, 1975). The Mann-Kendall test is a non-parametric test for identifying trends in time series data. This test was found to be an excellent tool for trend detection. One of the reasons to use this test is that the data does not require conformation to any particular distribution. The time series were pre-whitened to eliminate the effect of serial correlation before applying the Mann–Kendall test using the trend free pre-whitening technique (TFPW). The slope (change per unit time) was estimated by using a simple nonparametric procedure developed by Sen (1968). All three analyses are common to detect trends in time series and reference is made to studies by Tabari et al. 2012, Caloiero et al. 2011, Mavromatis and Stathis, 2011, Bhutiyani, 2007, Rio del et al. 2005

5 RESULTS ANDDISCUSSION

The variability analysis and changes in streamflow in various stream gauges which are installed in stream network of Mangla basin, Pakistan at different locations were found over the period 1971-2010. The analysis was perfomed on annual and seasonal (three months) times series. The number of stations with increasing and decreasing trends as well as significant trends in annual and seasonal times series are shown in Figures (2f, 3f & 4f). To examine the spatial consisttency of the observed trends, maps were created displaying the locations of stream gauges in all four subbasins (Kunhar, Neelum, kanshi and Poonch) with decreasing and increrasing trends. The spatial distribution of trends and changes in annual and seasonal minimum, mean and maximum streamflow are shown in Figures 2, 3 and 4 respectively.

Table 2: The variation interval of statistical parameters for annual time series.

Variables	**Mean (cumec)**	**Standard Deviation (SD)**	**Coefficient of variation (CV) %**	**Kurtosis**	**Skewness**
Minimum Flow	0.0….155	0.3…35	20…89	-1.0…8.9	-0.5…2.5
Mean Flow	6….1231	3….341	19…49	-0.9…1.9	-0.5…0.9
Maximum Flow	233….3041	75…1776	0.33…0.87	0.1….19	0.7…4.0

5.1 Variability in minimum (low) flows

The variation intervals of the statistics for the annual minimum flows of the selected stations are presented in Table 2. The mean annual minimum flow varies from 0.3 to 156 cumec. The coefficient of variation, CV changes between 20 and 1.1 whereas the skewness has a minimum –2.1 and a maximum 2.6. The annual minimum flows have decreasing trends at 67% of stations. MK and Sen's slope estimator depicts that minimum flow has decreased significantly ($p<0.01$) in Neelum basin at Muzaffarabad upto 9% of mean annual low (46 cumec) for period 1971-2010 and has also decreased 4% in Jhelum basin at Azad Pattan but non-significant. The Kanshi basin has significant increasing flow with the rate of 39% whereas the Poonch and Kunhar basin at Gari-Habibullah have also non-significant increasing trend with the 3% and 13% respectively. The highest decreasing trend was found at Naran in Kunhar basin with the rate of 67% per decade of mean annual minimum flow.

Winter season has the lowest minimum flow as compared to other seasons. Minimum flow in this season has increased at 5 stations (out of 9) in Jhelum basin. Streamflow in Poonch, Kunhar at Gar-Habibullah, Neelum and Jhelum at Azad Pattan Rivers have significantly ($p<0.05$) increased upto 15%, 11%, 1% and 2% of mean winter minimum flow respectively. Chinari has significant ($p=0.1$) decreasing trend. The flows in spring have the same behavior of trend as was in winter flows. Neelum and Kunhar basin have significant decreasing trends whereas Jhelum

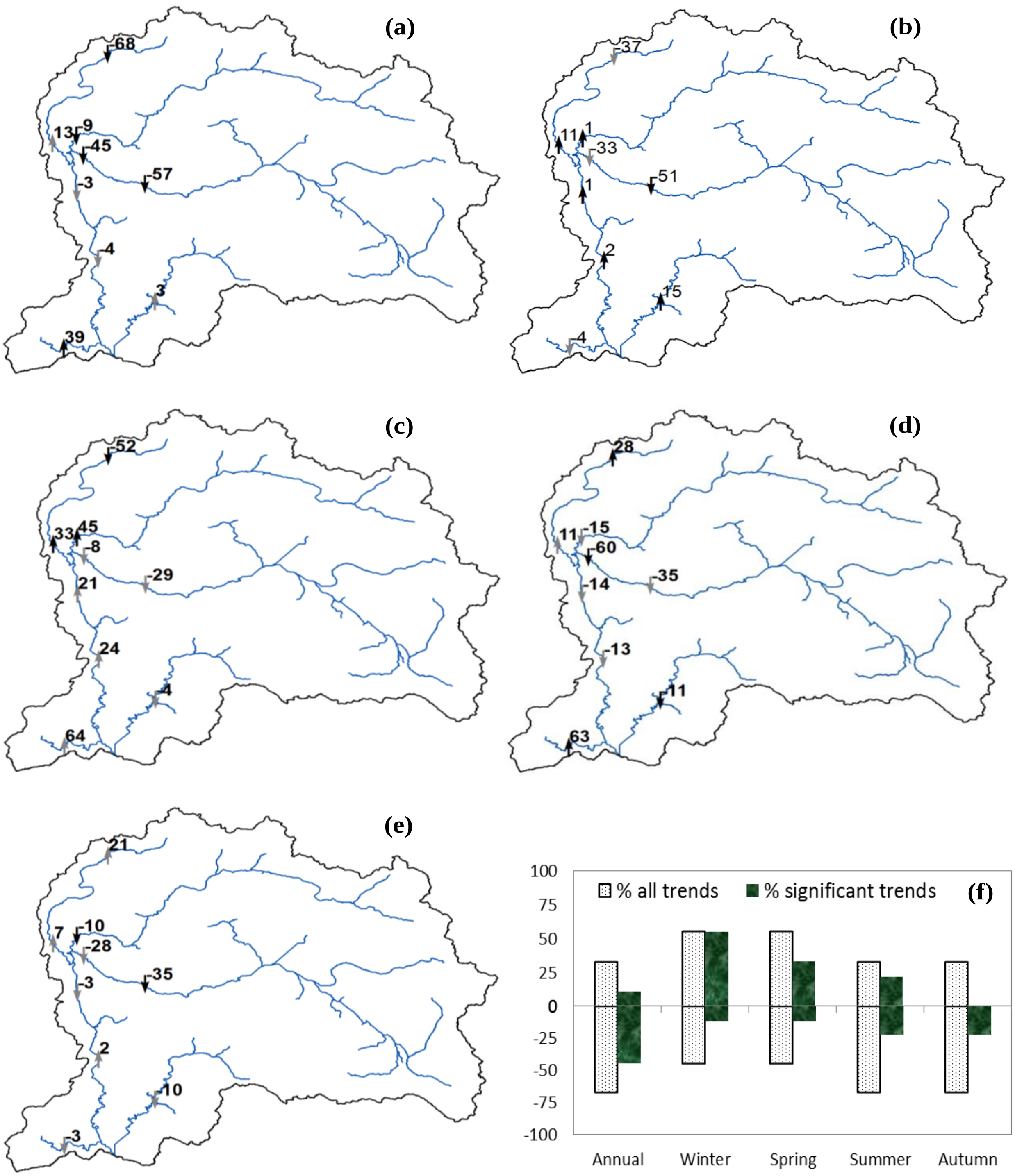

Figure 2: Spatial distribution of trends detected by Mann-Kendal and trend values estimated by Sen's method showing change in % decade^{-1} of minimum streamflows in: (a) annual, (b) winter, (c) spring, (d) summer, (e) autumn, and (f) % all and significant trends. (Upward and downward arrow shows positive and negative trends respectively, bold arrow shows significant trends at α=0.1).

and Kanshi Rivers have non-significant decreasing trends. Poonch basin has the increasing trend (non-significant). The minimum flow in summer has significant ($p<0.05$) decreasing trend at outlets of Poonch basins and also in Jhelum and Neelum basins have non-significant decreasing trends. Kanshi and Kunhar at Naran have significant increasing trends. In autumn season only two stations have significant decreasing trends.

5.2 Variability in mean flows

Trend analysis with the MK test displayed trend existence in mean annual flow at 4 flow stations for the perio1971-2010. The stations with trend are plotted in Fig. 3. The mean flow have more decreasing trends. The decreasing trends in annual mean flows were found at 78 % (33% significant) of stations. The annual mean flow in Jhelum basin at Azad Pattan has increasing trend with rate of 0.2 mm/year (1% of data period mean). Jhelum River at Kohala has significant ($p=0.1$) decreasing trend with the rate of 7%. The other three tributaries (Neelum, Kanshi and Poonch) of this basin have negative trends (changes in flow are given in Fig.3) whereas forth tributary Kunhar has the only significant positive trend at Gari-habibullah.

Winter mean flow at all rivers has increasing trends. The significant increasing trends were found in River Neelum, Kanshi and Jhelum at Kohala with the rate of 11%, 1% and 22% per decade of mean winter flow. Kunhar River at Naran has significant trend with the rate of 27% and Jhelum River at Chinari and Domel has also increasing non-significant trend. The mean flow for spring months has only significant increasing trends were found in Jhelum River at Azad Pattan and Kohala whereas significant decreasing trend was found in Kunhar River at Naran. Neelum, Kanshi and Poonch rivers have the non-significant decreasing trends. All stream gauges have the decreasing trends in summer season and 56% of stations have the significant trends. The significant trends were found in Rivers Neelum, Poonch, Kanshi and Jhelum (at Azad Pattan and Domel). The changes in flows are shown in Fig.3. 72% of stations have the decreasing trends whereas only 22% (2 stations) have the significant trends. The decreasing trends were found in rivers Jhelum (at Azad Pattan) and Neelum with the rate of 22% and 14% per decade. Only the Kunhar River has the significant increasing trend at both stream gauges (Gari-habibullah and Naran) with the rate of 8% and 9% per decade.

5.3 Variability in maximum flows

The variation intervals of the statistics for the annual maximum flows of these stations are presented in Table 2. The mean annual maximum varies from 233 to 3041 m/s^3. The coefficient of variation, CV, changes between 0.33 and 0.87 whereas the skewness has a minimum 0.7 and a maximum 4. The decreasing trends in annual maximum flows were found at 56 % (11% significant). The annual maximum flows in main Jhelum River have increasing (non-significant) trends at all stream gauges whereas the flows in all subbasins have the decreasing trends.

Winter season showed statistically significant changes at 4 (4 increases and 0 decreases). Fig. 4b presents the stations where and how much significant changes (at the level of 10%) have been observed. Summer and autumn maximum flow has decesead (increased) significantly at 9 (5) and 8(3) stations. The summer season has the maximum discharge values as compared in other seasons. The mean maximum flow in summer season (JJA) varies from 228 to 2666 cumec whereas maximum of summer maximum flow varies from 448 to 7622 cumec. All stream

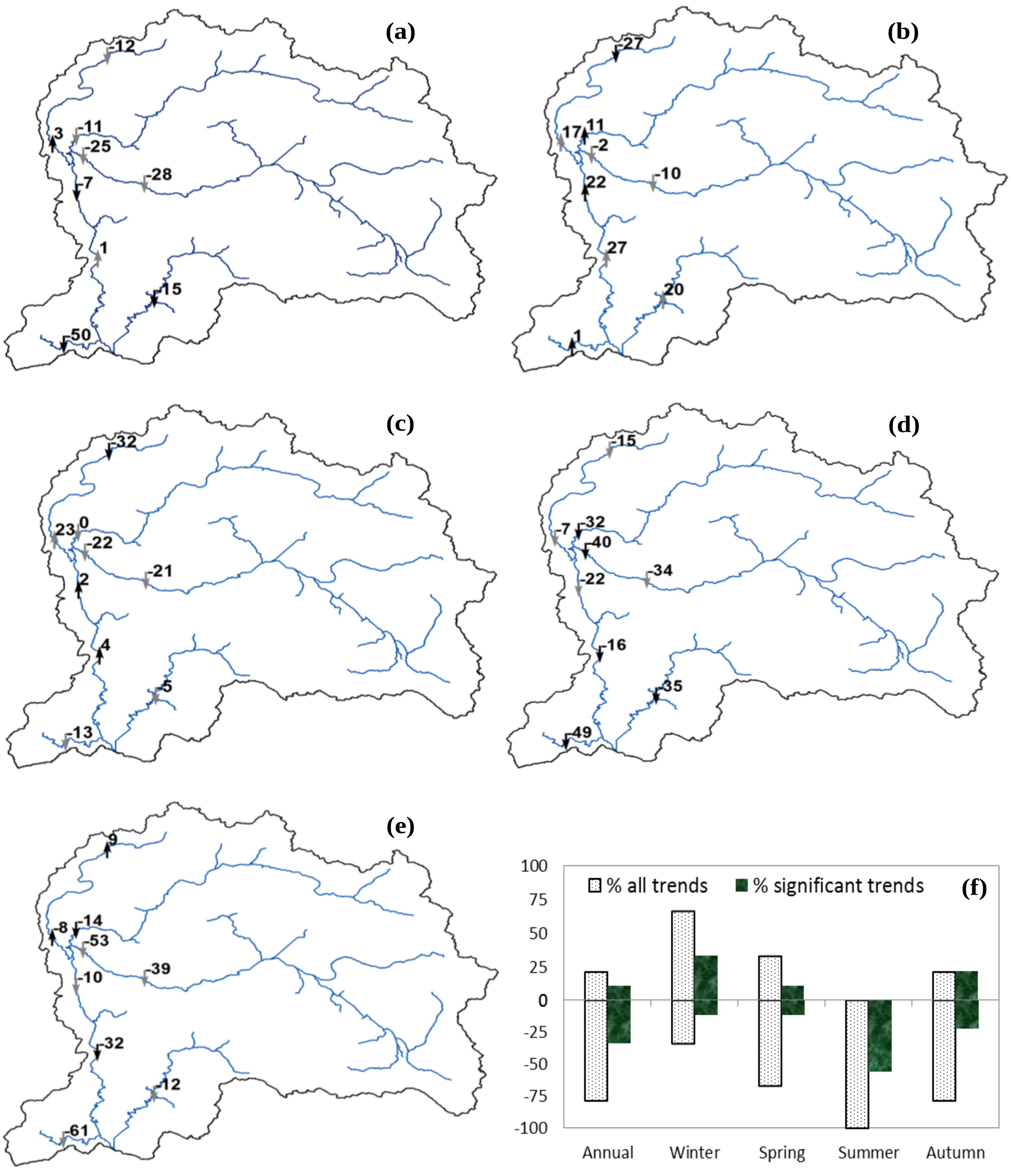

Figure 3: Spatial distribution of trends detected by Mann-Kendal and trend values estimated by Sen's method showing change in % decade^{-1} of mean streamflows in: (a) annual, (b) winter, (c) spring, (d) summer, (e) autumn, and (f) % all and significant trends. (Upward and downward arrow shows positive and negative trends respectively, bold arrow shows significant trends at α=0.1).

