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WATER SUPPLY AND HYGIENIC CONDITION OF URBAN SLUMS: A CASE STUDY OF RAJSHAHI CITY

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ABSTRACT
The number of slums has significantly increased in Bangladesh over the last three decades by heavy influx of migrants from rural areas. These increased figures have exerted severe pressure on urban housing and public services in Rajshahi City Corporation (RCC) with which the expansion of infrastructure and basic urban services could not cope. As a result hazardous environmental condition occurs. Against this background the study was performed. Data has been collected from field survey, some secondary sources and focused group discussion. This study involved 5324 households (15 slums) of RCC slums, Bangladesh. This study shows that due to economic constraints and lack of basic services such as water and sewerage, the urban poor often use inexpensive pit latrines and at the same time may draw domestic water from taps and nearby Padma river. This study reveals sanitary and hygienic practices of households in RCC slums and status of their domestic water sources. This paper has also explored that assessment of water resource availability and problems faced in getting safe drinking water and knowledge of the features of hygienic latrine; awareness about health. The paper may attribute to further research on water supply and sanitation study it will guide those who will work to improve the present.

INTRODUCTION

Rapid urban growth in a climate of economic constraints has resulted in the majority of residents in Bangladesh's large cities and an increasing proportion of Bangladeshi's overall, living in overcrowded slums. In these slums livelihood opportunities such as water supply and sanitation are poor. The situation of Rajshahi city is similar to other city situations in Bangladesh. There are about 15 slums (5324 households) in the Rajshahi City corporation area of varying sizes where the cities poor lived in [1]. The number of slum dwellers has been increasing in Rajshahi, a recent survey conducted by Bangladesh Bureau of Statistics and Centre for Urban Studies disclosed it. The population's increases but the services are not. Water supply facilities in terms of quality and quantity are almost necessary for assessing the living environment of the slum. In Bangladesh, over 97% of the population has access to tube-wells (hand-pumps), taps or ring wells. An effective lowered safe drinking water coverage to only 74% of the population. A large number of people use unsafe sources of water for personal and domestic needs like cooking, bathing and washing utensils, due to a lack of awareness about the safety of the water used for these purposes Sanitation facilities are the prime requirement for a healthy living environment. The sanitation systems found in Bangladesh are sewer system, septic tank, pit latrine, bucket latrine and others. About 13 corer people live in Bangladesh. Everyday these 13 crore people create average 30–50 thousand tons excreta. Poverty and lack of education are the causes of poor sanitation condition. For these reason environment is polluted dangerously. People leave excreta in the water and open space. In Bangladesh, only about 53% of the people have sanitary latrine and 39% people have unsanitary latrines. So, germs of excreta mix with air and pollute air. Among them most of the people are using hanging latrines which hang over river and water bodies. These latrines are not healthy for environment as well as human health. In many areas the sanitation coverage is much below the national coverage figure, only 13.5% in metropolitan slums. The populations of urban area increases but the services are not. Although located within city corporation limits, the slums and squatters facilities have limited access to the urban services [2]. These problems are acute in Rajshahi City but some other large metropolitan city has faced the same. These services are basic right for every urbanite, but the slum dwellers are not able to get these services. The study tries to find out the existing status of access of the slum dwellers to some selected urban services and explore the conditions and problems of such services in slum. The main goal of this study is to identify the status of water use, sanitation and hygienic condition of City Corporation slum.

METHODOLOGY

At first, the study topic has been conceptualized and then the objectives followed by the study area have been selected. After that data collection procedure follows which involves questionnaire preparation with the help of literature review and consultation with the supervisor.The primary data has been collected through household survey and the secondary data has been collected through some secondary sources (Internet, Rajshahi City Corporation office, Bangladesh Bureau of Statistics). The collected data has been analyzed with some statistical software (SPSS, MS Excel etc.).

RESULTS

Water supply and use

Perception of safe drinking water
Majority of the households of about 64% spontaneously has described that tube-well water as the safest drinking water. However, boiled water was thought to be safe by 9% of the households. Piped water as safe for drinking was mentioned more than 31%.

Sources of water for various uses
There are various sources of water such as tube-well, tap, river, pond, and well in slums areas. People in slum areas use these sources for various purposes such as drinking, bathing and washing clothes. Sources of water for various uses are described below.

Water sources for drinking purpose
The main sources of drinking water in slum area are the tube-well. For this purpose around 73% households use tube-well water, 26% people use tap water and other so on.

Water sources for washing cloths
Most of the households (above 41%) mentioned they used tap water for their washing clothes. River water is used by 32% and tube-well water is used by 21% household in the slum for the same purpose.

Water sources for bathing purposes

Most of the households (above 42 %) used tap water for their bathing purpose. The majority (33%) of the households described they used river water for bathing.

Ownership of water sources

Most of the households in slum area live below the poverty line. People in the slum area earn hand to mouth. It is impossible for them to install a single tube-well for water sources. For this they bought tap as singly or jointly or depend on City Corporation. About 43% of the households bought singly, 8% households jointly owned the water sources (tap or tube-well) and 49% were using it given by the city corporation (tube-well).

Storage of drinking water

In slum area water is not available as their demand. Only a few number of tube-well there is. For tap water, it comes particular times in a day. For this households in slum store drinking water to use it in off time. Different type of container used in storing drinking water, cooking pot is the most widely used container (36%) followed by pitcher (33%), jug/bottle (31%), and pot (16%).

Problems faced in getting drinking water

In this survey most of the householders reported that they faced problems in getting safe drinking water. Majority (62%) of the households (facing any problem) mentioned that they face water supply problem in particular time in a day and particular months of a year. 'Takes more time' (for queue, distance or less flow/discharge) is reported by more than 31% of the households. The respondents (28%) managed the problem by carrying water from distance. Others mostly managed the situation with hardship.

Distance of households from water sources

Mostly slum dwellers are dependent on tube-well water. However, all families do not have equal access to the tube-well water. This is mainly due to difference in the distance of the tube-wells from their individual houses. Usually women of slums collect water from the tube wells. As the sources are over populated they have to wait for a long time to collect a jar of water. More than one-third of the households had their source of drinking water available within 50 m to 100 m and majority (36%) within 20 m. But most of the people (35%) have to cross above 100 m to get water.

Condition of platform of water sources

In our observation, 63% platforms of the water sources were found unclean & unhealthy and rest of the 37% platform situation is good.

HOUSEHOLDS AND ENVIRONMENTAL SANITATION

Types of latrine

A few number (13%) of the households used apparently good latrines, which are not fully hygienic. It includes15% used open latrines and 72% used ring slab latrine without water seal.

Ownership of latrine

94% of the households owned the latrines they used either singly (82%) or jointly (12%). However, a few numbers (6%) of the latrines were owned by the city corporations.

Distance between latrine and tube-well

In this study it is observed the distance of latrines from the drinking water source. It is observed that 13% of the situation the distance between the drinking water source and the latrine is within 10m and 85% is situated greater than 10m.