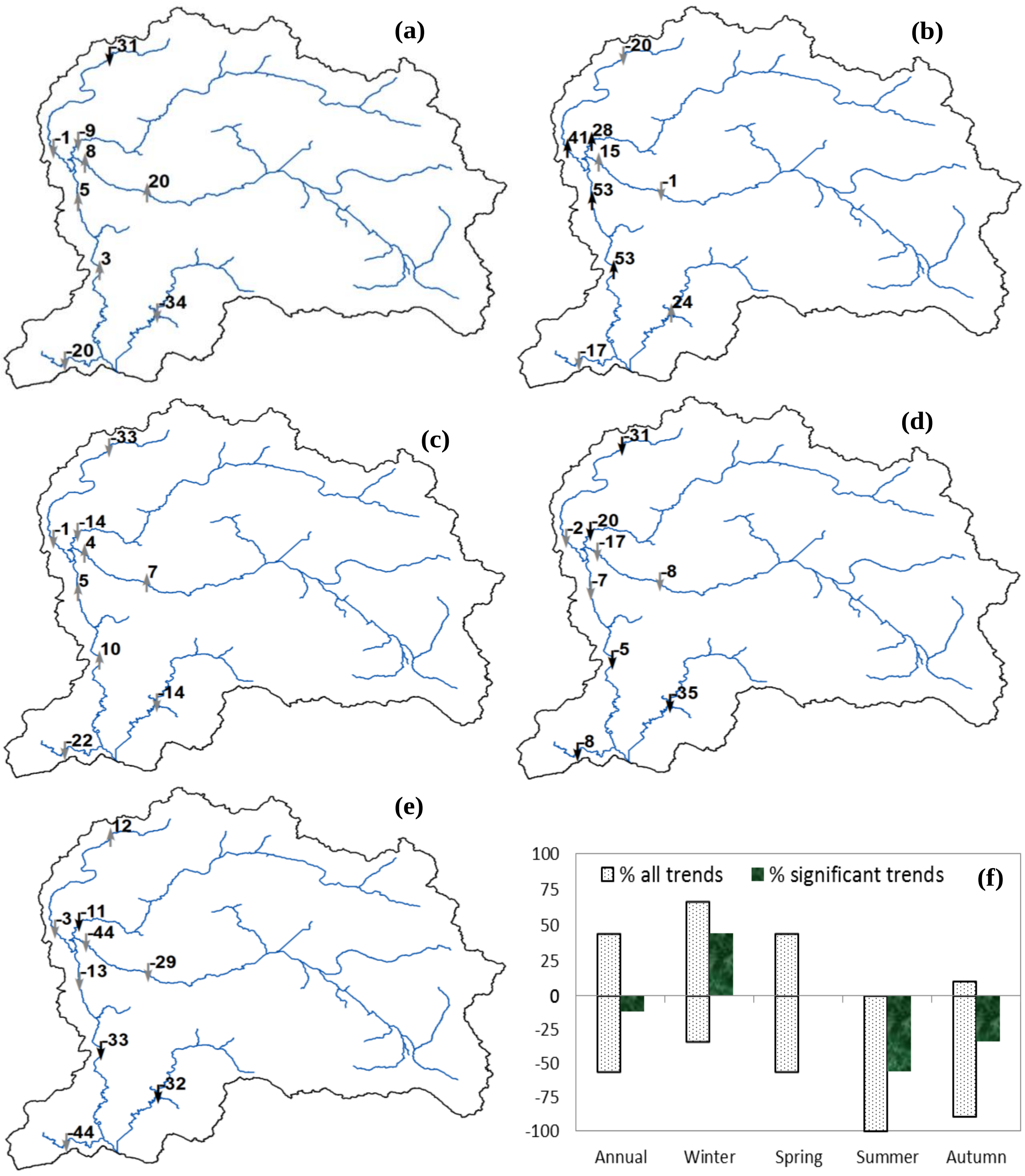

Figure 4: Spatial distribution of trends detected by Mann-Kendal and trend values estimated by Sen's method showing change in % decade^{-1} of maximum streamflows in: (a) annual, (b) winter, (c) spring, (d) summer, (e) autumn, and (f) % all and significant trends. (Upward and downward arrow shows positive and negative trends respectively, bold arrow shows significant trends at α=0.1).

guages have the decreasing trends and 56% of stations have the significant (see Fig.4d). The flow in Hunza river a predominated glaciated catchment has also significant trend ($p<0.001$) and has decreased upto 31% of mean maximum flow (228 cumec). The significant decreasing was observed in Kunkar, Neelum, Poonch and Jhelum (at Azad Pattan) rivers. In autumn season the mean maximum flow varies from 54 to 1220 cumec. This season has also more decreasing trend as summer season. The decreasing trend were observed at 89% of station but 33% have the significant trends for the period 1971-2010. The significant trend was found in Poonch, Neelum and Jhelum (at Azad Pattan) rivers. The changes in flows detected from Sen'method over the different period are showin Fig.4e.

6 CONCLUSIONS

The present study analyses the investigation of annual and seasonal maximum, minimum and mean streamflow in Mangla basin and its sub-basins (Kanshi, Poonch, Kunhar and Neelum) for period (1971-2010) by Mann Kendall tests in time series of temperature for Mangla catchment and its sub-basins (Kanshi, Poonch, Kunhar and Neelum). The following specific conclusions from this study are:

1. The annual minimum flow in main Jhelum River (at Azad Pattan) has decreased where mean and maximum flow has increased but non-significantly.
2. The annual mean and maximum flows in all subbasins have decreasing trends (except only in Kunhar for mean flow) whereas minimum flow has increasing trend except in Kunhar basin
3. The winter minimum, mean and maximum streamflows in main basin as well as in all subbasins have increased (except only in Kanshi for mean and maximum flow) whereas have decreased for the summer season.
4. The spring minimum and mean flows in high elevated basins have increasing trends whereas in decreasing trend in low elevated basins
5. The maximum flow for the spring, summer and autumn months has decreasing trend in main basin as well as in all subbasins.

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REFERENCES

- Archer, D. R., and H. J. Fowler (2004), Spatial and temporal variations in precipitation in the Upper Indus Basin, global teleconnections and hydrological implications, Hydrol. Earth Sys. Sci., 8 (1), 47-61.

- Bates, B. C., Kundzewicz, Z. W., Wu, S. and Palutikof, J. (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.

- Bhutiyani, M.R., Kale, V.S., Pawar, N.J., 2007. Long-term trends in maximum, minimum and mean annual air temperatures across the northwestern Himalaya during the 20th century. Climatic Change, 85, 159–177.
- Caloiero, T., Roberto Coscarelli, R., Ennio Ferraric, E., Mancinia, M., 2011. Trend detection of annual and seasonal rainfall in Calabria (Southern Italy). Int. J. Climatol. 31, 44–56.

- Government of Pakistan, Ministry of Economic Affairs and Statistics, Statistics Division. "Overall Water Availability". Pakistan Statistical Year Book 2007. http://www.statpak.gov.pk/depts/fbs/publications/yearbook2007/agriculture/1.15.pdf.
- Haan, C.T., 1977. Statistical Methods in Hydrology, The Iowa State Univ. Press, Ames.
- IPCC AR4 (Intergovernmental Panel on Climate Change Fourth Assessment Report), (2008): Climate change and water 2007. IPCC Technical paper VI (htt://www.ipcc.ch/pdf). [Accessed 20 June 2008].

- IPCC, 2001. Climate change 2001: synthesis report. Contribution of Working Group I and III to the Third Assessment of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge.

- Jones, P.D., Moberg, A., 2003. Hemispheric and large-scale surface air temperature variations: an extensive revision and update to 2001. J. Climate 16 (2), 206–223.
- Kendall, M.G., 1975. Rank correlation methods, 4th ed. Charles Griffin, London.
- Khan, A.R., Ullah, K.K. Muhammad, S., 2002. Water availability and some macro level issues related to water resources planning and management in the Indus Basin Irrigation System in Pakistan. /www.riob.org/ag2000/pakistan.htm
- Khattak, M. S., Babel, M. S., Sharif, M., 2011. Hydro-meteorological trends in the upper Indus River basin in Pakistan. Climate research, (46), 103–119.

- Mavromatis T., Stathis D., 2011. Response of the Water Balance in Greece to Temperature and Precipitation Trends. Theoretical and Applied Climatology 104, 13- 24, DOI 10.1007/s00704-10-0320-9.
- Parker, D. E., Horton, E. B., 1999. Global and regional climate in 1998. Weather 54, 173–184.
- Population Census Organization (PCO). 2012. http://www.census.gov.pk/
- Rio del, S., Penas, A., Fraile, R., 2005. Analysis of recent climatic variations in Castile and Leon (Spain). Atmospheric Research 73, 69–85
- Sen, P.K., 1968. Estimates of regression coefficients based on Kendall's tau. Journal of the American Statistical Association, 63(1968), 1379-1389.
- Tabari, H., Talaee, P. H., Ezani, A., Some'e, S. B., 2012. Shift changes and monotonic trends in autocorrelated temperature series over Iran. Theor Appl Climatol., 109, 95–108

Constructed Wetlands for Sustainable Wastewater Treatment

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Abstract
Conventional wastewater treatment systems entail heavy investment and high operating costs. The contemporary wastewater treatment systems in most of the developing countries which were built through funding by international agencies fail to treat wastewater satisfactorily. Reasons for poor treatment include lack of local expertise, high maintenance costs and poor governance. When paralleled to conventional treatment systems, constructed wetlands are low cost, easily operated and maintained, and sustainable treatment systems. They have a strong potential for application in developing countries. Constructed wetlands are accepted as a reliable low-cost and low energy wastewater treatment technology. They represent an appropriate solution for treatment of many wastewater types.
Pilot scale constructed wetlands were commissioned at NED University to check their treatment efficacy. Domestic and industrial wastewaters were treated separately under local environmental conditions. A free water surface wetland was used to treat domestic wastewater while a vertical flow wetland was used for industrial wastewater treatment. The studied constructed wetlands successfully removed the monitored pollutants from domestic and industrial wastewaters. The results confirm that constructed wetlands can successfully be used for wastewater treatment under local environmental conditions. Application of these systems on full scale can play an important role in managing the city's wastewater.

Keywords
Constructed wetlands; Low-cost; Sustainable; Treatment; Wastewater

1. Introduction
Universally, most of the developing countries are situated in those parts of the globe that are or will experience water shortages in the proximate future. The current water sources of water supply are polluted because untreated domestic and industrial wastewaters are discharged into waters bodies resulting in diminishing water quality. This practice not only contaminates the sources of drinking water but also negatively impacts irrigation, fish production or recreation (Kivaisi, 2001). Water pollution is one of the main perils to public health in developing countries. Therefore, two measures that are wastewater treatment and wastewater reuse can play a vital role in combatting water scarcity. In the context of developing countries it is important that designers should select low cost and low maintenance technologies for wastewater treatment.

The mega city of Karachi has three wastewater treatment plants to treat sewage. A summary of these wastewater treatment plants is presented in table 1. Treatment Plant-I located at Haroonabad, SITE and Treatment Plant-II located at Mehmoodabad comprise of preliminary , primary and secondary treatment levels. The secondary treatment level is based on attached growth biological treatment system of trickling filter. While the Treatment Plant-III located at Mauripur is based on waste stabilization pond system. Around 472 million gallons per day (MGD) of wastewater is produced by the city. The above three sewage treatment plants have a treatment capacity of 151.5 MGD (KWSB), i.e. they have a capacity to treat only 32 percent of the total wastewater produced. But poor maintenance, weak institutional capacity, economic constraints, poor governance and shortage of human resources have resulted in malfunctioning of these treatment plants. The treatment plants are now treating merely 12 percent of the total wastewater generated. This is not only the case for Karachi but the same applies to urban wastewater management in cities of developing countries.

Table1: Summary of Sewage Treatment Plants Located in Karachi (KWSB, 2015)

S. No.	Plant Number	Location	Treatment Capacity (MGD)	Current Treatment (MGD)
1.	Treatment Plant-I	Haroonabad, SITE	51	20
2.	Treatment Plant-II	Mehmoodabad	46.5	0
3.	Treatment Plant-III	Mauripur	54	35
		Total	***151.5***	***55***

MGD: million gallons per day; SITE: Sindh Industrial and Trading Estate

Constructed wetlands are considered to be a sustainable treatment alternative and have been successful in treating various kind of wastewater including domestic sewage. They are simple to construct, operate and have very low energy requirement. The basic categories of constructed wetland systems are: free water surface (FWS) wetlands, horizontal subsurface flow (HSSF) wetlands and vertical flow (VF) wetlands (Kadlec and Wallace, 2009). Wastewater that has undergone primary treatment can further be treated in these low energy treatment systems.

The city of Kolkata, India has East Kolkata Wetland (EKW) that is a distinctive example of a wetland ecosystem. It provides a wide array of benefits including protection of environment and recovery of resources. The wastewater generated by this city is diverted to the EKW through a network of drainage canals. The wetland system treats 145 MGD of raw sewage and storm water (Bunting *et al.*, 2002). The beds and estuaries of Malir and Lyari rivers of Karachi can be utilized for developing wetland treatment systems. These systems have the potential to provide multiple benefits of wastewater treatment, biodiversity enhancement and integration with landscape. The main objectives of this study are to:

1. To evaluate the performance of constructed wetland to treat domestic and industrial wastewaters;
2. To assess the application of constructed wetland for wastewater treatment in Karachi.

2. Materials and Methods

2.1 Experimental Setup

Two experimental setups were developed at NED university campus. The first setup was developed for treatment of domestic wastewater (FWS wetland) while the second one was for industrial wastewater treatment (VF wetland). Details of the two setups are detailed in the following subsections.

2.1.1. Domestic wastewater treatment system

A pilot-scale free water surface wetland (FWSW) was commissioned at NED University of Engineering and Technology (Figure 1). The system is designed as a plug flow reactor for a flow of 1 m^3/d. It consists of a rectangular cell that has a length to width ratio (L:W) as 4:1. The rectangular cell was constructed with cement concrete blocks. Its base was made impermeable using concrete based floor. The cell was filled with sweet earth and fertilizer was applied during plantation of *Phragmites karka*. Soil tubes were used to collect young plant saplings of *Phragmites karka* from a natural wetland. Vegetation density was 4 plants per m^2. The constructed wetland inlet and outlet comprise of PVC pipes. For making the system hydraulically efficient the inlet and outlet pipes were fabricated with slotted openings. Immediately after plantation the FWSW was submerged with tap water so that the plants could establish themselves. After an establishment period of 6 weeks, the FWSW was fed with domestic wastewater for acclimatization. The plant growth was monitored during this period and found to be good. Pre-treated wastewater is collected in a storage tank. Wastewater enters the treatment system through the wetland inlet pipe (regulated by a valve) and travels via gravity towards the wetland outlet pipe.

2.1.2. Industrial wastewater treatment system

The experimental set up consisted of two vertical flow constructed wetlands (VFCW) with different plants and media packed in ready-made pots made up of concrete (Figure 2). These pots have a diameter of 0.3 m and height of 0.45 m. A 10 cm bottom layer of gravel was capped with 24 cm layer of sand to facilitate plant growth. To collect samples, a valve made up of PVC material was fitted at the bottom of the VFCW.

The VFCW were planted with two plant species; *Phragmites karka* (VFCW 1) and *Typha angustifolia* (VFCW 2). Soil tubes were used to collect young plant saplings of *Phragmites karka* and *Typha angustifolia* from a natural wetland. Five collected saplings were planted in each VFCW. Immediately after plantation the VFCW were submerged with tap water so that the plants could establish themselves. After an establishment period of thirty days, the two VFCW were fed with refinery wastewater for acclimatization. The plant growth was monitored during this period and found to be good. Wastewater from a local refinery was collected in PVC vessels and transported to NED University for experimentation. The refinery wastewater was added manually. Hydraulic loading rate of 85 mm/d was maintained. The VFCW were operated on a pulse load system.

2.2 Sampling methods

Domestic wastewater

For wastewater analysis, grab samples were collected from the inlet and outlet of the FWSW after every two weeks from September 2010 to April 2011. Wastewater samples were tested for various physical, chemical and biological parameters using American Public Health Association standards methods (APHA, 2005). Among the parameters analyzed were temperature, dissolved oxygen (DO), pH, total dissolved solids (TDS), total suspended solids (TSS), 5 days biochemical oxygen demand (BOD_5) at 20°C, chemical oxygen demand (COD), ammonia nitrogen (NH_4-N), ortho-phosphate (PO_4-P), faecal coliforms (FC), total coliforms (TC). The samples were investigated in the water quality laboratory of environmental engineering department.

Industrial wastewater

The influent added to VFCW was wastewater from a local oil refinery. PVC valve fitted at the VFCW bottom was used to collect effluent samples every two weeks from October to December 2013. Wastewater samples were tested for various physical and chemical parameters using American Public Health Association standards methods (APHA, 2005). Among the parameters analyzed were turbidity, pH, total suspended solids (TSS), oil and grease, biochemical oxygen demand (BOD), chemical oxygen demand (COD), chloride, and total phenol. All parameters except phenol were analyzed in the Water Quality Laboratory of Department of Environmental Engineering NED University of Engineering and Technology.

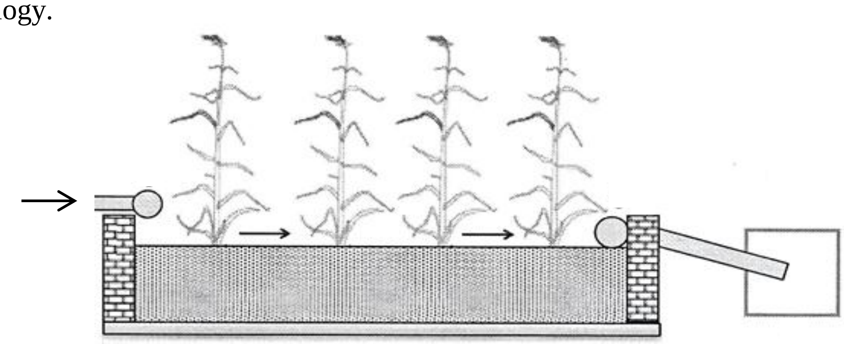

Figure 1: Free Water Surface Wetland (FWSW) for Treatment of Domestic Wastewater

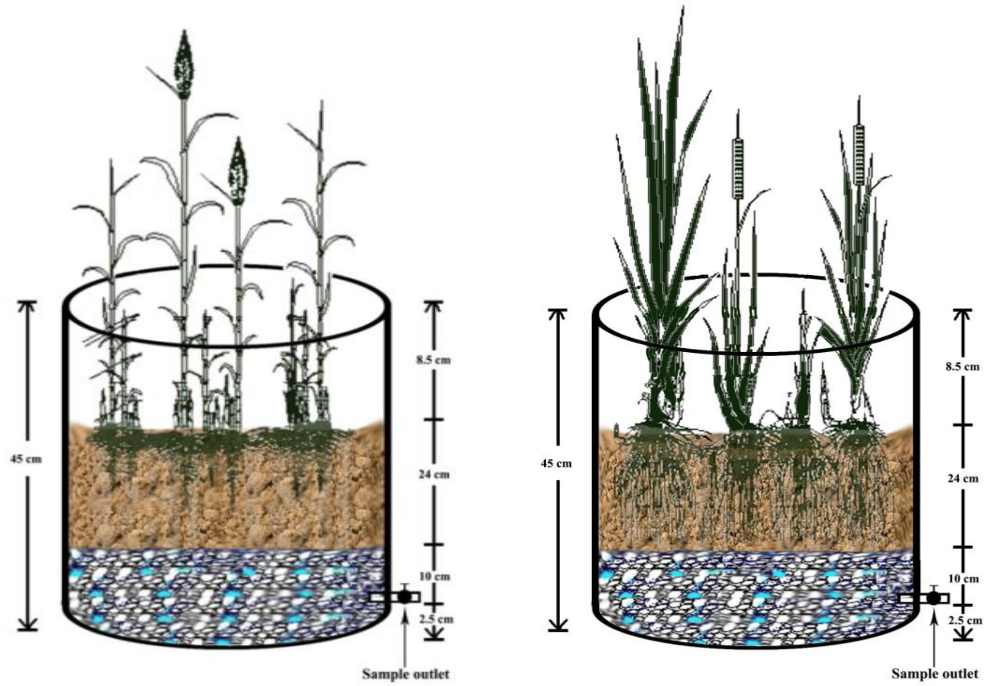

Figure 2: Vertical Flow Constructed Wetland (VFCW) for Treatment of Industrial Wastewater (a) VFCW 1 planted with *Phragmites* (b) VFCW 2 planted with *Typha*

3. Results and Discussion

Water Quality Improvements by Free Water Surface Wetland

Table 2 represents the water quality improvements provided by the FWSW treating domestic wastewater The inlet TSS concentration to the FWSW was in the range between 95 - 350 mg/L while outlet TSS values were between 13 - 92 mg/L. The solids removal efficiency ranged from 73% to 86% with a mean reduction of 78%. In wetland systems, total suspended solids are removed predominantly through physical processes including settling and seizure mechanisms (Kadlec and Wallace, 2009).

The FWSW successfully stabilized organic matter. The BOD and COD concentration at inlet fluctuated between 32.5 -110 mg/L and 56 - 225 mg/L, respectively. After passing through the wetland cell concentrations for BOD and COD were in the range between 13-71 mg/L and 35-95 mg/L, respectively. The average reduction in BOD concentrations over the monitoring period was 50% with mean effluent BOD_5 concentration of 34 mg/L (Table 2). While the average reduction in COD concentrations over the monitoring period was 44% with mean effluent COD concentration of 68 mg/L (Table 2). The BOD to COD ratio was in the range of 0.55 to 0.27 confirming that organic matter was removed by the FWSW via biological degradation.

Nutrient removal by FWSW was good. The average inlet ammonia-nitrogen and ortho-phosphate concentrations were 19.2 mg/L and 7.6 mg/L, respectively. The average ammonia-nitrogen and ortho-phosphate outlet concentrations were 9.7 mg/L and 3.7 mg/L. Ammonia-nitrogen reduction in the wetland system was 49% while ortho-phosphate reduction was 51%. Nitrogen compounds are transformed and eventually removed from the wetland system through processes like ammonia volatilization, nitrification and denitrification. The latter two are microbial mediated processes. In wetland systems, removal of phosphorus is through various processes including accretion, biomass storage, precipitation and sorption .

Analyses of indicator bacteria, total coliforms (TC) and faecal coliforms (FC) at the FWSW inlet and outlet showed that the wetland system efficiently removed both TC and FC. The mean removal rates over the monitoring period were in the range of 93 to 99%, showing a high efficiency of the constructed wetland system in removing the indicator bacteria. Mean concentration of TC at the wetland inlet and outlet were 2.1×10^6 counts/100mL and 8.0×10^3 counts/100mL, respectively (Table 2). While the mean concentration of FC at the wetland inlet and outlet was 1.1×10^6 counts/100mL and 3.0×10^3 counts/100mL, respectively (Table 2). In wetland systems, FC and TC are removed by various mechanisms including natural die-off and predation (Kadlec and Wallace, 2009).

Table 2. Mean influent, effluent concentrations and removal efficiency (RE) for Free Water Surface Wetland

S.No.	Parameter	Unit	Inlet	Outlet	RE (%)
1.	pH	-	7.1	7.2	-
2.	Dissolved oxygen	mg/l	1.7	4.5	-
3.	TSS	mg/l	201	45	78
4.	COD	mg/l	123	68	45
5.	BOD	mg/l	69	34	51
6.	Ammonia-nitrogen	mg/l	19.2	9.7	49
7.	Ortho-phosphate	mg/l	7.6	3.7	51
8.	Total coliforms	Counts/100mL	2.1×10^6	8×10^3	93
9.	Faecal coliforms	Counts/100mL	1.1×10^6	3×10^3	98

Water Quality Improvements by Vertical Flow Constructed Wetlands

Table 3 represents water quality improvements provided by the VFCW treating industrial wastewater. The VFCW successfully reduced turbidity with good removal efficiencies of >90%; 91% for VFCW 1 and 95% for VFCW 2. Layers of gravel and sand packed in the pots facilitate filtration of the wastewater as it travels vertically downwards due to gravity. The mean inlet pH was 8.1while the mean outlet pH for VFCW 1 and VFCW 2 were 7.1 demonstrating the buffering capability of wetlands (Kadlec and Wallace, 2009). Table 3 shows that the two VFCW removed total suspended solids as well as oil and grease. Solids are generally removed through capture and settling (Kadlec and Wallace, 2009). Evaporation, leaching and sedimentation are physical processes that remove mineral oils in wetlands (Mashuri *et al.* 2000).

The mean COD removal efficiencies for the two VFCW were higher than BOD removal efficiencies. The nature of wastewater i.e. industrial wastewater is the possible reason for this difference. With regard to COD removal, VFCW 2 performed better than VFCW 1. While for BOD removal, VFCW 1 performed better than VFCW 2. This may be attributed to the different type of vegetation planted in the two systems i.e. VFCW 1 was planted with *Phragmites* while VFCW 2 was planted with *Typha. Phragmites* have roots extending to greater than > 1 m in the soil and assist in oxygen transfer which in turn support aerobic conditions and associated microbial degradation. Wetlands remove phenol through various processes including microbial degradation, plant uptake, sorption and volatilization (Imfeld *et al.,* 2009). However, for removal of phenolic compounds biodegradation is thought to be the most effective pathway (Liu *et al.,* 2009). The reason for lower removal efficiency of VFCW 1 may be due to slow development of phenol biodegrading microbes in VFCW 1.

Table 3. Mean influent, effluent concentrations and removal efficiency (RE) for Vertical Flow Constructed Wetlands

S.No.	Parameter	Unit		VFCW 1	VFCW 2
			Inlet	Outlet (RE %)	Outlet (RE %)
1.	Turbidity	NTU	181	16.6 (91)	9.8 (95)
2.	pH	-	8.1	7.1 (-)	7.1 (-)
3.	TSS	mg/l	283	35.4 (87)	76.1 (73)
4.	Oil and Grease	mg/l	1146	263.8 (77)	203.1 (83)
5.	BOD	mg/l	328	208.1 (37)	211.7 (36)
6	COD	mg/l	746	320.2 (57)	309 (72)
7.	Chloride	mg/l	34	1.3 (96)	0.6 (98)
8.	Total phenol	mg/l	1.71	0.55 (68)	0.04 (97)

Constructed Wetland Technology for Wastewater Treatment in Karachi

The present centralized wastewater treatment systems treat only a fraction of total wastewater generated by the city. Further expansion of existing treatment plants is practically impossible because of no land availability. Moreover, wastewater from residential areas mixes with the untreated industrial effluents and reaches the Arabia Sea via Lyari and Malir rivers. The beds of these rivers can be utilized to treat and reuse this wastewater. Constructed wetlands that are sustainable, low energy systems and low maintenance are considered to be an attractive alternative to conventional wastewater treatment plants. The results of the above study show that these systems can remove pollutants from domestic as well as industrial wastewaters. A study by Liu *et al.*, 2008 compared the O & M cost of conventional wastewater treatment plants and constructed wetlands in China. They reported lower O & M costs US$ 0.0082 – 0.039 m^3/y for constructed wetlands as compared to US$ 0.1151 – 0.2465 m^3/y for conventional wastewater treatment plants. If constructed wetland technology is properly designed and implemented it is probable that the wastewater treatment problem of Karachi can be sorted out on a sustainable basis.

4. Conclusions

Results show that constructed wetlands can successfully remove pollutants from domestic as well as industrial wastewaters in the environmental setting of Karachi. Discharge of untreated wastewater is a persistent problem afflicting people of Karachi and negatively impacting the associated ecosystems. Planning and commissioning of centralized energy and cost intensive wastewater treatment plants has proven unsuccessful not only in Karachi but also in other urban areas of the developing world. Alternatively, constructed wetlands can be applied as a sustainable, low cost and low energy technology for solving the wastewater treatment problem.

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References

APHA (2005). Standard Methods for the Examination of Water and Wastewater, AWWA, WEF (21st edition) American Public Health Association, Washington, DC.

Bunting, S., Kundu,N., Mukherjee, M. (2002). “Renewable natural resource-use in livelihoods at the Calcutta peri-urban interface: literature review.” *Working Paper, University of Stirling, UK Institute of Aquaculture.*

Imfeld G., Braeckevelt M., Kuschk P. and Richnow H.H. (2009). Monitoring and assessing processes of organic chemicals removal in constructed wetlands. *Chemosphere*, Vol. 74, No. 3, pp. 349-362.

Kadlec R.H. and Wallace S.D. (2009). Treatment Wetlands. CRC Press, Boca Raton.

Kivaisi, A.K. 2001. “The potential for constructed wetlands for wastewater treatment and reuse in developing countries: a review.” *Ecological Engineering*, Vol. 16, No. 4, pp. 545–560.

Karachi Water and Sewerage Board website (*http://www.kwsb.gos.pk/*), accessed on 14 May 2015.

Liu, D., Ge, Y., Chang, J., Peng, C., Gu, B., Chan, G.Y.S., Wu, X., (2008). Constructed wetlands in China: recent developments and future challenges. *Frontiers in Ecology and the Environment*, Vol. 7, No. 3, pp. 261-268.

Liu Z.H., Kanjo Y. and Mizutani S., (2009). Removal mechanisms for endocrine disrupting compounds (EDCs) in wastewater treatment-physical means, biodegradation, and chemical advanced oxidation: a review. *Science of the Total Environment*, Vol. 407, No. 2, pp. 731-748.

Mashauri, D.A., Mulungu, D.M.M. and Abdulhussein B.S. (2000). Constructed wetland at the University of Dar es Salaam. *Water Research, Vol.* 34, No. 4, pp. 1135–1144.

Development of Black Spot Identification Criteria for Karachi

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Abstract

Traffic Crashes and traffic injuries has become a major problem globally and causing over 1.3 million deaths each year. In 2020 Road Traffic Injuries becomes the third major cause of injury and deaths worldwide with 1.9 million deaths per year. In Pakistan almost 30,000 deaths occurred in road accident per year with the fatality rate of 17.4 per 100,000 people.

This study focuses on development of appropriate black spot identification method for Karachi as other countries develop their own to identified BS. It is important to develop some absolute critical value of traffic accident to compare the observed accident frequency of any road section. The study has an objective to identifying and develops the appropriate black spot identification criteria for traffic accidents in Karachi. It includes the understanding of different methods for black spot identification and takes 6 arterials of Karachi to analysis the technique with their fatalities of crashes and implemented the results.

Right now in Pakistan, there are no criteria and any type of study for black spot identification method. So it is important to develop some techniques for black spot and prioritized our road network system in terms of safety and select appropriate measures to reduce crashes on a road section which causing major casualties.

This paper provides a methodology to identify the black spot for any road section and prioritizes the most dangerous sections in the overall system which is useful for further detailed review and find out the causes of traffic crashes.

Keywords

Black Spot Identification, Black Spot Criteria, Road Traffic Injuries, Karachi, Pakistan

1. Introduction

Traffic Crashes and there injuries has become a major problem causing health injuries and economic and social losses globally and causing over 1.3 million deaths each year.[1] 91% of the world's fatalities on the roads occur in low-income and middle-income countries, even though these countries have approximately half of the world's vehicles.[1] Globally as projected by WHO, In 2020 Road Traffic Injuries becomes the third major cause of injury and deaths with 1.9 million deaths per year as shown in Table 1.

Table 1: Rank Order of DALYs for 10 Leading Causes of the Global Burden of Disease

	1998		2020
Rank	Disease or Injury	Rank	Disease or Injury
1.	Lower respiratory infections	1.	Ischaemic heart disease
2.	HIV/AVIDS	2.	Unipolar major depression
3.	Perinatal conditions	3.	Road Traffic Injuries
4.	Diarrhoeal diseases	4.	Cerebrovascular disease
5.	Unipolar major depression	5.	Chroonic obstructive pulmonary disease
6.	Ischaemic heart disease	6.	Lower respiratory infections
7.	Cerebrovascular disease	7.	Tuberculosis
8.	Malaria	8.	War
9.	Road Traffic Injuries	9.	Diarrhoel diseases
10.	Chroonic obstructive pulmonary disease	10.	HIV/AIDS

In Pakistan almost 30,000 deaths occurred in road accident per year with the fatality rate of 17.4 per 100,000 people.[1] In Karachi, it has been estimated that for nearly 33% of road accident are causing fatalities and almost 35,000 accidents are reported annually. According to research by Sindh Medical College, it shows that in year 1996-97 road accident is the 2nd top caused of fatalities in Karachi as shown in Table 2. [2] Hence, traffic safety has become a major area of concern for the authorities

Table 2: Types of Injuries

Types of Injuries	No.	%
Firearm injuries	502	38.3
Road Traffic accident	387	29.5
Asphyxia	98	7.5
Train accidents	89	6.8
Fall from Heights	68	5.2
Sharp Edged Weapons	58	4.4
Electrocution	52	4
Hard blunt weapons	32	2
Explosives	17	1.3
Burns	8	0.6

2. What is Black Spot?

Black spot is a term used to refer to a section of road that is regarded as a high-risk location for traffic crashes.[4] Identification of black spots is the procedure to locate those spots in the road network that are particularly dangerous or more accident then average number of accident. Black spot programs are designed to reduce the crash risk in these areas by improving the physical conditions or management (e.g., building roundabouts, improving lighting).[4] Identification of locations for safety improvement is the starting point of all the road safety programs. The most widely used technique to determine whether a site has a safety problem is based on the road accident history and this is known as determination of black spot location.