Latrine used by children less than 5 years old

It is observed that children are generally used the yard and the places near the tube-wells for defecation. Data shows that only 42% of the children used latrine and those who do not use latrines; only 42% of their feces are disposed off in the latrine. Others are thrown to the drain, ditch or garbage stack.

Hygienic knowledge for wearing sandal while going to latrine

Majority (63%) of the member of households mentioned that wearing sandal while going to latrine. A significant proportion (49%) of the member of households could rightly mention the reason for wearing sandal.

Knowledge on the kind of disease caused by contaminated water

There is almost universal knowledge among the households from all contexts that contaminated water can cause jaundice. More than 58%of the households mentioned this. The second most (48%) mention the disease was diarrhea and 33% talk about dysentery and rest for the typhoid. The households seem to have fair knowledge on the mode of transmitting germs from human excreta.

Features of hygienic latrines

'Faces cannot visible' mentioned by 42% of the households. 'No foul smell' was mentioned by nearly same number of about 40% of the households. "Water sealed" was also mentioned about 24% of the households.

CONCLUSION

Due to the lack of sufficient water sources, most people of all slums use unsafe water sources like ponds, rivers and even ditches which cause sufferings from diseases. The results indicate that the majority of the households used ring slab latrines. The distance between the wells and the pit latrines was estimated to be generally short. This raises the risk of contamination of the water sources as coliforms migrate from the pit latrines to the wells. Types of hygienic latrine were found to be generally poor from observation and from responses.

REFERENCES

Department of Urban Planning And Development, Rajshahi city Corporation, Rajshahi, Bangladesh, November, 2011.

Elizabeth, W. K.M. and Augustine M. Ngindu," Quality of Water the Slum Dwellers Use: The Case of a Kenyan Slum."Journal of Urban Health: Bulletin of the New York Academy of Medicine, Vol. 84, No. 6, 2007.

M. Ahmed and Md. Rahman," Water Supply and Sanitation: Rural and Low Income Urban Communities",Dhaka, ITN-Bangladesh, 2003.

M. Ahmed & Hasin Jahan," Participatory management of Low-Cost Water Supply and Sanitation", Fourth Edition: May, 2010.

Rana, M.S. (2009)," Status of water use sanitation and hygienic condition of urban slums: A study on Rupsha Ferighat slum, Khulna", Town Planner, Meherpur Municipality, Meherpur 7100, Bangladesh, 2009.

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WATER REQUIREMENTS FOR VARIOUS CROPS AND IMPACT OF IRRIGATION IN BARIND AREA- AN EVALUATION BASED ON THE METEOROLOGICAL PARAMETERS

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ABSTRACT
The study was carried out during pre (1964-1985) and post project (1986-2008) of Barind Integrated Area Development Project (BIADP) to evaluate the impact of irrigation on meteorological parameters in Barind area, Rajshahi district, Northwest Bangladesh. The study was conducted to estimate the consumptive use (C_u) and Consumptive irrigation requirement (CIR) for rice, wheat and potato by Blaney-Criddle method. The consumptive use and crop water requirement were more before the implementation of the project but these were decreased after implementation of the project. Since agriculture is the mainstay for the economy, Bangladesh is very sensitive to impacts of climate change on the agricultural sector.

Keywords: Impact evaluation, Meteorological parameters, Water requirements, Blaney-Criddle method, BIADP.

INTRODUCTION

In order to achieve sustainable agricultural growth and to maintain ecological balance, the Barind Integrated Area Development Project (BIADP) under the Barind Multipurpose Development Authority (BMDA) was launched during late eighties century Chapai Nawabgang, Naogan and Rajshahi districts which is include 25 Upazilla (sub-district) in the 'Barind Area' at the north western part of Bangladesh covering an area of 7500 km². Out of 5.4 million population 14% were to be the beneficiaries of BIADP irrigation facilities (Kranti Associates Ltd. 2000). In the area limited scope to conserve rain water for irrigation, and lack of modern agricultural technology resulted in agricultural and socio-economic backwardness. Ground water has been the source of irrigation in the agro based barind area by installation of Deep Tube wells (DTWs) and Shallow Tube wells (STWs). The multi cropping agricultural practices boosted the crop intensity from 117% in pre-BIADP (before 1985) to about 200% at present (after 1985). Definitely it has been a huge ambitious task for the BMDA to implement like BIADP with objectives like poverty alleviation, human resource development, food security etc. The area has a scope for extraction by 2-cusec capacity 8,728DTW (BMDA, 2001). BMDA is responsible for DTW irrigation management only. At present the total cultivable area is about 0.58 mha of which only 26% (0.58mha) have been brought under irrigation by both surface and ground water. The present research is carried out to evaluate the BIADP by comparing pre- (1964-1984), and post- (1985-2010) period. Study also included analysis of available metrological data.

METHODOLOGY

The monthly rainfall data, the maximum and minimum temperature (°C) data, the monthly sunshine hour's data for Rajshahi station were collected from Bangladesh meteorological department, Dhaka. The crop coefficient of various crops was collected from Rice Research and Wheat Research Institute of Rajshahi. The Blaney-Criddle method was used for the determination of consumptive use and crop water requirement. The data required for other methods for the determination of consumptive use and crop water requirement is not available for all the years before implementation of the project. Hence, Blaney-Criddle method is used to carry out the project objectives.

DATA ANALYSIS

As the consumptive use is depending on the temperature and monthly sunshine hours the trend of maximum, minimum temperature and monthly sunshine hours was analyzed during pre- (1964-1985) and post- (1986-2008) implementation stages of BIADP. To get real view of crop water requirement rainfall data was also analyzed. To determine the deference of Cu, C.I.R the graphical representation was done for the periods of 1964-1985 and 1986-2008 for IRRI rice, wheat and potato. Thus the each gradient represents the value of Cu, C.I.R for pre and post project respectively. To determine the individual years Cu and C.I.R for the period of 1975-1984 and 1999-2008 at minimum and maximum temperature the values of Cu and C.I.R for individual years was plotted against years for each crop. Statistical data of Cu and C.I.R is given for crops during 1964-1985 and 1986-2008 by taking the average value of temperature, sunshine hours, rainfall of February, March, April, May and June for IRRI rice; November, December, January and February for Wheat and Potato.