3. Black Spot Criteria

As criteria to identify black spots vary from country to country, some international black spot criteria as shown in the Table 3.[5] In Pakistan, there are no criteria and any type of study for black spot identification method.

Table 3: Black Spot Criteria in Different Countries

Country	Section Length	Frequency
Australia	Fairly Short	At least 3 casualty crashes in 5 years
England	300 m	12 crashes in 3 years
Germany	300 m	8 crashes in 3 years
Norway	100 m	4 crashes in 3 years
Portugal	200 m	5 crashes in 3 years
Thailand	Vary	At least 3 crashes in 1 years

4. Methods

The study has an objective to identifying and develops the appropriate black spot identification criteria for traffic accidents in Karachi. It includes the understanding of different methods for black spot identification and takes 6 arterials of Karachi to analysis the technique with their observed frequency of fatalities.

4.1. Data Collection And Compilation

Road traffic fatal injuries data used in this study were collected from the five major trauma centers in the city for the period of January 1, 2008 till December 31st, 2008.

There were 1185 cases of traffic fatalities registered in Karachi during the study period. The victims were predominantly young (18-40 years) males (90%). Only 915(77%) can be plot able on GIS and 270(23%) crashes are not plot able. Almost 3% crashes had no specified location in the information. The distribution of observed fatalities as shown in Figure 1

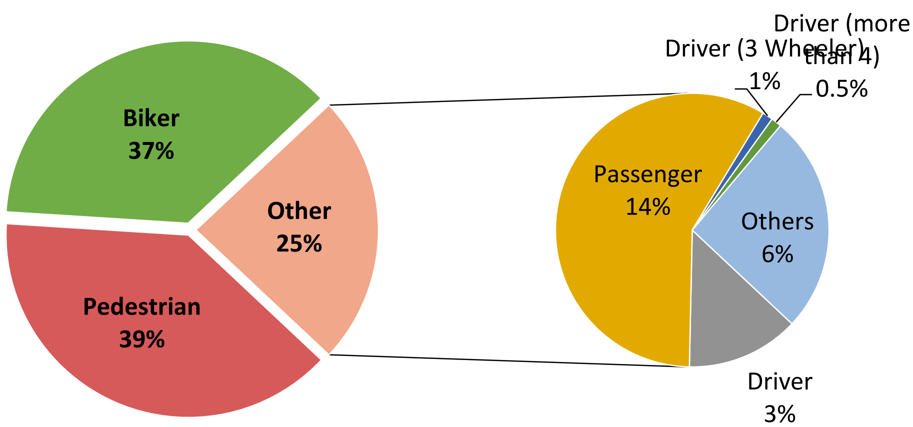

Figure 1: Accident Fatalities (%) in Karachi

4.2. Data Processing

The data processing involves the following step shown in Figure 2 and with this process the data of fatalities was plotted on the vector map of city (Figure 3)

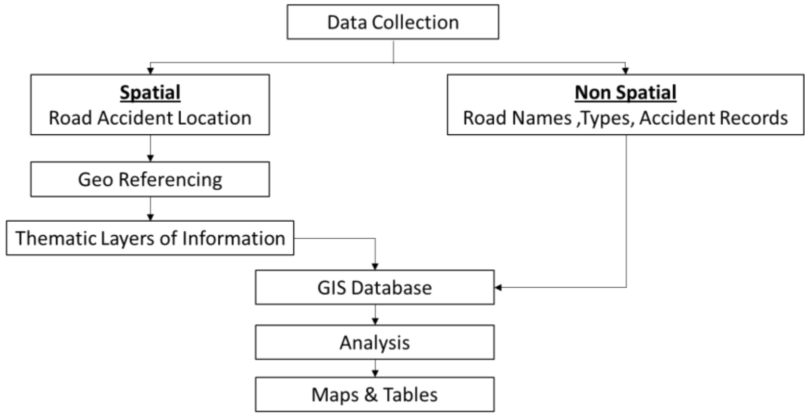

Figure 2: Data Processing

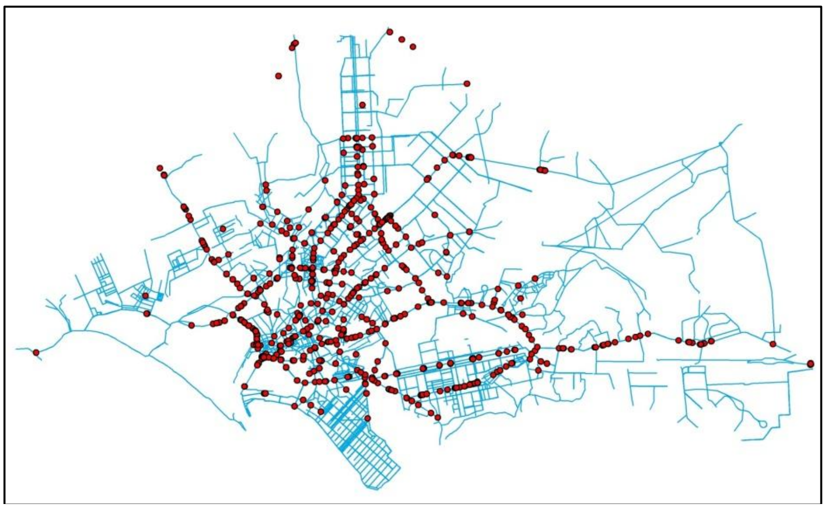

Figure 3: Geographical Distribution of Road Traffic Fatalities in Karachi

The above process implemented on six arterial of Karachi that was considered and it covers 232 crashes (20% of total crashes in Karachi) which show in Table 4.

Table 4: Road Traffic Fatalities in Karachi

Road	Length	Fatal Crashes	Fatal Crashes / Km
Korangi Road	9.4	65	6.9
Shahrah-e-Faisal	16.3	66	4.05
Shahrah-e-Pakistan	5.3	21	4
Korangi Industrial Rd	11.4	39	3.4
M.A Jinnah Road	5.5	15	2.7
University Road	11.7	26	2.2

4.3. Identification Method

In view of the importance of correct identification of black spots, numerous methods have been proposed to identify black spots. The technique that is used in this study to identify hazardous locations is known as

Rate Quality Method. The method states that a location is considered to be a black spot if its safety parameter shows higher values than the critical value. They assured control of the quality of the analysis by applying a statistical test.[3] It consists of following three parameters for each road section

i. Accident Frequency
ii. Accident Rate
iii. Severity Index

Each of these values is compared with a critical value. In this method, location will be identified as black spot even if only one safety parameter is greater than its own critical value.

In this study, we used only accident frequency parameter to analysis the Black spot because it's simple to calculate and only required observed frequency of traffic crashes rather than the traffic volume of roads. Since we used only fatalities in this study which has highest severity in traffic safety therefore we don't need examine the severity index.

4.4. Black Spot identification Analysis

For selected arterials, road section are analysis to calculated the critical accident frequency and compare with the observed frequency for the study period. And a road section consider to be a black spot if

$$A_j > A_c$$

Where,
A_j = Observed accident frequency
A_c = Critical Value for accident frequency

Critical Accident Frequency (A_c) can be calculated by Rate Critical Method by using Equation (1)

$$\text{Ac} = Favg. + Ka\sqrt{Favg./_{Lj}} - 0.5/_{Lj} \quad (1)$$

Where,
Lj = Length of road section (km)
Favg. = Average accident frequency for all road section
Ka = Constant for significance test (Ka= 1.645 for 95% confidence level)

4.5. Results

In this study, for implemented rate quality method with accident frequency parameter we take 300m sections for six arterials of Karachi and the average fatal accident estimated as 1.2 for 300m sections of each six roads. By using Equation 3, calculate critical fatal frequency which comes out to be 3. Thus critical value is 3, which means that each 300m road section having 3 or more fatal accidents should be included in the black spot list.

Table 5 : Identified Black Spot

Accident Frequency (Times per year for 300m Section)	Number of Identified black Spot					
	Shahrah e Faisal	Korangi Road	M.A Jinnah Road	Shahrah e Pakistan	University Road	Korangi Industrial Road
3 and greater	11	8	0	2	2	6

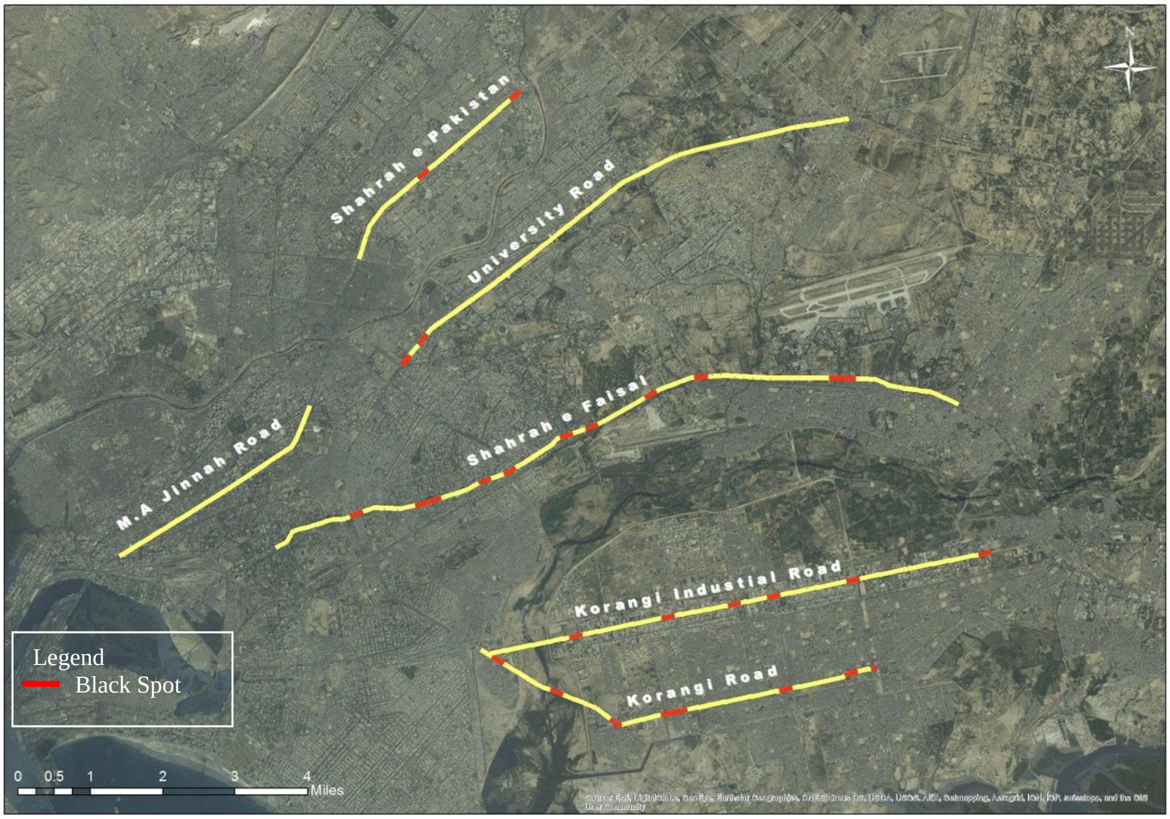

Figure 4: Graphical Representation of Identified Black Spot

5. Conclusion And Recommendations

Road accidents are considered as one of the top three public health problem globally. To overcome the situation, developed countries implemented the black spot improvement programs. Lesson learned through developed countries have made it evident that BS identification is the first and most important step is to identify the site for safety improvement. Different countries BS criteria can also use as a helpful tool for developing the criteria for Karachi. But for more statistical approach to identify black spot is Rate Quality Method. In Karachi, it is suggested that 3 or more fatal accident for any 300m section declared as Black Spot.

This study could also lead to the following recommendations

i. Identified black spots in this study can be selected for more detailed review for counter measures to reduce the crashes.

ii. In this study only accident frequency is consider for BS. In order to more precise, accident rate and severity can also be used to improve the identification process.

iii. As this study based on fatalities of one year, to improve the significance of criteria and accident trends which are change yearly we can used several years of data for this method.

iv. Based on the results, it is recommended that the study and methodology applied on other roads and cities to identified black spot.

6. References

1. World Health Organization (2010), World Report on Road Traffic injury Prevention, Online at http://whqlibdoc.who.int/publications/2004/9241562609.pdf
2. Farhat Hussain Mirza, Kausar Arif and Perwaiz Ahrned Makhdoom (1998), "Two Years' Study of Pattern and Frequency of Fatal Injuries".
3. Dr. Wichuda Kowtanapanich, "Black Spot Identification Methods in Thailand".
4. Australian Academy of Science (2006), Online at http://www.science.org.au/nova/070/070glo.htm, Accessed on May 15,2015
5. Sujin Mungnimit, Kiettipong Jierranaitanakit, and Songrit Chayanan (2009), "Sequential Data Analysis for Black Spot Identification".
6. Swedish National Road Consulting AB (SweRoad) (2001), "Black Spot Manual", *Road Improvement And Traffic Safety*, Final Report Volume I, No.81, pp 6-11.
7. Junaid Abdul Razzak, Uzma Rahim Khan and Sabeena Jalal, "Application of Geographical Information System (GIS) for mapping road traffic injuries using existing source of data in Karachi, Pakistan". Published 2011
8. Apparao. G, P. Mallikarjunareddy and Dr. SSSV Gopala Raju (2010), "Identification Of Accident Black Spots For National Highway Using GIS".
9. Liyamol Isen, Shibu A and Saran M. S (2013), "Identification and Analysis of Accident Black Spots Using Geographic Information System", *Proceedings of International Conference on Energy and Environment-2013 (ICEE 2013)*,India, pp.131-139.

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Risk Assessment of Construction Projects for Urban Tunnels Using Fuzzy Fault Tree Analysis (FFTA)

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Abstract
Tunnel construction projects, especially urban tunnels, due to their complexity, use of new technologies, and special work conditions are exposed to specific risks. Negligence of these risks can cause frequent time delay and cost overrun in these projects; therefore, these risks should be accurately identified and assessed in order to be presented to top management or even subcontractors. In this paper, after identifying tunnel construction projects' specific risks, root causes are identified, and the fault tree of each risk is developed. Risk assessment is of a fuzzy nature due to existing uncertainty of linguistic terms; therefore, in order to calculate the probability of incidence and the severity of the risk on the criteria of time, cost, quality and safety, fuzzy logic was used. For combining the effects of these criteria and calculating the significant degree of each criterion, Analytic Hierarchy Process (AHP) was applied. Finally, this method was applied on Tohid tunnel construction project. The risk factors were ranked, and a sensitivity analysis helped us in responding to the high risks in a more efficient manner. The results of this study show that based on the used methodology, risk assessment can be performed more accurately for complex projects.

Keywords
Risk Assessment, Tohid Tunnel, Fault Tree, Fuzzy Logic, Analytical Hierarchy Process

1. Introduction

The need to construct underground structures, such as urban tunnels, is increasing owing to the lack of enough space on the ground surface, need to shorten connective routes between populated and industrial areas, and also congestion in urban areas. Considering the abundant and complicated problems in constructing tunnels, it is necessary to identify risks in every stage of these projects. These risks; then should be presented to the top management in order to make them capable of controlling time and cost of the project properly. Previous researches have dealt with risk management and concentrated on ranking generic risks using probability and severity methods (Arends et al., 2004; Duzgun and Einstein, 2004; Bravery et al., 2006; Jannadi, 2008; Reilly and Brown, 2004; Reilly and Parker, 2007). In this paper we focused on identification and assessment of detailed, special and executive risks of urban tunnel projects. This action helped us to have a responding plan according to the importance of root causes of each high risk, and resulted in more efficient risk action plan.

2. Materials and Methods

In this paper, we focused on identification of detailed, special and executive risks of urban tunnel projects and developing fault tree diagram for each major risk aspects, and; then, fuzzy fault tree analysis (FFTA) was used for calculation of top event probabilities. Severity of each risk is a function of time, cost, quality and safety; therefore, Analytic Hierarchy Process (AHP) was applied.

2.1 Fault Tree Method

Fault tree method is particularly useful in functional paths of high complexity in which the outcome of one or more combinations of noncritical events may produce an undesirable critical event. Typical candidates for fault tree analysis are functional paths or interfaces which could have critical impact on flight safety, munitions handling safety, safety of operating and maintenance personnel, and probability of error free command in automated systems in which a multiplicity of redundant and overlapping outputs may be involved (Amo, 1998).

2.1.1 Advantages of Using a Fault Tree

Fault trees can provide valuable information to decision-makers. Some of its advantages are summarized as follows

- Fault trees provide visual representation to communicate the logic behind the occurrence of top events, i.e., risk events. This information can be used more effectively by the project team as a way to communicate risk.

- Fault trees can be utilized as a proactive tool to help create proactive response strategies. By understanding the logic behind each risk event, proactive response strategies can be designed to control those root causes at early stages before risk events are realized.

- Fault tree analysis and importance analysis provide valuable information to risk analysts by allowing the prioritization of the contribution of events to the occurrence of the top event. Using such an approach, the project team can work on establishing proactive risk response strategies to minimize critical root causes.

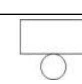
- Fault trees can be used to conduct root cause investigation after the realization of any risk event. By analyzing the logic between different root causes, decision-makers can understand why a risk event is realized.

- Fault trees are flexible to model any system and to help analyze the effect of change of one or more basic events on the probability of failure of the top event (Abdelgawad, 2011; Vesley, 2002).

2.1.2 Symbols Used in Fault Tree Analysis

Special symbols are used when the risks are analyzed using fault tree. Some of these symbols used in this paper are shown in table 1.

Table 1- Some of symbols used in Fault Tree (Vesley, 2002)

The event placed in the most top of the fault and the related causes are identified and analyzed.	Top event	
A basic initiating fault requiring no further development	Basic event	
Output fault occurs if at least one of the input faults occurs	Or gate	

2.2 Fuzzy Calculations of Fault Tree

As mentioned before, since the analyzer is forced to think accurately and deeply about the system, drawing fault tree is of a great importance. However, when the fault tree is become quantitative, it will be more functional. This is done by allocation of a rate of fault or fault probability to each basic event and calculation of the rate of fault of the system (Abdelgawad, 2011).

In case of quantitative analysis of fault tree, we have to find out the incidence probability values for all basic events. In this paper, data related to Tohid tunnel were collected by the concerned specialists. To interpret the collected data as expressed in terms of very low, low, medium, high and very high incidence probability, it was necessary that those terms to be converted into fuzzy numbers. The conversion was made by attribution of trapezoidal fuzzy numbers which are shown in Fig (1) and Fig (2).

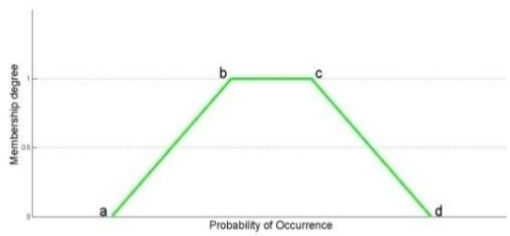


Figure 1-A sample of trapezoidal fuzzy number

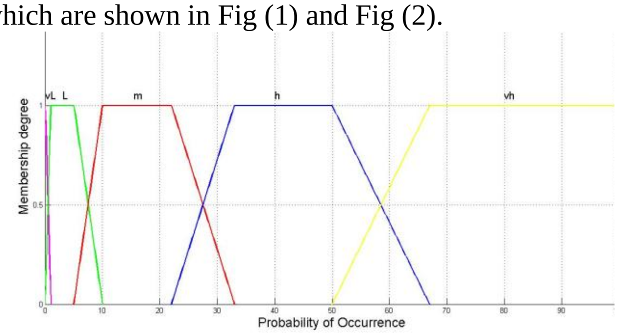


Figure 2- Fuzzy numbers proportional to incidence probability of input data

Hereafter, instead of lingual expressions of very low, low, medium, high and very high, their corresponding fuzzy numbers are applied for calculations and making quantitative analysis. It is mentioned that each trapezoidal fuzzy number can be displayed as [a b c d] and these numbers are applied for evaluations.

To do quantitative calculation of the gates and events, the following equations are applied. The output value of "OR" gate, is given by the following equation (Abdelgawad, 2011):

$$\text{FPro}_T\,(\text{top event})^{\alpha} = \{1-\prod_{i=1}^{n}[1-(a_i+(b_i-a_i)\alpha)],\, 1-\prod_{i=1}^{n}[1-(d_i-(d_i-c_i)\alpha)]\} \quad (1)$$

FProT (top event) stands for the probability of rate of fault in the gate output and each of input fuzzy number indicates the rate of input faults.

3. Case Study: Tohid Tunnel Construction Project

Tohid Tunnel Project is an urban underground structure, located in Tehran within the area of Chamran highway, Tohid square, Jomhouri square, and Navab highway, with a length of about 3 km (Tunnel + entry ramps) (Perlite, 2015).

Subsequent to studied on the comprehensive plan of Tehran, in order to make an easy access from the north to the south of Tehran and vice versa, along the north-south corridor, between Chamran highway constructed during the 70s, and Navab highway constructed during the 90s, sufficient studies were made by Tehran municipality in 1998 so that the connection of the said two highways, i.e. to fill the gap between Tohid square to Jomhouri square becomes practicable and operational.

The significance of the above issue, the congested traffic on Tehran highways, and the intense exigency of Tehran as a metropolitan city to have the above highways connected, made Tehran municipality to launch exhaustive studies to tackle such purpose, and by comparing the existing alternatives, the best alternative which was construction of a tunnel similar to Tehran Resalat short tunnel, was adopted and approved.

To this end, in early 2007, a contractor (Perlite) was assigned to construct the Project, and on 11.06.2007 the contract to kick off the Project was signed and notified to the contractor, whereby on 19.06.2007 the construction works of Tohid Tunnel Project were actually commenced (Perlite, 2015).

3.1 Technical Specifications of the Project

Tohid Tunnel Project was designed in the shape of a twin tunnel adjacent structure, shared by a middle interface wall, and constructed by piles of 1.5 m in diameter, spaced by a 4 m interval. The twin tunnels were excavated on a cross sectional area (face) of about 305 m2. Each tunnel is comprised of three driving bands, with a length of 2,136 m, and a total Project length of about 3,000 m, of which 864 m is for the ramps to enter and exit the tunnels, and the total length of the tunnels (for both entry and exit) is 4,272 m.

The peak height of the tunnels is about 8.5 m, and the general height and width of the Tunnel for the passage of the vehicles was designed at 5 m and 11 m respectively. The overburden soil on the Tunnel was minimum 6 m at the portals, but reached maximum 23 m at the I2 Subway station, and 21 m at Azerbaijan street (Perlite, 2015).

3.2 Construction Works Details

Given the tight limited time of the project, not only the project was constructed both from the north and south ends, but also 4 access shafts were contemplated along the tunnel length, i.e. at Tohid square, Niyayesh junction, Azadi junction, and Jomhouri square. Meanwhile, the shaft sunk at Niyayesh street will be used as a ventilating shaft to ventilate the tunnel in future.

Given 29 months to complete such a burdensome massive project, accompanied by a difficult and complicated location to handle and heavily congested traffic, makes construction of such project an unprecedented unique record in the world, which is also considered as one of the greatest honors for the Iranian engineering society. Some unique and outstanding features of this project in Iran and even in the middle east, is the passage of the tunnel route underneath Tehran subway lines 2 & 4. Tohid tunnel project passes underneath Tehran subway at two points (Perlite, 2015).

4. Results

Firstly, main risks and their root causes are identified mostly by interviewing specialists in this field and also through literature review (El-Sayegh, 2007; Jannadi, 2008; Kim et al., 2006; Reilly and Brown, 2004; Sanchez et al., 2007; Son and Cording, 2006). The identified major risks (top events) are classified in ten categories as follows:

1- Missing certain equipment
2- Inability to supply executive equipment
3- Encounter with unknown layers
4- Diversion of tunnel track
5- Collapse of tunnel wall
6- Tunnel floor flooding or roof leakage
7- Risk of damage to surrounding buildings

8- Damage to infrastructures (water, electricity, telephone, gas and sewer lines)
9- Claims of individuals and organization
10- Traffic routes restriction and heavy traffic during tunnel execution

The fault tree of Tunnel floor flooding or roof leakage risk is for instance shown in Fig (3). Then, the fault trees (specially the root causes) were validated by Tehran metro construction project (line 3) technical team and were adapted by them.

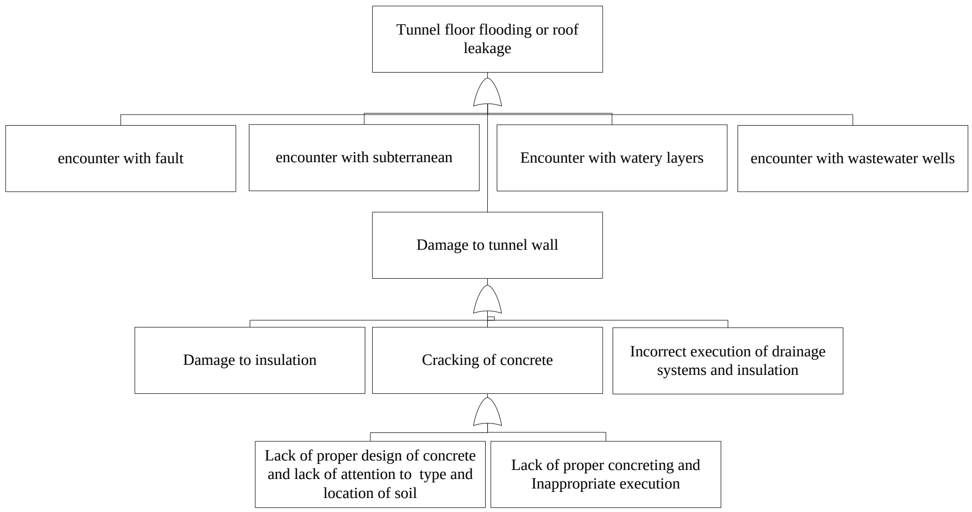


Figure 3: Fault tree diagram (Tunnel floor flooding or roof leakage)

In the present research, we have reached fuzzy number after completion of calculations for incidence probability of risk of tunnel floor flooding or roof leakage. Fuzzy numbers proportional to the severity of the main risks on the criteria of time, cost, quality and safety are shown in Fig (4) and incidence probability of risk of tunnel floor flooding or roof leakage is shown in Fig (5).

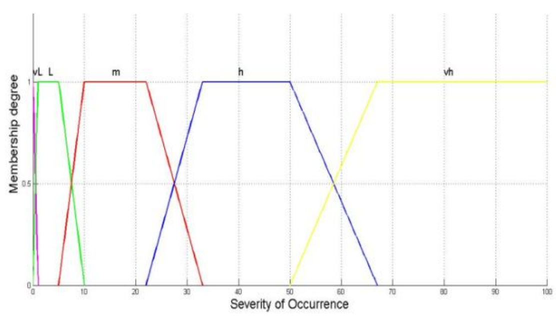


Figure 4- Fuzzy numbers proportional to the severity of the main risks on the criteria of time, cost, quality and safety

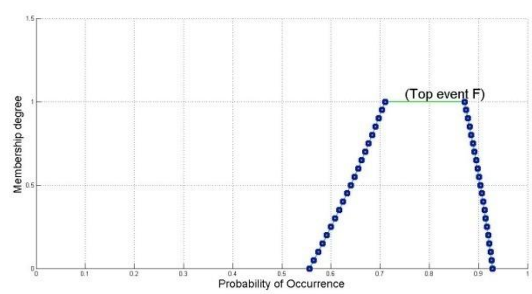


Figure 5- Incidence probability of risk of tunnel floor flooding or roof leakage

Now, this is the time to consider the severity of this risk on the main objects of the project (including time, cost and quality) and any other factors such as safety. To do this, new questionnaires were prepared and the effects of each risk on four parameters as described above were identified. Then, using the technique of Analytical Hierarchy Process (AHP), the weight of each of these factors was calculated. The weights as calculated for criteria of time, cost, quality and safety were 0.269, 0.232, 0.241 and 0.257 respectively and the rate of incompatibility was 0.001. Since, the rate of incompatibility is less than 0.1, the numbers as obtained for the said criteria are correct and the responses made by the individuals indicate a good compatibility. Therefore, these numbers can be applied as coefficient for next calculations (Dalalah et al., 2010). The above weights have been used for calculating the total severity which is the product of integration of the effect of risk on the criteria. Fuzzy number proportional to the severity of tunnel floor flooding or roof leakage on the cost, time, quality and safety are shown in Fig (6) to Fig (9).

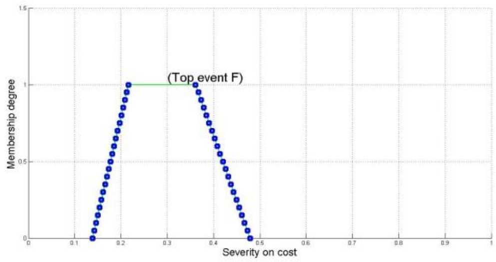


Figure 6- Fuzzy number proportional to the severity of tunnel floor flooding or roof leakage on the cost

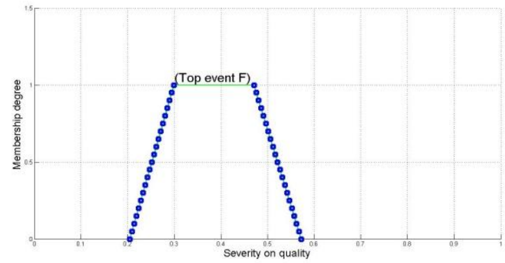


Figure 7- Fuzzy number proportional to the severity of tunnel floor flooding or roof leakage on the quality

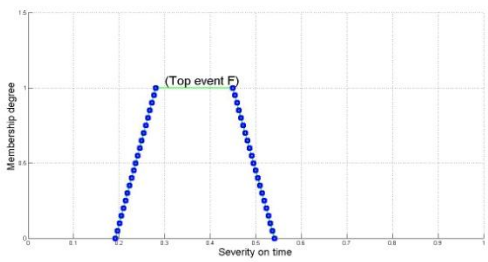


Figure 8- Fuzzy number proportional to the severity of tunnel floor flooding or roof leakage on the time

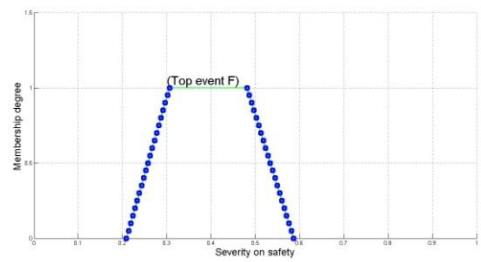


Figure 9- Fuzzy number proportional to the severity of tunnel floor flooding or roof leakage on the safety

Integration of these two parameters for each of the risks is the last step in risk assessment. This is done through calculation of trapezoidal fuzzy number and we use the concept of α-cut. To find the risk factor, Equation 2 is applied where P stands for "risk incidence probability" and C is the "consequence of risk" on the objects of the project, respectively (Cooper et al., 2005).

$$\text{Risk Factor} = (P+C)-P*C \tag{2}$$

When risk factor is calculated using fuzzy data, a final fuzzy number is given after defuzzification. For defuzzification, Middle of Maximum (MOM) approach is applied. Finally, the value of 0.859 is attributed to risk of tunnel floor flooding or roof leakage from Fig (10), and the ranking of the risk factors are shown in Table 2.