GRAPHICAL PRESENTATION OF CIR AND Cu

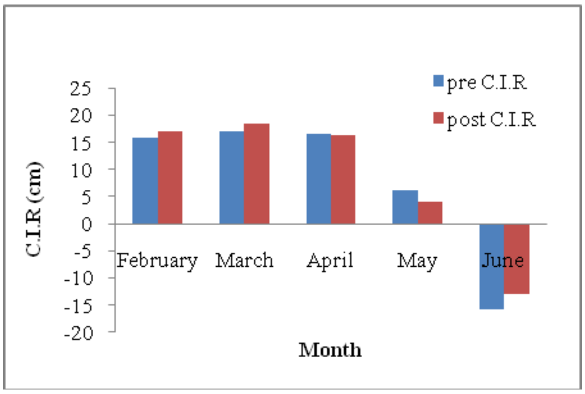

Fig.1. Variation of C.I.R of Rice for Maximum Temperature

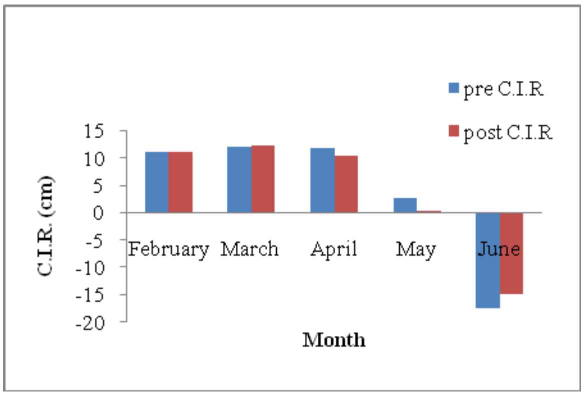

Fig.2. Variation of C.I.R of Rice for Minimum Temperature

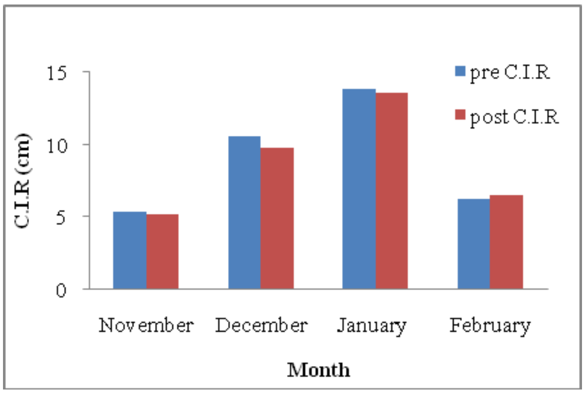

Fig.3. Variation of C.I.R of Wheat for Maximum Temperature

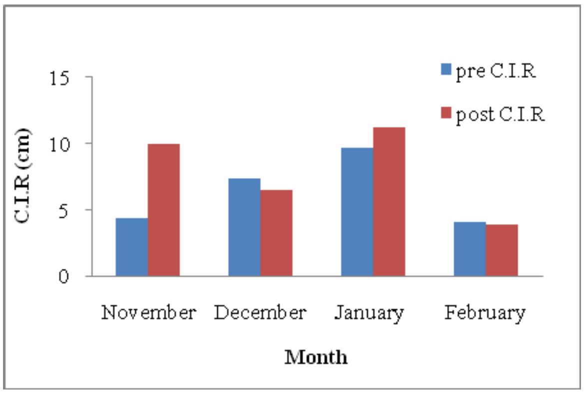

Fig.4. Variation of C.I.R of Wheat for Minimum Temperature

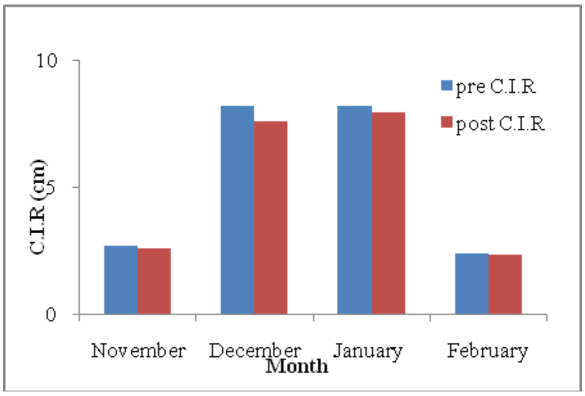

Fig.5. Variation of C.I.R of Potato for Maximum Temperature

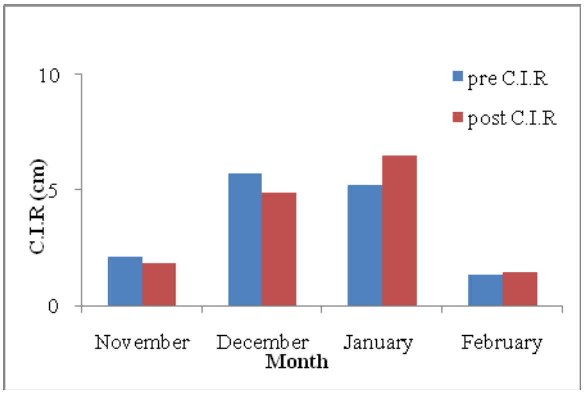

Fig.6. Variation of C.I.R of Potato for Minimum Temperature

RESULTS AND DISCUSSIONS

CIR for IRRI rice during pre-project for maximum temperature in the month of February, March, April, May and June were 15.83 cm, 17cm, 16.52 cm, 6.22 cm, -15.81 cm respectively and after project implementation for the same crops these values were 17.07 cm, 18.3 cm, 16.37 cm, 3.97 cm, -13.02 cm respectively (Fig.1). The negative value of CIR of the month June indicates that rainfall of this month exceeds the water needs for irrigation. CIR for rice during pre-project at minimum temperature in these months these values were 10.93 cm, 12.01 cm, 11.77 cm, 2.73 cm, 17.46 cm, respectively and on the contrary during post project for the same crops these values were 11.14 cm, 12.09 cm, 10.33 cm, 0.23 cm, -14.88 cm respectively (Fig.2). CIR for pre-project duration at maximum temperature for potato crops in the months of November, December, January and February for studied area were 2.68cm, 8.20cm, 8.18cm, 2.37cm respectively but for post-project duration these values were 2.56cm, 7.59cm, 7.94cm, 2.32cm respectively (Fig.3).

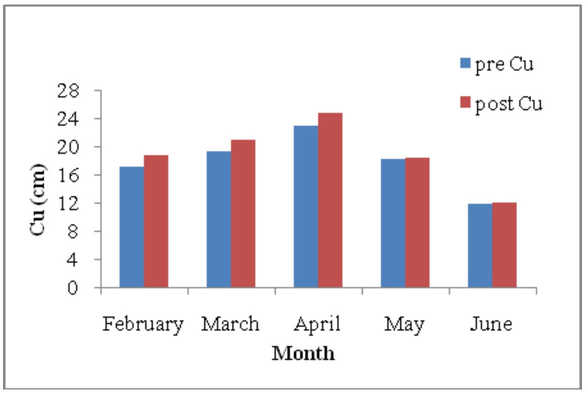

Fig.7. Variation of Cu of Rice for Maximum Temperature

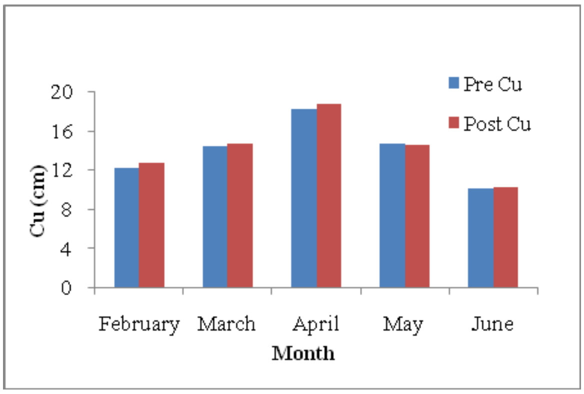

Fig.8. Variation of Cu of Rice for Minimum Temperature

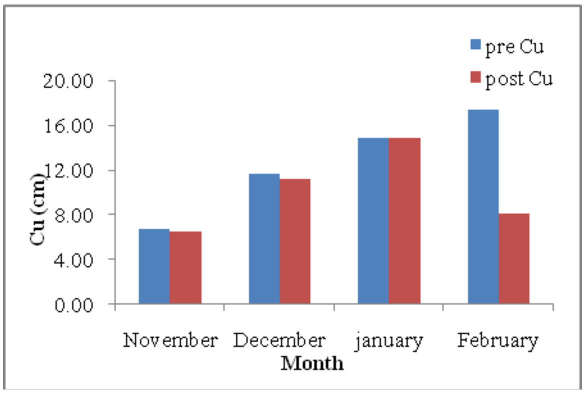

Fig.9. Variation of Cu of Wheat for Maximum Temperature

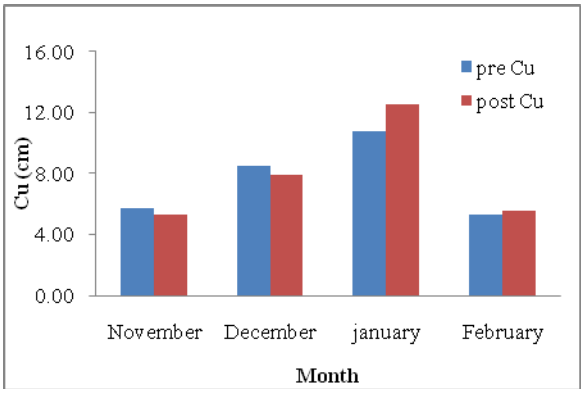

Fig.10. Variation of Cu of Wheat for Minimum Temperature

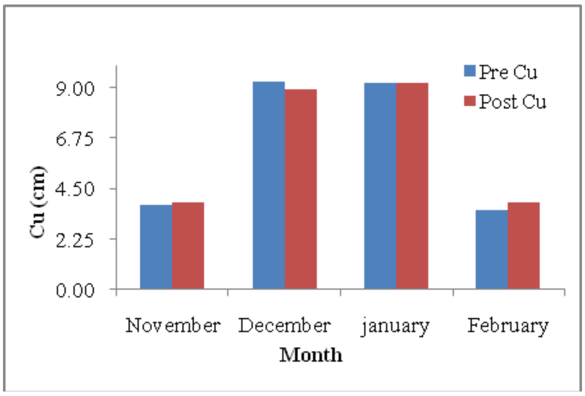

Fig.11. Variation of Cu of Potato for Maximum Temperature

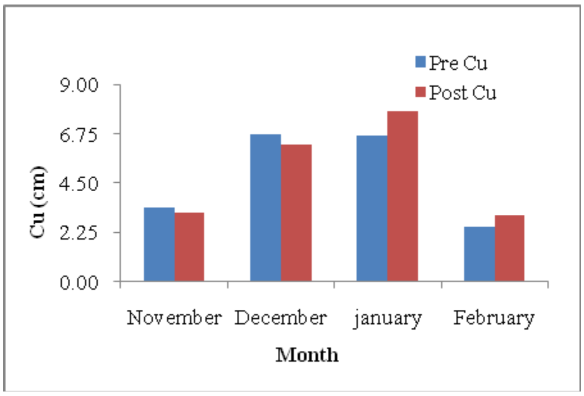

Fig.12. Variation of Cu of Potato for Minimum Temperature

CIR during pre-project for the same crops at minimum temperature in these months were 2.94cm, 5.70cm, 5.21cm, 1.35cm respectively where for post-project this values were 1.82cm, 4.91cm, 6.50cm, 1.46cm respectively (Fig.4). For Wheat, irrigation requirement during pre-project at maximum temperature in the month of November, December, January, and February for study area were 5.40cm, 10.60cm, 13.85cm, 6.25cm respectively where for post-project these values were 5.21cm, 9.89cm, 13.60cm, 6.56cm respectively (Fig.5). In addition, irrigation requirement for pre-project at minimum temperature in these months were 4.40cm, 7.44cm, 9.73cm, 4.10cm respectively where for post-project minimum temperature this value were 3.97cm, 6.53cm, 11.28cm, 3.97cm respectively for the same crops (Fig.6).

CONCLUSION

The study represents that the CIR and Cu is decreasing for rice, wheat and potato after implementation of the project. From the analysis of the meteorological data after implementation of BIADP the rainfall is in increasing trend, maximum temperature and minimum temperature is in decreasing trend and also a positive effect has been found for monthly sunshine hours. The Cu for rice, wheat and potato was more before implementation of the project due to increasing trend of maximum, minimum temperature and sunshine hours which is decreasing after implementation of the project. The CIR is decreasing at present due to the increasing of rainfall.

REFERENCES

Das, Kumar Suman (2007) - M.Sc thesis on, Study of Irrigation Efficiencies and Crop Water Requirement in Various Crops under Barind Area, BUET, Dhaka-1000, Bangladesh.

Garg, S.K. (1976)-Irrigation Engineering and Hydraulic Structure, Khanna Publishers, 2- 8, Nath Market, Nai Sarak, Delhi-110006.

Israelsen, W. O. and others (1962) –Irrigation Principles and practice, John Weilly and Sons, Inc. New York, London, Sydney.

Modi, P.N.(1988)-Irrigation Water Resources and Water Power Engineering, Standard Book House, 1705-4 Nai sarak, Delhi-110006

Michael, A.M.(1978)-Irrigation Theory and Practice, vikas publishing house(p) Ltd .57G,Masjid road, Jangpura .New Deihi-110014

Mahmud, N.N. (1996) - M.Sc. thesis on Irrigation Requirement of various Crops under G-K project, BUET, Dhaka-1000, Bangladesh.

Rahman, Azizur Md (2006)-M.Sc. thesis on estimation of potential recharge of ground water resources –A case study in low Barind area, Bangladesh. University Applied Sciences Cologne, Germany.

Sarma, S.k. (1984)-Principals and Practice of irrigation Engineering, S. Chand and Company Ltd. Ram Nagar, New Delhi-110055

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ENHANCEMENT OF DRAINAGE SITUATION IN SMALL TOWNSHIP OF BANGLADESH USING GIS: AKHAURA MUNICIPALITY AS AN ILLUSTRATION

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ABSTRACT

Bangladesh is a relatively small but densely populated country in South-East Asia. This country is susceptible to many natural calamities due to its geographic and topological features. As a developing country, Bangladesh is experiencing an economic boom through several economic activities. There are eight City corporations in major cities all over Bangladesh. There are more than 300 municipalities in Bangladesh. These municipalities are under Local Government Division (LGD) of Bangladesh. The landuse pattern is changing in the municipalities. Due to increased connectivity and increased economic activities more people are attracted to these small townships resulting in growth in settlements. A prerequisite in the developments of these towns is to design an integrated system for storm water management. This paper gives an insight towards the integrated drainage system design of the municipalities using the advanced GIS (Geographic Information System) tools. As an illustration of planning approach, Akhaura municipality is taken. Bangladesh is far behind from the integrated planning approach of the municipalities. It is high time we should give attention towards the development of a planning approach, which can be applied in designing the drainage system of municipalities. Use of GIS will enable us to design a sustainable and integrated system more scientifically, accurately and rationally.