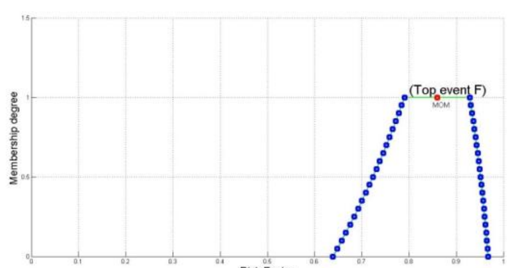


Figure 10- Fuzzy number proportional to the risk factor of tunnel floor flooding or roof leakage

Table 2- Graded Risks

Risk ranking	Risk factor	Risk (top event)
1	0.859	Tunnel floor flooding or roof leakage
2	0.784	Risk of damage to surrounding buildings
3	0.780	Collapse of tunnel wall
4	0.699	Claims of individuals and organization
5	0.274	Damage to infrastructures (water, electricity, telephone, gas and sewer lines)
6	0.619	Inability to supply executive equipment
7	0.585	Traffic routes restriction and heavy traffic during tunnel execution
8	0.551	Encounter with unknown layers
9	0.436	Missing certain equipments
10	0.424	Diversion of tunnel track

6. Conclusion

A real world case study was implemented in order to illustrate its potential applications in urban tunnel projects. The results demonstrate that the two most significant risks are (i) risk of tunnel floor flooding or roof leakage, and (ii) risk of damage to surrounding buildings. Moreover, the diagrams which were illustrated in this paper can be used as a basis for risk assessment of tunnel construction project.

After identifying the main risks and factors that affect in their occurrence, in short, the following strategies to reduce and control risks in the future tunneling projects are presented:

- Issues and problems arising from lack of understanding about earth around the tunnel will cause or exacerbate many of the risks. Therefore, it is recommended to allocate sufficient funding and time for studies and special geotechnical studies to obtain more information, and have a sufficient dominance on advance process in drilling time.

- By selecting the appropriate manager, who has administrative skills, and is familiar with knowledge management and project control, and has necessary management experience, it is possible to overcome many risks, because an efficient manager has ability to control risks before taking the intensity, and forming a crisis.

- Using specialist force and selecting contractors with good experience can be a mechanism for preventing many of risks.

- Machines have a great contribution in the implementation and cost of project. Therefore, it is recommended to control their situation using time and operational tables, and also with optimum utilization of machinery, and timely repair and maintenance reduce costs and their related accidents.

- Tunnel drainage system is designed based on identifying groundwater and aquifer layers, and aqueduct and sewage wells of houses. It is also necessary to supervise adequately on the proper implementation of concreting and insulating of tunnel to make sure that tunnel insulation system works ideally.

- In addition to adequate tests about predictions subsidence, it is needed to get more information about the surrounding buildings.

To validate the results of the case study, different interviews with experts were conducted. The majority of them agreed that the results were meaningful and presented the real critical hazards of the project. Present research is about tunneling projects, and particular risks in this section were assessed. Using the presented method is recommended for all similar complex projects in the construction sector.

7. References

Abdelgawad, M. (2011). "Hybrid decision support system for risk criticality assessment and risk analysis", Ph.D. Thesis, University of Alberta, Alberta, USA.

Amo, R.G. (1998). *Handbook, Electronic Reliability Design, MIL-HDBK-338B*, US Department of Defense, USA.

Arends, G., Bielecki , R., Castle, J., Drabek, S., Haack, A., Nedbal, F., Nordmark, A.,Sterling, R. (2004). "Risk budget management in progressing underground works : International Society for Trenchless Technology (ISTT) and International Tunnelling Association (ITA) joint working group report". *Tunnelling and Underground Space Technology*, Vol. 19, pp 29–33.

Bravery, P., Cross, S., Gallagher, R., Hautefeuille, O., Reiner, H., Spencer, M., Smith, P., Stolfa, A., Wannick, H. (2006). *A code of practice for risk management of tunnel works*, The International Tunnelling Insurance Group, Munich.

Cooper, D., Grey, S., Raymond. G., Walker, P. (2005). *Project risk management guidelines: Managing risk in large projects and complex procurements*, John Wiley & Sons Ltd.

Dalalah, D, AL-Oqla, F., Hayajneh, M. (2010). "Application of the Analytic Hierarchy Process (AHP) in multi-criteria analysis of the selection of cranes". *Jordan Journal of Mechanical and Industrial Engineering*, Vol. 4, No. 5, pp 567-578.

Duzgun, H.S.B, Einstein, H.H. (2004). "Assessment and management of roof fall risks in underground coal mines". *Safety Science*, Vol. 42, No. 1, PP 23– 41.

El-Sayegh, S.M. (2007). "Risk assessment and allocation in the UAE construction industry". *International Journal of Project Management*. Vol. 26, No. 4, pp 431-438.

Jannadi, O.A. (2008). "Risks associated with trenching works in Saudi Arabia". *Building and Environment*, Vol. *43, No.* 5, pp 776-781.

Kim, H., Hwang, E., Kim, Z. (2006). "The model tests for the damage assessment of brick structures in urban tunneling". *Tunnelling and Underground Space Technology*, Vol. 21, No. 3, pp 305-305.

Perlite Construction Company. (2015). Online at http://www.perlite-co.com/Projects/Tohid/lang/En. Accessed on March 1, 2015.

Reilly, J., Brown, J. (2004). "Management and control of cost and risk for tunneling and infrastructure projects". *Tunnelling and Underground Space Technology*, Vol. 19, No. 4, pp 330-337.

Reilly, J., Parker, H. (2007). "Benefits and life-cycle costs of underground projects". *Proceedings of the AITES-ITA World Tunnel Congress*, Prague, Czech Republic, Vol. 1, pp. 679–684.

Sanchez, M.A., Foyo, A., Tomillo, C., Iriarte, E. (2007). "Geological risk assessment of the area surrounding altamira cave: a proposed natural risk index and safety factor for protection of prehistoric caves". *Engineering Geology*, Vol. *94, No.* 3, pp 180-200.

Son, M., Cording, E.J. (2006). "Tunneling, building response, and damage estimation". *Tunnelling and Underground Space Technology*, Vol. 21, No. 3, pp 326-326.

Vesley, D.W., Dugan, D.J., Fragole, J., Minarik II, J., Railsback, J. (2002). *Fault tree handbook with aerospace applications*. NASA Office of Safety and Mission Assurance, NASA Headquarters, Washington DC, 20546.

Accident Analysis of Unsignalized Intersections

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Abstract
Accidents are rare events and the accidents that involve slight or no personal injury often remain unreported. In most Asian countries accident data contain some errors which render it useless for analysis. This gives rise to the problem of data scarcity for roadway facilities such as unsignalized intersections. Lack of literature on this issue has provided the motivation for this study. This paper aims to evaluate the effect of traffic parameters such as volume, speed and spacing between vehicles on the accidents that occur at unsignalized intersections. The data set utilized for this research contains very low sample size (n = 14). Relationship between the crash frequency and the traffic parameters is explained using graphical analysis. The ratio between the traffic that moves in opposite direction was introduced to examine the effect of speed, volume and spacing on accidents. Sites that had volume ratio greater than one had mean accident frequency twice as much as compared to those that had less than one. Sites with speed ratio greater than one had 20% less mean accident frequency as compared to those that had less than one. Sites that had spacing ratio less than one had mean accident frequency twice as much as compared to those that had greater than one. It was concluded that near to far traffic ratios are helpful for the analysis of low sample size data.

Keywords
Volume, speed, spacing between vehicles, data segregation, ratio

1. Introduction

Despite all the care taken in the design of roadway amenities, traffic accidents do occur. Irrespective of the degree of sophistication involved in the management of fixed and flow facilities of road network incidents happen, especially on intersections which are particularly dangerous sectors of the traffic infrastructure (Louveton et al., 2012). Although they are rare events and accidents that involve slight or no personal injury often remain unreported. Accident analysis is necessary to explore the flaw behind their occurrence, with respect to the user and the system, and to formulate future remedial measures. In low and middle income countries the little accident data that is available contains errors which render it useless for analysis. This gives rise to the problem of data scarcity for particular roadway facilities such as unsignalized intersections. Lack of literature that addresses this issue has provided the motivation for this study. It is mentioned in the literature that the frequency of accidents increase with the increase in volume of traffic (Turner and Nicholson 1998). Similarly the frequency of accidents increases with the increase in speed (Spek et al., 2006). But the account of gap between vehicles is still to be explored extensively. This paper aims to evaluate the effect of traffic parameters such as volume, speed and spacing/gap between vehicles on the accidents that occur at access points or unsignalized intersections. Any accident study that involves a sample size less than 60 is considered as fairly low as evident from Lord (2006). For researches that involve driver behavior to be analyzed using Driver Behavior Questionnaire (DBQ), the benchmark is even higher, that is, 349 data points (De Winter et al., 2009) as stated in De Winter (2013) . The data set utilized for this research contained very low sample size, which were 14 sites only. Such small amount of data points makes them inappropriate for the development of sound 'Safety Performance Functions'. Therefore, first they were graphically analyzed with respect to their magnitude. Thereafter a new parameter was introduced into the analysis, known as the near to far ratio. These ratios were calculated for all the three traffic variables and their effect on the corresponding accident frequencies was analyzed.

2. Methodology

Several methods are available for traffic data collection. Spot speed can be collected using the 'Stop Watch' method (IDOT, 2002) which involves two observers that note the time required to cross a certain length of road for a particular vehicle. Another method is to use 'Radar Meter' (IDOT, 2002). Volume can be collected manually using tally marks or mechanical counters (IDOT, 2002). Digital data loggers can also be used to record the type and volume of vehicles. Gap or spacing between vehicles can also be noted manually, but it is extremely difficult for high volume roads that have smaller gaps between vehicles. Therefore, traffic data was collected using MetroCount MC 5600 for this study (MetroCount®, 2002). These data loggers have the ability to record multiple traffic parameters such as speed, spacing between vehicles, headway, type and number of axles of each vehicle, direction of travel and the time the vehicle passed. The particular version of equipment used for this study could not classify non-motorized vehicles such as bicycles and animal driven vehicles like bullock-carts and donkey-carts.

After the collection of traffic data on 14 intersections, it was analyzed with respect to the number of accidents occurred on each site. Accident data was acquired from the Malaysian Institute of Road Safety Research (MIROS). Descriptive analysis was performed on all the three parameters mentioned above. For the analysis of Volume, speed and spacing; sites were arranged in ascending order with respect to their magnitude and their corresponding accident frequencies were examined. The volume, speed and spacing between vehicles whose direction of travel is near to the point where the minor road merges with the major road were classified as near side volume, speed and spacing respectively. The traffic parameters for the vehicles travelling in the opposite direction of near side vehicles were classified as far side volume, speed and spacing respectively (Ahmed et al., 2015). The near and far side directions are illustrated in Figure 1. Ratios were calculated for near side to far side direction of travel and accident frequencies were then analyzed with respect to near to far volume, speed and spacing ratios respectively.

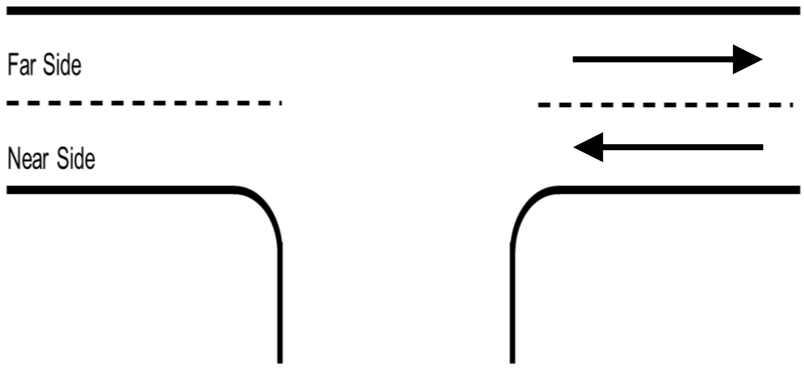


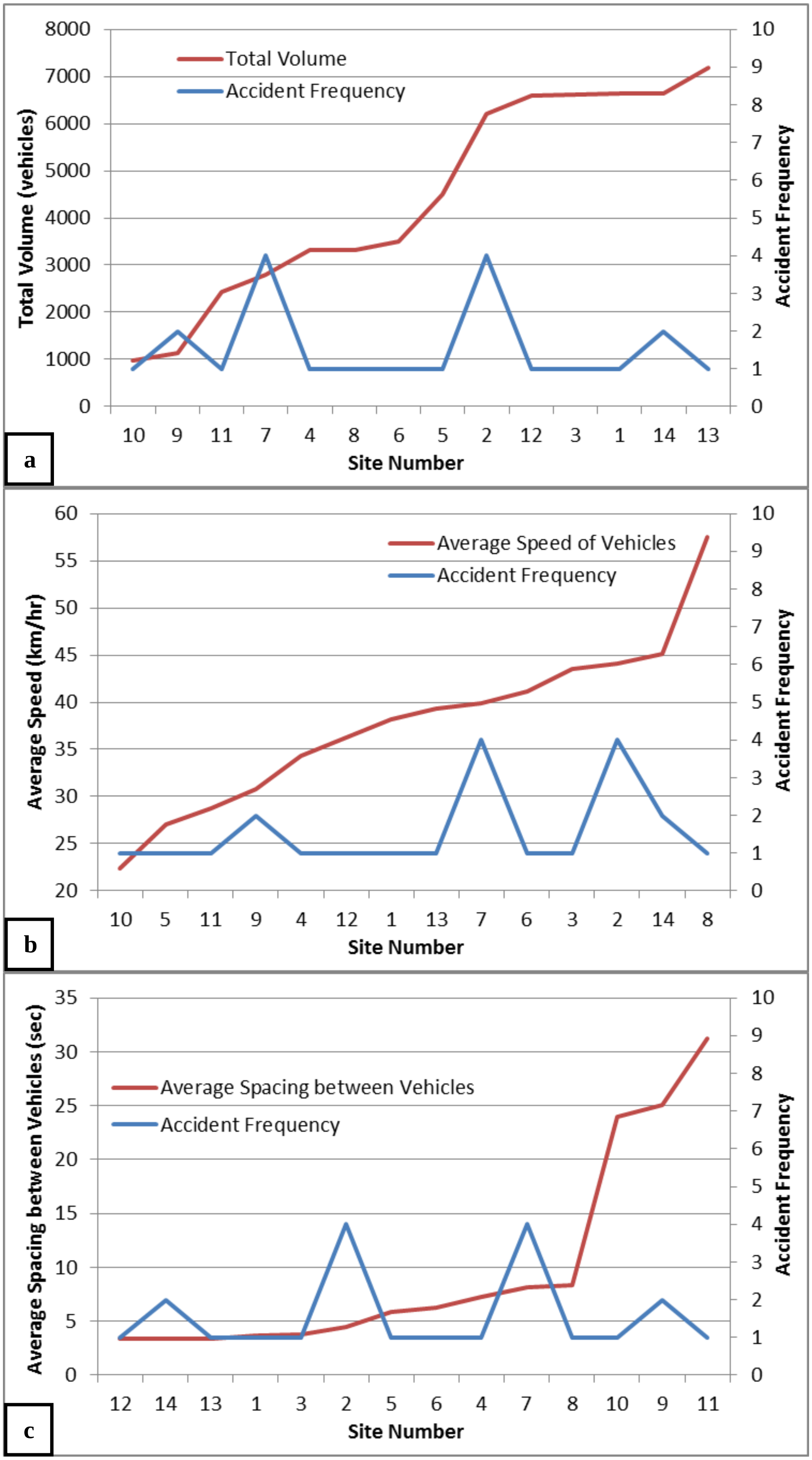
Figure 1. Typical Intersection indicating Near and Far side direction

3. Results and Discussion

The results comprised of two different parts. First the graphical analysis of the data is presented and then the commentary on the effect of the ratios calculated is discussed in the subsequent sections.