Keywords: GIS, Urban Drainage System, Rainfall, Flood Level, Digital Elevation Model

INTRODUCTION

Improvement of the drainage system is one of the highest priority needs of the municipality authority for living environment of its urban population. The Akhaura Municipality suffers from drainage congestions and water logging especially during rainy season. It creates an unhealthy environmental situation and causes inconvenience to the residents of the Municipality including damages to the infrastructure, loss of business and spreading of diseases. It is observed that there is a lack of planned and adequate drainage network system in the municipality. Existing drains are inadequate in capacities and lack in gradient and also do not reach the suitable outfall. Moreover, those drains are insufficient to deal with the full drainage resulting from rainfall runoff. It is very convenient to use the knowledge of GIS in designing a drainage system of a municipality. Akhaura is a much talked about municipality in recent time, as it is used as a transit route to Tripura, India. This study includes a systematic design of drainage system of Akhaura municipality, which can be replicated as an approach for other municipalities of Bangladesh also. This study was conducted under the project 'Groundwater Management and TPP for Survey, Investigation and Feasibility Study in Upazila and Growth Center Level Pourashava having no Piped Water Supply System' under Department of Public Health

Engineering (DPHE). The project aimed to design an integrated water supply, drainage, sanitation and solid waste management system for 148 municipalities for the next thirty years.

APPROACH AND METHODOLOGY

The specific objectives include: on the basis of outfall dividing the total water-shed into number of drainage zones, improvement of drainage network by construction of new primary and secondary drains and taking consideration of water-logged areas. Firstly, rainfall and water level analysis are performed taking the nearest gauge stations provided the stations have quality data. A representative Digital Elevation Model (DEM) of the municipality is a must for drainage system planning. A DEM and shape files of existing road networks, bridges and culverts, drain networks and land use pattern are produced after performing a quality survey using the modern survey equipments. Then a field visit is performed for understanding the existing drainage system, possible outfalls, water logged areas and average year flood level. The study area is classified according to the average year flood level. The land above the average year flood level is brought under gravity drainage system. Drains, catchments and zones was delineated with the help of GIS considering existing roads, DEM, infrastructure, homestead, contour maps, outfalls, natural canals and rivers in and around the municipality. The drain length and catchment areas can easily be calculated by the GIS software. Discharges are calculated by Modified Rational Method. Finally, long profiles of the drains are drawn with drain sections. The methodology is shown in **Fig. 1**.

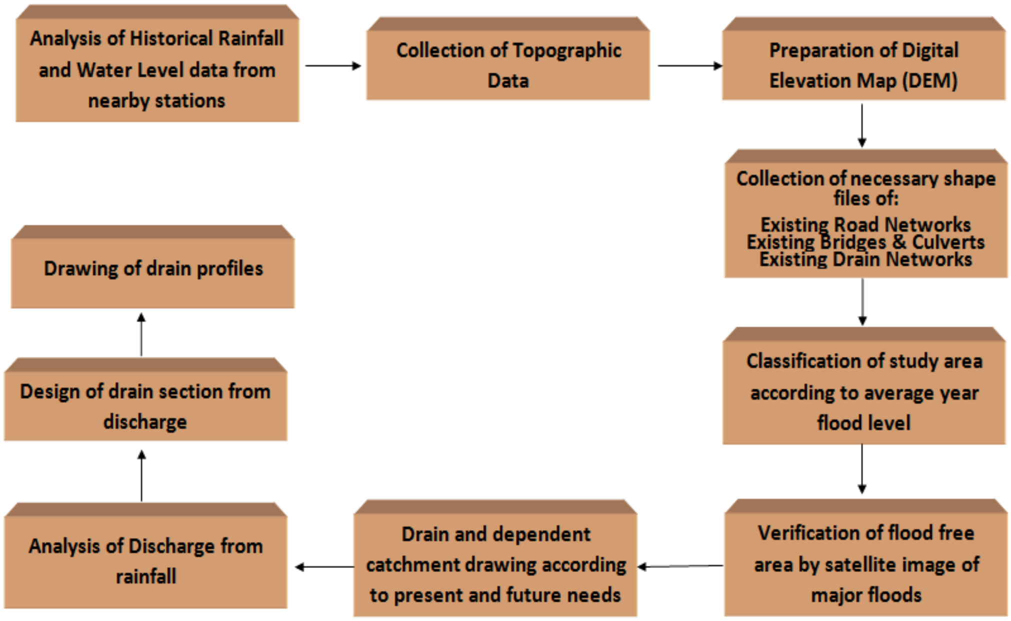


Figure 1. Design methodology of drainage system

DESCRIPTION OF THE MUNICIPALITY

Location and Topography

Akhaura municipality is located in Akhaura Upazila, Brahmanbaria District under Chittagong Division. The change in elevation of most of the Municipality area is gradual. The land elevation of the Municipality effectively ranges between 3.14 mPWD and 13.89 mPWD. The use of present Municipality's area can be broadly divided into lands for agricultural (57%) and non-agricultural (43%). Major settlements are in the areas of Wards No. 1, 3, 5, 8 & 9 with some scattered settlements in Wards No. 2, 4, 6 & 7.

Rainfall
Brahmanbaria (R103) is a rainfall gauging station with reasonable length of records and is located nearest to the municipality. The average yearly rainfall is about 2163 mm. About 63 % rainfall occurs during the period from June to September. It is selected as the reference station for assessment of storm intensity for Akhaura Municipality. A correlation factor (CF) is calculated to correlate the IDF (Intensity-Duration-Frequency) curve of Dhaka to Bhahmanbaria for calculating the rainfall intensity. The rainfall stations are shown in **Fig. 2**.

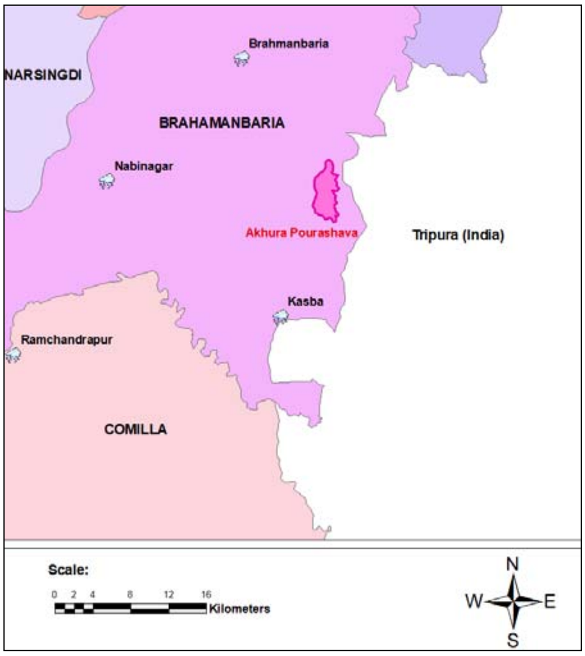


Figure 2. Rainfall stations near Akhaura municipality

River and Canal System
The municipality lies in the Titas River system. The river Titas flows through the western boundary of the municipality. There are three khals in Akhaura municipality namely Akhaura Borobazar Khal, Kharompur Khal and Santinagar Khal. The khals flow from east to west and also carry some contribution from India. Most of the Municipality areas drain out their storm water through these khals and eventually routes to the Titas River. Akhaura Borobazar Khal is a Borrowpit flowing alongside the Akhaura Borobazar road. Kharompur Khal drains and routes water from northern parts of the Municipality and Santinagar Khal drains water of southern parts of the Municipality. Kharompur Khal and Santinagar Khal have good conveyance while Borobazar Khal is little obstructed in some places with waste disposals. The River and Canal/ Khal system are shown in **Fig. 3**.

Flooding
The Municipality lies in the Titas River basin. The water level gauging is available at Akhaura (296) station in Titas River. After statistical analysis of water level of the gauge station the average year flood level is estimated to 6.67 mPWD. Water-level data are given in **Table 1**.
The area of the municipality is relatively low in elevation. The whole are is divided into five classes according to average year flood level. It is assessed that 37% of land of the Municipality is above the average flood level while 8 % land is subjected to shallow depth (less than 30 cm) of flooding. The rest of the land ranges from moderate to very deep flooding. The Classification of the area according to average year flood level is shown in **Fig. 4**.

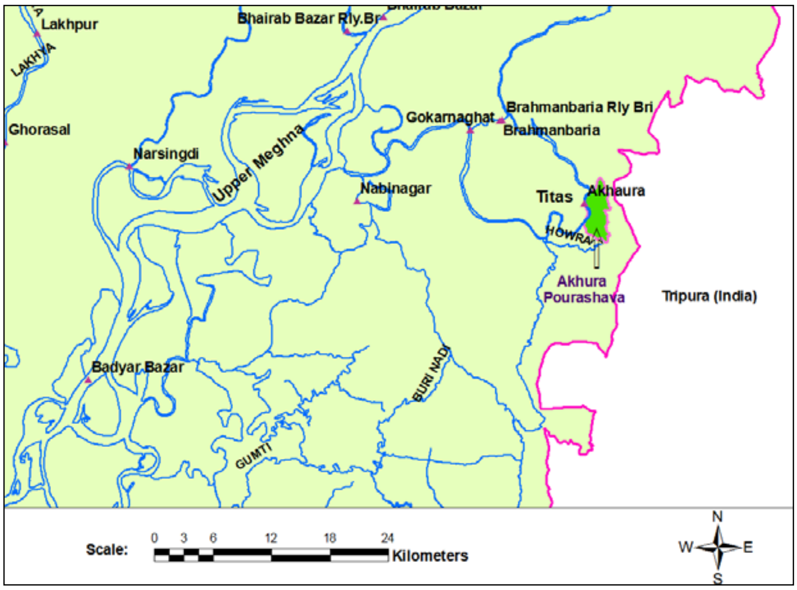


Figure 3. River System around Akhaura municipality

Table 1. Water-level data of Akhaura station over Titas river

Year	Annual max. flood Level (mPWD)	Year	Annual max. flood Level (mPWD)	Average year flood level (mPWD)
1985	6.69	1995	6.63	
1986	6.56	1997	6.20	
1987	6.68	2001	5.99	
1988	7.00	2002	6.53	
1989	6.72	2003	6.55	6.67
1990	6.67	2004	7.61	
1991	6.73	2005	6.10	
1992	6.65	2007	6.87	
1993	6.75	2008	6.40	
1994	6.60			

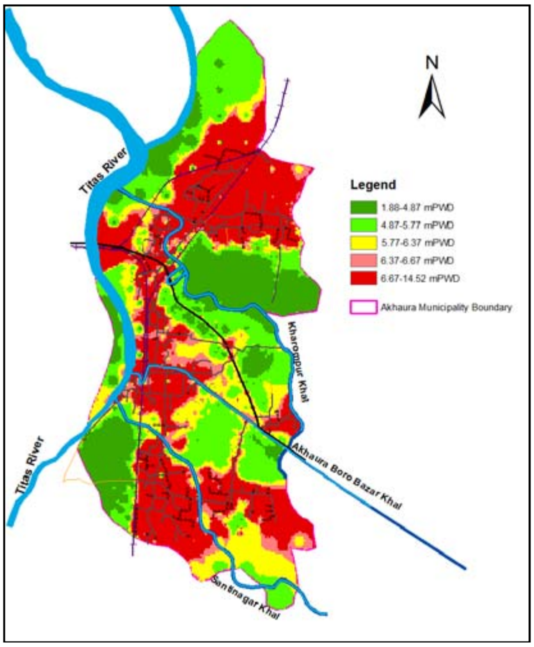
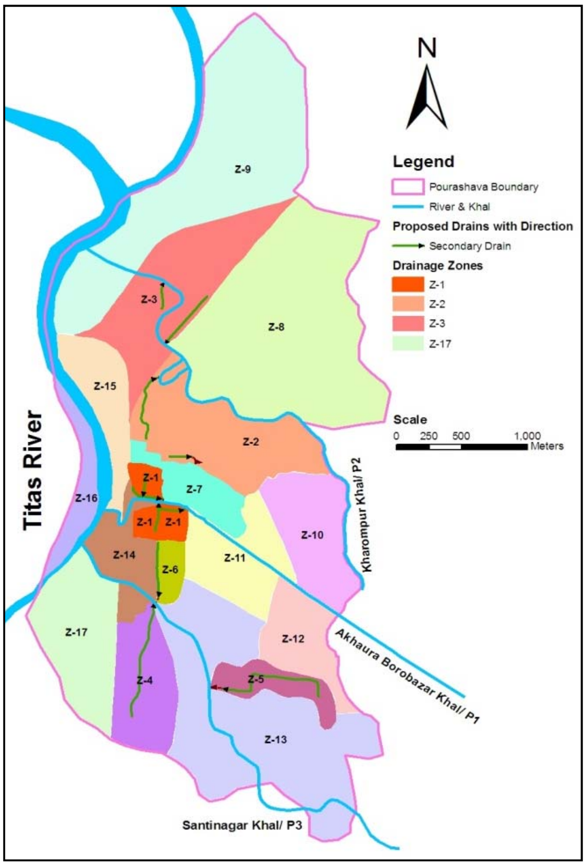