3.1 Graphical Analysis

As mentioned in the literature accident frequency is directly proportional to the volume and speed of traffic and it is perceived by the author that it is inversely proportional to the gap between vehicles. It means that the higher the volume and speed of vehicles the higher will be the accident frequency and the higher the spacing between vehicles the lower will be the accident frequency. Therefore, graphs were plotted for accident frequencies versus traffic variables. The results were neither in compliance nor in complete contradiction with the assumptions stated above. Sites with both high frequencies as well as low frequencies were observed as the volume ascended from 970 vehicles to 7182 vehicles, as shown in Figure 3(a). Multiple accidents were observed on sites with number of vehicles less than 3000 as well as greater than 6000 during the peak period, that is, from 6:30 to 9:30 a.m. Similarly in terms of speed, sites that experienced two accidents were observed on intersections with major road speeds less than 31 km/hr as well as greater than 45 km/hr, as shown in Figure 3(b). However some compliance with the basic assumption was seen in terms of speed as the sites that experienced higher frequencies were observed to have higher mean speeds. In terms of gap also, both high and low accident frequencies were observed on sites that had gaps higher than 24 seconds and lower than 5 seconds. However most of the sites that had a higher accident frequency had gaps less than 8.5 seconds between vehicles that traveled through them, as shown in Figure 3(c).



Total Volume
Accident Frequency
Total Volume (vehicles)
Accident Frequency
8000
7000
6000
5000
4000
3000
2000
1000
0
10
9
8
7
6
5
4
3
2
1
0
10 9 11 7 4 8 6 5 2 12 3 1 14 13
Site Number
a
Average Speed of Vehicles
Accident Frequency
Average Speed (km/hr)
Accident Frequency
60
55
50
45
40
35
30
25
20
10
9
8
7
6
5
4
3
2
1
0
10 5 11 9 4 12 1 13 7 6 3 2 14 8
Site Number
b
Average Spacing between Vehicles
Accident Frequency
Average Spacing between Vehicles (sec)
Accident Frequency
35
30
25
20
15
10
5
0
10
9
8
7
6
5
4
3
2
1
0
12 14 13 1 3 2 5 6 4 7 8 10 9 11
Site Number
c

Figure 3. (a). Accident Frequency versus Total Traffic Volume for each site. (b). Accident Frequency versus Average Speed for each site. (c). Accident Frequency versus Average Spacing between Vehicles for each site.

3.2 Near to Far Ratios

A remarkable relationship between accident frequency and the new variable, that is, the ratio between the near to far side volume was observed. Multiple accidents or data points that had accident frequencies greater than one were observed only on sites that had near to far volume ratio greater than one, as shown in Figure 4(a). From the above analysis it is inferred that intersections where the volume of traffic that moves in the near side direction was higher than the volume of traffic that moves in the far side direction experience more accidents as compared to the ones in which the situation was vice versa. Contrary to it, most of the sites with multiple accidents were observed where the average speed of vehicles that move in the near side direction was less than the average speed of vehicles that move in the far side direction, as shown in Figure 4(b). In terms of spacing or gap between vehicles, the sites that experienced multiple accidents were the ones that had near to far gap ratio less than one, as shown in Figure 4(c). These results were further strengthened when the data was divided into groups with respect to ratios less than one and greater than one and their respective mean accident frequencies were calculated. Sites that had volume ratio greater than one had mean accident frequency twice as much as compared to those that had less than one. Sites with speed ratio greater than one had 20% less mean accident frequency as compared to those that had less than one. Sites that had spacing ratio less than one had mean accident frequency twice as much as compared to those that had greater than one. From the above results it can be concluded that near to far traffic ratios are helpful for the analysis of low sample size data.

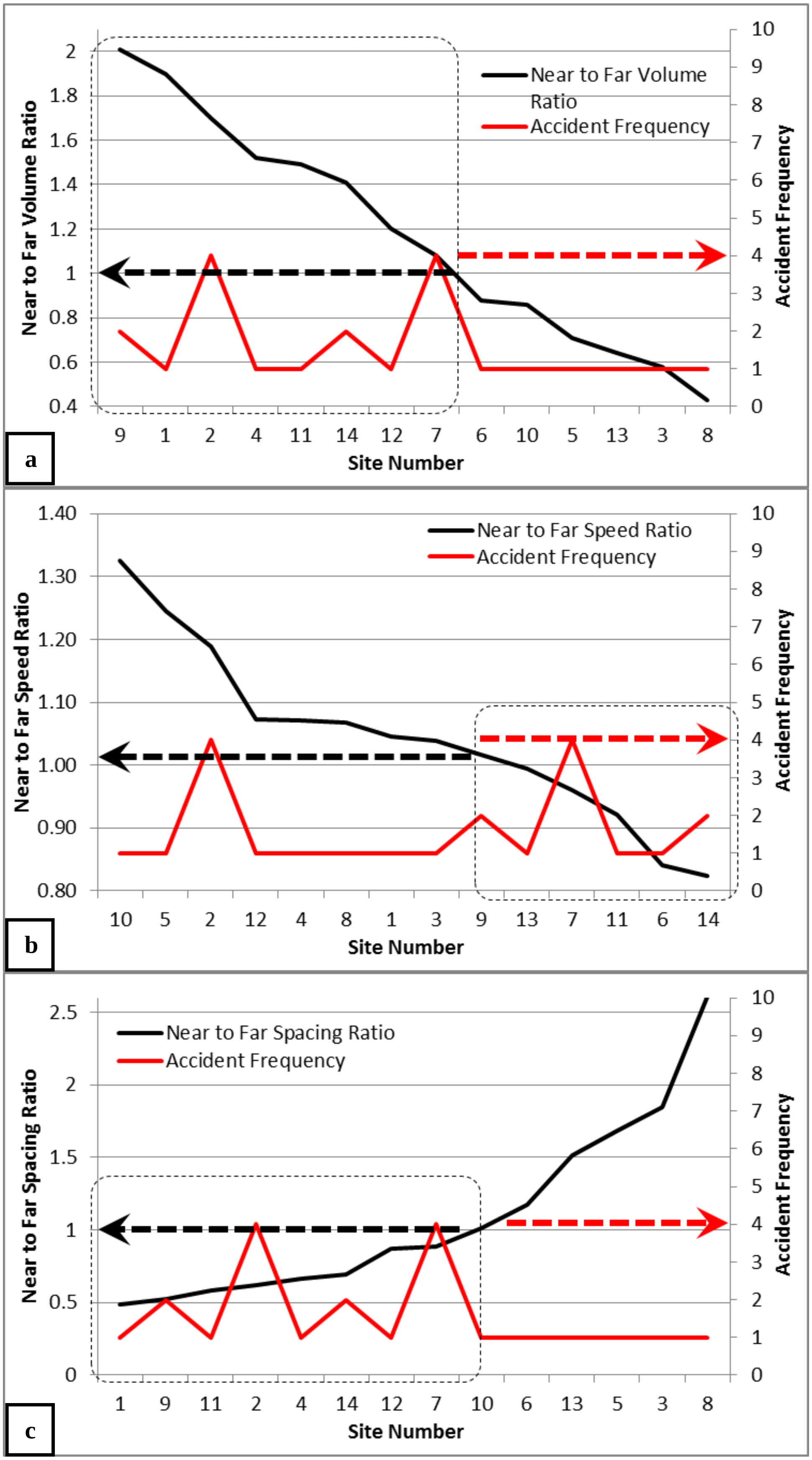

Near to Far Volume Ratio
Accident Frequency
Near to Far Volume Ratio
Accident Frequency
Site Number
a
Near to Far Speed Ratio
Accident Frequency
Near to Far Speed Ratio
Accident Frequency
Site Number
b
Near to Far Spacing Ratio
Accident Frequency
Near to Far Spacing Ratio
Accident Frequency
Site Number
c

Figure 4. (a). Accident Frequency versus Total Traffic Volume for each site. (b). Accident Frequency versus Average Speed for each site. (c). Accident Frequency versus Average Spacing between Vehicles for each site.

4. Conclusion

Traditional traffic parameters such as volume, speed and spacing between vehicles are an effective tool for safety analysis, but ungrouped data and low sample size were found to be the reason due to which these parameters failed to provide definite results to comment on the trend of accident frequency. However, segregation with respect to the direction of travel and grouping the data helped to obtain an explanation about the relationship between them. Increase in volume and speed causes an increase in accident frequency while increase in spacing between vehicles reduces it. It was found that intersections that experienced more than one accident had near to far volume, speed and spacing between vehicle ratios greater than, greater than and less than one respectively. This indicates that variation in traffic that moves in opposite direction has a strong effect on the occurrence of accidents at unsignalized intersections. It is recommended that the effect of variation of traffic with respect to travel direction on the behavior of minor road drivers should be explored further.

5. Acknowledgment

The authors are obliged to the Malaysian Institute of Road Safety research (MIROS) for providing accident data for this research.

6. References

A. Ahmed, A.F.M. Sadullah, A.S. Yahya. (2015). “Field study on the behavior of right-turning vehicles in Malaysia and their contribution on the safety of unsignalized intersections”. *Transportation Research Part F*, DOI:10.1016/j.trf.2015.03.006

De Winter, J.C.F. (2013). “Small sample sizes, overextraction, and unrealistic expectations: A commentary on M. Mattsson”. *Accident Analysis and Prevention*, Vol. 50, pp. 776–777.

De Winter, J.C.F., Dodou, D., Wieringa, P.A. (2009). “Exploratory factor analysis with small sample sizes”. *Multivariate Behavioral Research*, Vol. 44, pp. 147–181.

Lord, D. (2006). “Modeling motor vehicle crashes using Poisson-gamma models: Examining the effects of low sample mean values and small sample size on the estimation of the fixed dispersion parameter”. *Accident Analysis and Prevention*, Vol. 38, pp. 751–766.

Louveton, N., Montagne, G., Berthelon, C., Bootsma, R.J. (2012). “Intercepting a moving traffic gap while avoiding collision with lead and trail vehicles: Gap-related and boundary-related influences on drivers’ speed regulations during approach to an intersection”. *Human Movement Science*, Vol. 31, pp 1500–1516.

MetroCount®. (2002). “MetroCount Roadside Unit Operator Guide”. *Microcom Pty Ltd., Australia*. http://metrocount.com/downloads/MC5600%20RSU%20Operator%20Guide.pdf

IDOT. (2002). “Handbook of simplified practice for traffic studies”. *Iowa Department of Transportation*, Project TR-455, Iowa State University, Institute for Transportation, IOWA, USA. http://www.ctre.iastate.edu/PUBS/traffichandbook/index.htm

Spek, A. C. E., Wieringa, P. A., Janssen, W. H. (2006). “Intersection approach speed and accident probability”. *Transportation Research Part F*, Vol. 9, pp 155–171.

Turner, S. and Nicholson, A. (1998). “Intersection accident estimation: the role of intersection location and non-collision flows”. *Accident Analysis and Prevention*, Vol. 30, No. 4, pp. 505–517.

Critical Geometric Parameters Causing High Fatalities in Karachi Pakistan

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Abstract
Road traffic accidents are responsible for about 1.3 million deaths annually in Asia, and over a thousand deaths in Karachi, the largest metropolis of Pakistan. Imperfections in road geometric design, coupled with ineffective implementation of relevant traffic rules and regulations, are included among major causes of accidents. The main objective of this paper is to identify critical geometric parameters causing high number of accidents in Karachi for effective measures to be devised to reduce the number of fatalities. RTI (Road Traffic Injuries) data collected from 2008-2011 was analyzed. On the basis of detailed black spot analysis, field surveys were carried out at fourteen (14) selected locations on major arterials of Karachi. Chi square analyses were performed to ascertain relationship between the number of fatal accidents and responsible geometric parameters.

The results and key findings of the analysis included identification of critical highway geometric design elements in terms of road traffic accidents, the frequency and severity level of each identified design element. The relation between speed and crash occurrence is examined by relating the crashes to the difference between observed and safe speed. Statistically significant relationships are found between road accidents and road geometric design elements among which the median height and the number of lanes have high correlation with the number of accidents on a particular road section.

Keywords
Road traffic accidents, road geomteric design, Chu square analyses, statistically significant relationships, fatalities.

1. Introduction

According to recent studies road traffic accidents have been responsible of about 1.3 million deaths in Asia and 1,100 deaths in the metropolis of Karachi. As of Karachi serious flaws in infrastructure coupled with ineffective implementation of relevant laws have been identified as the major causes of accidents.

The engineering concern is, therefore, demands to study in detail the flaws related to design of road infrastructure, especially the geometric components which are either ill-designed or ineffective in implementing the traffic operations they are intended for.
This paper seeks to find critical road geometric parameters directly or indirectly responsible for deterioration of traffic safety conditions. Four years RTI (Road Traffic Injuries) data from 2008-2011 is analyzed. In general, numbers of crashes are affected by three factors:

- The road environment or condition of road
- Vehicle factor or the condition of vehicle using the road system
- Human factor or the skills, concentration and physical state of road users.

There is a statistical significant relationship between road geometric factor and accident rate which has been studied extensively in this project with respect to roadways and roadside features. The objectives of the study include:

- To investigate the role of geometric parameters in causing traffic accident.
- Supplement black spot data with field study to be able to find root cause of traffic accidents.
- To build a relationship between road geometry and black spots.

The scope of this study is listed below (Marium, et. Al., 2012):

- Data available from road safety research RTIRPC is the basis of identifying black spot locations; whereby data have been collected from five trauma receiving hospitals of Karachi namely JPMC, CIVIL, ABBASI SHAEED, LIAQUAT NATIONAL and AGA KHAN HOSPITALS. These five hospitals are selected because most of the accidents are recorded in these five hospitals and only few accidents are reported in any other local hospitals.
- Field study of selected black spots and collection of geometric parameters data
- Graphical analysis and statistical analysis by chi square testing.

2. Literature Review

Available studies, both recent and past, have dwell upon the importance of highway geometric design parameters in the overall safety of road users.

Karlaftis and Golias (2002) summarized in-depth analysis of the relationship between rural road geometric characteristics, accident rates. They developed methodology that quantitatively assesses the effects of various highway geometric characteristics on accident rates as well as forecasting accident rates on rural roads.

In a recent study carried out in Ghana, Africa, road traffic crashes were analyzed for 76 rural highway sections and the experimentation parameters included injury crash data, traffic flow and speed data, and roadway characteristics and road geometry data. Traffic flow, highway segment length, junction density, terrain type and presence of a village settlement within road segments were found to be statistically significant explanatory variables ($p < 0.05$) for crash involvement. (Ackaah and Salifi (2011))

In Ireland, A method of estimating geometric data from digital maps was implemented on some 70km of highways. 19 curves and 19 tangents were then selected to represent the overall geometric makeup of the highway. Numerous geometric indices were measured on site. A spot speed survey was conducted at the midpoint of each tangent and curve and operating speed was calculated for each site. The spot speed survey is used to estimate the operating speed on straights (tangents). The results showed that a relationship exists between geometric design consistency and safety. (Watters (2004)). Rahil, et.al. (2014), categorized accidents in Al-Sail Road in Taif city in KSA, and developed statistical models that can be used in the prediction of the expected number of all of these categories of accidents. Geometric design consistency studies can be used to identify inconsistent sections on highways, which can then be targeted for improvement. Inadequate geometric design can lead to severe accidents. (IHSDM, 2010)

3. Methodology

Four years RTI (Road Traffic Injuries) data from 2008-2011 is analyzed. In general, numbers of crashes are affected by three factors:

- The road environment or condition of road
- Vehicle factor or the condition of vehicle using the road system
- Human factor or the skills, concentration and physical state of road users.

Figure 1 highlights the description of the steps of methodology.