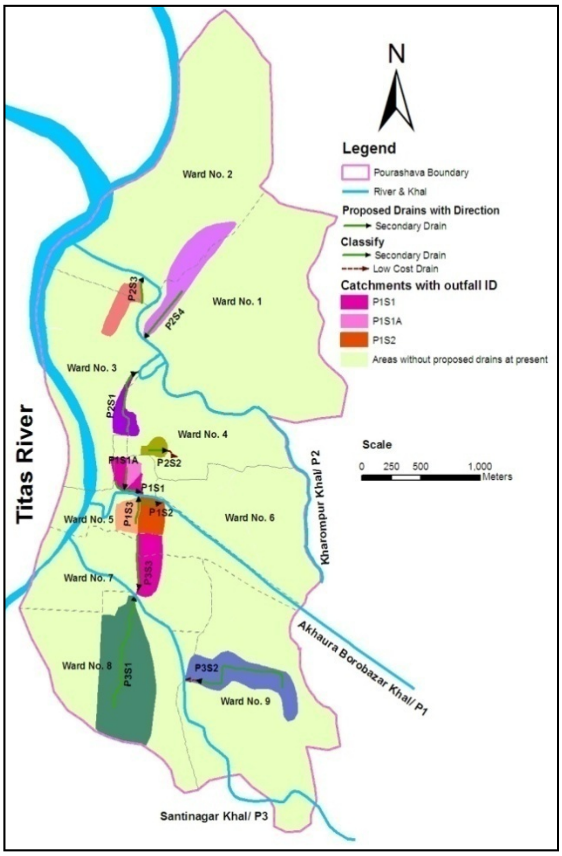
Figure 4. Classification of the area according to average year flood level

PROPOSED DRAINAGE SYSTEM

About 37% of land of the municipality is above the average flood level. Proposed drainage system has been planned for the core area of the municipality as well as for the extended area in near future in consideration of priority needs. The area of the municipality has been planned for improvement under gravity drainage system. The whole municipality has been divided into 17 zones for drainage improvement plan shown in **Figure 5 (a)**. Zones 1 through 6 are planned with proposed storm drains as they are in the core area of municipality or will be characterized as core area in near future. Rests of the zones are not planned with proposed storm drains while they are planned with their outfalls for future drainage details. Zones 7, 11, & 12 will eventually drain in the Akhaura Borobazar Khal (P1), which is running alongside the Akhaura Borobazar and finally route and drain to the Titas River. Zones 8 & 10 will drain their water through Kharompur Khal (P2). Zone 8 has hilly part as well as low-lying area. Naturally the high lands drain through the adjacent low-lying area and eventually drains to Kharompur Khal/ P2. Zones 13 & 14 will drain to Santinagar Khal/ P3. Zones 9, 15, 16 & 17 will drain in the Titas River. The delineated catchments and drainage routes are shown in **Figure 5(b).** Rational method is suitable for peak discharge calculation of small (<50 km^2) areas (Subramanya, 2008). As catchments of the municipalities are relatively small sized, rational method is used for peak discharge calculation. The summary of runoff discharges of all 17 zones are given in **Table 2**.



a. Drainage Zones



b. Catchments

Figure 5. Drainage Zones and Catchments of Akhaura municipality

Table 2. Design Discharges of the zones

Drainage Zone	Drainage Area (ha)	Discharge (m^3/sec)	Drainage Zone	Drainage Area (ha)	Discharge (m^3/sec)
Zone-1	17	1.45	Zone-10	52	3.62
Zone-2	81	4.18	Zone-11	49	3.65
Zone-3	58	4.86	Zone-12	37	2.39
Zone-4	46	2.63	Zone-13	160	9.26
Zone-5	22	1.37	Zone-14	32	2.43
Zone-6	10	0.74	Zone-15	37	2.54
Zone-7	26	1.83	Zone-16	21	1.61
Zone-8	191	12.36	Zone-17	65	3.56
Zone-9	169	9.49			

P1S1, P1S1A, P1S2, P1S3, P2S1, P2S2, P2S3, P2S4, P3S1, P3S2 and P3S3 are 11 secondary drains which are planned for the storm drainage of most of the municipality area. These secondary drains have been proposed for the drainage of municipality in consideration of topography, existing infrastructure, present runoff and drainage pattern, and experiences and views of the local people. About 17 nos. of cross drainage works (e.g.; box culverts/ pipe culverts) will be required in connection with the whole proposed drainage network. About 13 nos. of cross drainage works will be required for the priority drainage systems and the rest will be required for the future drainage systems. Efforts have been given to best utilize the alignment of existing drains of the municipality for the proposed primary and their secondary drains. For a given discharge the geometric section of a drain depends mainly on bed slope and the frictional resistance of the contact surface to flowing water. Manning's Equation is used for the calculation of flow velocity and determining drain section. Longitudinal profile of drain P2S3 is given in **Fig. 6**.

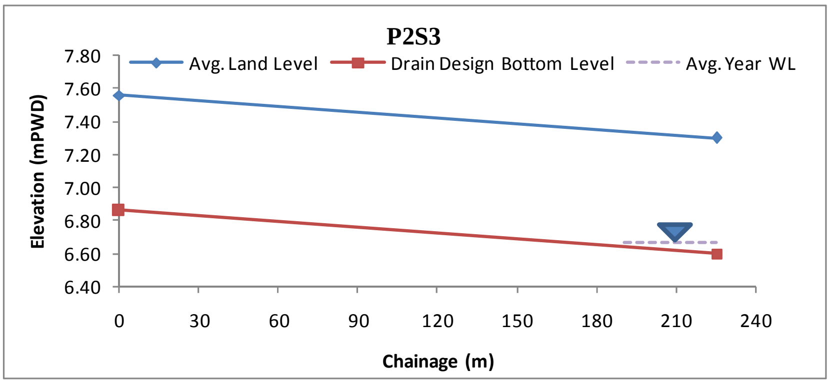


Figure 6. Longitudinal profile of Drain P2S3

CONCLUSION

A functional drainage system is an essential part of every township. Manmade interventions hinder the natural drainage system which results in hazards in day to day life. Preservation of the natural drainage system as the outfalls is the prerequisite for an integrated drainage planning. A drainage model is made under this project to create a tool for Akhaura municipality which would enable the simulation of storm runoff for different design severity and facilitate the design of complex drainage system. Maintaining such a model would be a good practice in decision making support for alleviating drainage problems associated with future sustainable urban developments. The drainage model has been skipped here for brevity. We should emphasize in the use of modern and sophisticated tool like GIS in planning and designing of drainage system for the greater benefit of society.