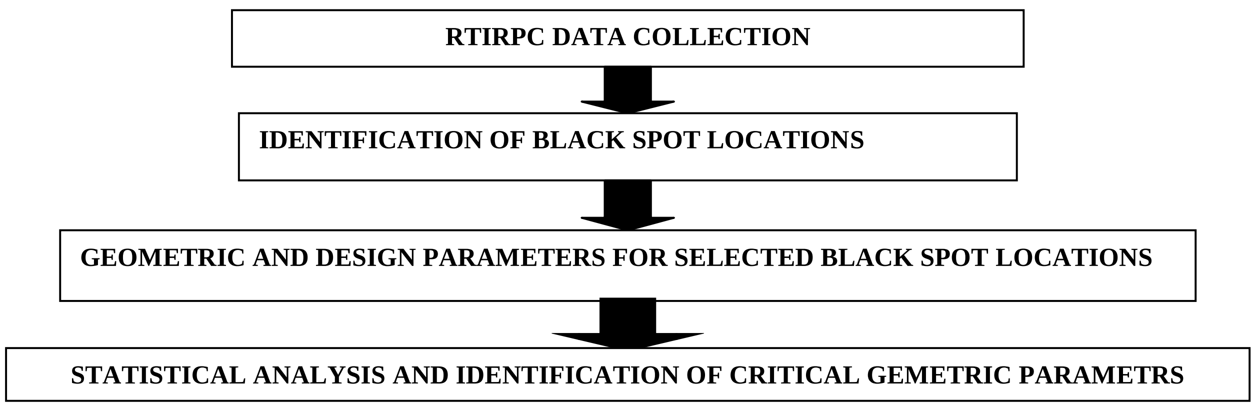

Figure 1 Methodology Framework

3.1 Identifying Black Spots Locations

When data analysis was completed after that the black spot locations were identified, from the analyzed data location which were having the greatest number of accidents were selected as the black spot location in this way 14 black spot locations were identified, different factors of these roads were identified using Google earth. At each location 0.5 km of the stretch was selected for investigation and field survey. Those black spot locations are in **Error! Reference source not found.**.

3.2 Field Survey of the Locations

A field survey of the location was carried out to identify the various geometric parameters of the identified black spot locations. From field survey various factors which were identified:-

- Lane width and number of lanes
- Number of turnings on road
- Wrong way on roads
- Speed
- Median height

- Number of local streets on each road
- Conflicting point

Figure 2 and Figure 3 depict some of the site conditions on the locations covered in field survey.

Table 1 Selected Black Spot Locations

S.NO	LOCATIONS	TOTAL ACCIDENTS
		2009-2011
1	Jinnah Bridge	169
2	Nursery	144
3	2minute Chowrangi	20
4	NaganChowrangi	55
5	Tibet Centre	48
6	NumaishChowrangi	466
7	Grumandir	128
8	Akhter Colony	108
9	Singer Chowrangi	29
10	ChamraChowrangi	51
11	Siemens Chowrangi	47
12	Nazimabad no. 7	130
13	Jama Cloth	98
14	UnderBaloch colony fly over	96

Lane Width and Number of Lanes

Lane width and number of lanes were identified by field survey of the location. Lane width was measured during the field survey by theodolite. Lane width was a very important factor in determining the rate of accidents due to geometric parameter.

Number of turnings on road

Number of turnings can be defined as the number of approaches on the roads, which means vehicle coming from one stream of road can turn into how many directions or vehicle can be, merged and diverged in how many directions. Number of turnings can be very critical therefore a number of turnings on 0.5 km of stretch were also observed during the field survey of the locations.

Wrong way on roads

Vehicle movements were also observed during the field survey of the black spot locations, it was observed that almost on every location there was wrong way traffic movement such as taking wrong way movement from U-turns, service roads, main roads and etc.

Speed

Speed can be a very important factor that can cause accidents. Speed was also measured during the field survey with a speed gun, speed of every vehicle such as truck, car, bus, motor bike, truck, auto was noted and after that average speed of every vehicle for every location was calculated.

Median height

The median was measured to find the glare effect of vehicle during night time. Median height was measured with the help of measuring tape during the field survey of the locations.

Number of local streets on each road

Numbers of local streets were also observed in the field survey of the location, because the number of local streets approaching main roads can cause accidents such as there can be sight obstruction, illegal movements, wrong way movements etc.

Conflicting points

Conflicting points of the roads were also observed during the field survey of the black spot locations, single stream of road can have one or more than one conflicting points and that can be a cause of accidents.

Figure 2 Heavy Vehicle Movement **Figure 3 Traffic Mix**

4. Data Analysis

Explorative statistical analysis of various geometric design parameters identified earlier were performed to identify relation between critical road geometric parameters and average rate of accidents. Furthermore the analysis also lead to formulation of statistical hypotheses for carrying out chi square testing.

Figure 4 provides a sample of such analysis. On x-axis geometric parameters are taken, the geometric parameter which had been examined on blackspot roads were lane, speed, number of local streets, number of turning, number of conflicting points and median height. On y-axis average rate of accident are taken, these rates are the average values of accidents occur due to time, accidents at intersection, accidents at midblock, victim of accident and vehicle of accident. The values for accident rate are in decimal because an average value of data has been calculated. Only those parameters are shown which were later found statistically significant. Table 2 and **Error! Reference source not found.** provide some insight to the data collected and summarized.

Hypothesis testing approach was applied to find statistical significance between accident trends and various geometric design parameters. **Error! Reference source not found.** provides the formulation of statistical analysis development matrix.

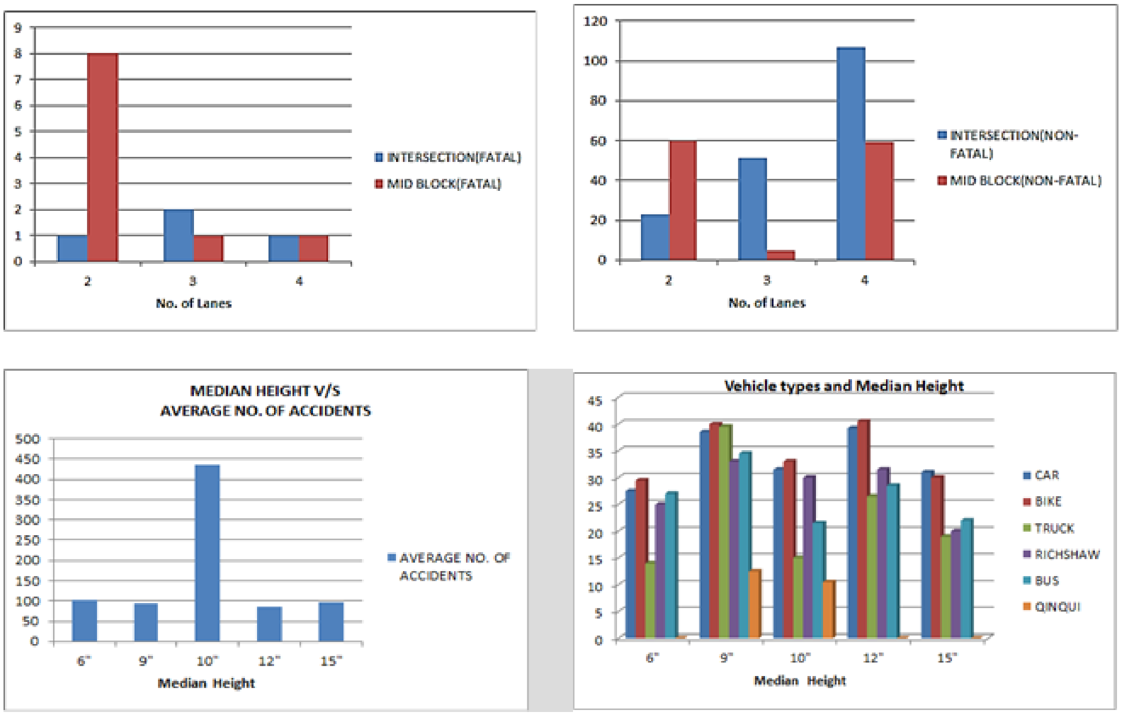

Figure 4 Graphical analysis of parameters

5. Statistical Significance Analysis

5.1 Result of Statistical analysis

Chi square test was performed for statistical analysis and it was found from the analysis that:

1. The average rate of accidents is dependent on the number of lanes
2. No. of lanes are dependent on total no. of accidents but the combination of time of accidents and the number of lanes is significantly independent.
3. No. of lanes are independent of non-fatal daylight accidents.
4. No. of lanes are dependent on driver of two wheeler accidents for non-fatal accidents.
5. No. of lanes are dependent on motorbike accidents for non-fatal.
6. The average rate of non-fatal accidents at an intersection is dependent on the number of lanes.

5.2 Critical geometric parameters

From statistical analysis it may be concluded that:

- No. of lanes are dependent on total no. of accidents, average rate of accidents, average rate of non-fatal accidents at an intersection, driver of two wheeler accidents for non-fatal accidents, motorbike accidents for non-fatal.
- The median height is dependent on average rate of accidents, accidents due to motorbikes, motorbike accidents (for non-fatal), accidents occur at dusk, day and dark time, accidents at midblock of road (for non-fatal accidents), accidents of driver of two wheeler, pillion passenger and pedestrian.
- The average rate of nonfatal accidents of driver of two wheeler is dependent on the number of conflicting points

- The number of local streets is dependent on motorbike accidents.
- The number of turnings is dependent of accidents at intersection.

Table 3 Geometric Parameters and Types of Accidents

LOCATION	No OF LANE	MEDIAN HEIGHT	TOTAL FATAL	TOTAL FATAL	TOTAL NON FATAL	TOTAL NON FATAL	FATAL AGE						NON FATAL AGE					
			MALE	FEMALE	MALE	FEMALE	0-10	11-20.	21-30	31-40	41-50	>50	0-10	11-20.	21-30	31-40	41-50	>50
Jinnah Bridge	2	6"	9	0	108	9	1	2	6	2	1	5	9	36	61	29	13	11
Akhter colony	3	6"	7	1	103	21	0	0	3	1	1	3	8	35	42	18	9	8
Tibet center	3	6"	2	0	42	4	0	0	1	1	0	0	0	13	20	5	4	3
AVERAGE 6"			6	0.3	84.3	11.3	0.3	0.6	3.3	1.3	0.6	2.6	5.6	28	41	17.3	8.6	7.3
2 min chowrangi	4	9"	1	1	47	10	0	0	0	0	0	2	3	12	27	7	4	7
Chamra chowrangi	4	9"	8	0	106	14	0	1	3	2	0	2	3	27	41	25	16	8
AVERAGE 9"			4.5	0.5	76.5	12	0	0.5	1.5	1	0	2	3	19.5	34	16	10	7.5
Nagan chowrangi	4	10"	0	0	43	12	0	0	0	0	0	0	2	18	20	9	2	4
Numaish chowrangi	4	10"	4	0	711	104	0	0	2	1	1	0	41	127	321	128	61	38
AVERAGE 10"			2	0	377	58	0	0	1	0.5	0.5	0	21.5	72.5	170.5	68.5	31.5	21
Nazimabad number 7	3	12"	1	0	105	24	0	0	1	0	0	0	7	23	44	35	10	15
Siemens Chowrangi	3	12"	0	0	42	0	0	0	4	0	1	0	0	6	22	10	1	2
Singer chowrangi	3	12"	1	0	27	4	0	0	0	0	0	1	1	6	11	8	3	2
Gurumandir	4	12"	2	0	46	3	0	1	0	0	0	1	3	8	13	17	3	5
Nursery	4	12"	2	0	129	12	0	0	2	0	0	0	3	26	47	30	18	17
Under baloch fly over	4	12"	2	0	92	26	0	0	2	0	1	0	5	20	38	23	17	18
AVERAGE 12"			1.3	0	73.5	11.5	0	0.16	1.5	0	0.3	0.3	3.2	14.8	29.2	20.5	8.67	9.8
MA jinnah road	4	15"	0	0	86	10	0	0	0	0	0	0	4	25	38	13	8	8
AVERAGE 15"			0	0	86	10	0	0	0	0	0	0	4	25	38	13	8	8

Table 4 Geometric Parameters and Road Users

LOCATION	No OF LANE	MEDIAN HEIGHT	Fatal Patient was					Non fatal Patient was				
			Driver of 2wheelers	Pillion Passenger	Driver of 4Wheelers	Pasenger	Pedestrian	Driver of 2wheelers	Pillion Passenger	Driver of 4Wheelers	Pasenger	Pedestrian
Jinnah Bridge	2	6"	10	4	0	0	3	87	34	3	15	10
Akhter colony	3	6"	2	0	0	0	6	56	31	1	8	24
Tibet center	3	6"	0	0	1	0	0	25	8	0	2	7
AVERAGE 6"			4	1.3	0.3	0	3	56	24.3	1.3	8.3	13.6
2 min chowrangi	4	9"	0	0	0	0	0	35	12	1	3	11
Chamra chowrangi	4	9"	5	2	0	0	1	48	17	2	9	41
AVERAGE 9"			2.5	1	0	0	0.5	41.5	14.5	1.5	6	26
Nagan chowrangi	4	10"	0	0	0	0	0	25	13	1	7	9
Numaish chowrangi	4	10"	3	0	0	0	5	436	151	4	63	130
AVERAGE 10"			1.5	0	0	0	2.5	230.5	82	2	35	69.5
Nazimabad number 7	3	12"	1	0	0	0	0	70	31	2	8	17
Siemens Chowrangi	3	12"	2	0	0	2	1	29	6	2	10	4
Singer chowrangi	3	12"	0	0	0	0	1	17	3	1	2	7
Gurumandir	4	12"	0	1	0	0	1	32	7	0	0	10
Nursery	4	12"	0	0	0	0	3	69	13	3	15	38
Under baloch fly over	4	12"	0	0	0	0	2	47	16	1	5	43
AVERAGE 12"			0.5	0.16	0	0.3	1.3	44	12.6	1.5	6.66	19.8
MA jinnah road	4	15"	0	0	0	0	0	41	22	1	9	23
AVERAGE 15"			0	0	0	0	0	41	22	1	9	23

6. Conclusions And Recommendations

This paper has identified critical highway geometric design elements in terms of road traffic accidents and investigated the frequency and severity level of each of the identified critical geometric design elements. It provided a basis for the importance of engineering design for highway safety. A strong association between adverse road geometry and traffic accident's occurrence has been recognized and in order to achieve this, the statistically significant relationships between road accidents and road geometric design has been identified rather extensively for specific roadway and roadside features.

6.1 Key findings

1. There is a strong relationship between road traffic accidents and road geometry.
2. Among some of the parameters analyzed in the study, there is a highlighting correlation between the number of accidents and the number of lanes on a particular road section and also with the number of conflicting points.
3. This relationship can be visualized by small road surveys with the help of easy and hand equipped survey tools and techniques.

6.2 Recommendations d Design Guidelines in the Context of Developing Countries.

While this paper provided relation between the black spot road accidents and the geometric design of roads in Karachi has been valuated with the help of statistical analysis methods, there are numerous techniques for the determination of fundamental relationships between road geometric design parameters and road design. In further studies Geometric design consistency studies can be used to identify inconsistent sections on highways, which can then be targeted for improvement. Consequently local authorities can make optimal use of available resources and can considerably improve the safety performance of the highway.

References

Abo El-Hassan M. Rahil; Moustafa A. Kamel; Emad A. Hamouda; Badr T. Alsulami, (2014), Effect of geometric elements on Accidents' Rates, International Journal of Engineering Research and Development, e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.comVolume 10, Issue 3 (March 2014), PP.71-75

Interactive Highway Safety Design Model (IHSDM), Administration Tool, ITT Corporation, Information Systems, P.O. Box 39550, Colorado Springs, CO 80949-9500, Version 6.0.0, Jul 15, 2010

Karlaftis MG1, Golias I (2002) Effects of road geometry and traffic volumes on rural roadway accident rates. Accid Anal Prev. 2002 May;34(3):357-65.

Marium Fatima, Ayisha Irshad, Maha Heyat, Syeda Batool, Madiha Erum (2012), Investigation Of The Relationship Between Black Spot Road Accidents And Geometric Design Of Roads In Karachi, A Final Year project, submitted to Department of Civil Engineering, NED University of Engineering and Technology, Karachi (2012) [unpublished]

Watters, P M O Mahony, (2004) Trinity College Dublin, IE, The relationship between geometric design consistency and safety on rural single carriageways in Ireland, 2004

Williams Ackaah, Mohammed Salifu, (2011) Crash prediction model for two-lane rural highways in the Ashanti region of Ghana ; IATSS Research; Volume 35, Issue 1, July 2011, Pages 34–40