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REFERENCES

Akhaura Pourashava Report (Drainage, Sanitation and SWM), Mathematical Modelling for Safe Drinking water Source Identification (Component- 1), Groundwater Management and Feasibility Study for 148 Pourashava having no piped water supply, November 2011, Department of Public Health Engineering, Bangladesh

Mark, O. (et al.) (1996), A Mouse GIS Study of the Drainage in Dhaka City, Available via: http://proceedings.esri.com/library/userconf/proc97/proc97/to500/pap487/p487.htm (accessed on 17th September 2012)

Mashael Al Saud (2012). Use of Remote Sensing and GIS to Analyze Drainage System in Flood Occurrence, Jeddah - Western Saudi Coast, Drainage Systems, Muhammad Salik Javaid (Ed.), ISBN: 978-953-51-0243-4

Peavy, H.S., et al, (1985) "Environmental Engineering", McGraw-Hill Book Company

Subramanya K. (2008), Engineering Hydrology, 3rd Eds, Tata McGraw-Hill, India

Urban Drainage Manual, May 1998, Local Government Engineering Department, Bangladesh

ID : SEM 020

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PROSPECT OF GREEN CONCRETE PRODUCTION BY USING BOROPUKURIA FLY ASH

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ABSTRACT
Concrete is one of the most widely used construction materials in the world. Cement being the prime constituents of concrete, leads to the release of significant amount of CO_2, a greenhouse gas (GHG). Due to limited natural resources, concern over GHGs, or, both, there are regions in the world where cement production is being curtailed, or, at least, cannot be increased to keep up with the population increase. Therefore, it is necessary to look for sustainable solutions for future concrete construction where the use of "green" materials may ensure low energy costs, high durability, low maintenance requirements, and contain a large proportion of recycled or recyclable materials. The use of fly ash in concrete construction has got increasing importance not only for enhance properties of concrete but also its environmental credentials. Fly ash is a by-product produced from pulverized coal combustion in power generation and formed from the non-combustible minerals found in coal. In the year 2006, two units of 125 MW coal based power plant has started generation in Barapukuria, Bangladesh. The power sector master plan of Bangladesh projects a high growth in coal based power generation although there is lack in strategy on the use of generated fly ash. This study aimed to explore the possibility of using Boropukuria fly ash in concrete construction. Two different grades of concrete (M28 and M38), each with eight different cement replacement level 0, 10, 20, 30, 40, 50, 60 and 70% were used for the experimental program. Among all the concretes studied, the optimum amount of cement replacement is reported as 30%, which provides around 13% higher compressive strength and 50% lower rapid chloride permeability values as compared to OPC concrete.

Keywords: Cement, Compressive strength, Concrete, Fly ash, RCPT

INTRODUCTION
Concrete, typically composed of gravel, sand, water, and Portland cement, is an extremely versatile building material that is used extensively worldwide. Reinforced concrete is very strong and can be cast in nearly any desired shape. Portland cement is a fine grey powder which serves as the chief ingredient of concrete and constitutes 10 to 15% by weight of concrete's total mass. Although the Cement only comprises 10-15% of concrete by weight, its production is responsible for most of concrete's environmental impacts. The cement, composed of lime and silica (sourced from limestone, clay, and sand), is fired in a rotary kiln at 2700° F, consuming enormous quantities of fossil fuels and thereby producing high amounts of CO_2. In addition, the chemical reaction that creates Portland cement produces CO_2 as a by-product. The net cement production in the world is increased from about 1.4 billion tonnes in 1995 to almost 3 billion tonnes in the year 2010 and expected to be around 5 billion tonnes in the year of 2040. Unfortunately, significant environmental problems result from the manufacture of Portland cement, CO_2 emission is in the range of 0.72–0.98 tonne CO_2 per tonne of

cement (IEA, 2006) from which 50–70% comes from calcinations, 40–30% from fuel combustion and around 10% from transportation and other ancillaries (Barker et al., 2009). According to IPCC (Metz et al., 2007) and IEA (2006) 5 to 7% of worldwide CO_2 emissions are caused by the cement industry and adding the greenhouse gas equivalent of 330 million cars driving 12,500 miles per year.

Fortunately, waste product can be substituted for large portions of Portland cement, significantly improving concrete's environmental characteristics. Fly ash, consisting mostly of silica, alumina, and iron, forms a compound similar to Portland cement when mixed with lime and water. Fly ash is a noncombusted by-product of coal-fired power plants and generally ends up in a landfill. However, when high volumes are used in concrete (displacing more than 25% of the cement), it creates a stronger, more durable product and reduces concrete's environmental impact considerably. Due to its strength and lower water content, cracking is reduced. By displacing a large percentage of the cement in concrete, fly ash significantly reduces the associated environmental impacts of CO_2 production and air pollution. The nature of fly ash, tiny spherically shaped particles that act as ball bearings, make it able to fill small voids and produce denser concrete that requires less water for installation, resulting in water savings. Its density makes it less permeable to water in finished form, protecting reinforcing steel and increasing the concrete's durability. It also lowers the heat of hydration, in turn reducing shrinkage and thermal cracking. Class F fly ash, as well as some Class C fly ashes, produce a concrete that is more resistant to sulfate attack and alkali-aggregate reactivity. Furthermore, fly ash concrete has higher ultimate strength than conventional concrete, so in some applications less material is required to accomplish a given structural need. Some building health experts have raised concerns about the presence of trace heavy metals in the fly ash. Others mention that the metals are effectively locked into the cementitious matrix, preventing their release. Furthermore, by using fly ash in concrete rather than sending it to a landfill, the potential for the metals to leach into the environment is reduced. Concerns have also been raised about the higher incidence of Radium-226 in fly ash than in cement. However, a study conducted by the EPA suggests that the slight increased risk imposed by the greater exposure was offset by the reduced exposure to radon gas which is less likely to pass through the denser, less permeable structure of fly ash concrete.

Permeability is defined as the coefficient representing "the rate at which water is transmitted through a saturated specimen of concrete under an externally maintained hydraulic gradient. It is inversely linked to durability. Decrease in permeability reduces deterioration of concrete caused by various factors such as chloride attack, sulfate attack, freezing and thawing, alkali-aggregate reaction, carbonation, etc. Optimum use of fly ash must be ensured to achieve the desired strength as well as durability requirement of the structural concrete. The rapid chloride permeability test (RCPT) ASTM C-1202 is an electrical test in which the test result is a direct function of the resistance of the test specimen. In principle, the use of electrical properties to measure the ionic transport properties of concrete is well grounded and is affected by two aspects of the concrete: the connectivity of the capillary pore system and the electrolytic capacity (ionic concentration) of the pore solution. The capillary pore system is of primary interest, with respect to assessing the durability of concrete. Capillary absorption, hydrostatic pressure, and diffusion are the means by which chloride ions can penetrate concrete. The most familiar method is diffusion, the movement of chloride ions under a concentration gradient. For this to occur the concrete must have a continuous liquid phase and there must be a chloride ion concentration gradient. In one study (Thomas, 1996), a replacement of 10% cement with class F fly ash can even significantly reduce the chloride permeability of cement mortars at 7 days. The RCPT data can be used only for preliminary assessment of chloride permeability. At the present time this is the only test method that is widely accepted by the concrete industry. Previous studies (Hossain, 2004) have shown that use of cement replacement materials such as fly ash, silica fume, blast-furnace slag, etc. may greatly reduce the probability of steel corrosion as well as the permeability of concrete. The monitoring of concrete resistance to chloride penetration is also possible on the basis of electrical resistivity measurements. The electrical resistivity of concrete structure exposed to chloride indicates the risk of early corrosion damage, because a low resistivity is related to rapid chloride permeability and to high corrosion rate (Ampadu, 2002). The use of supplementary cementing materials such as ground blast furnace slag, silica fume, metakaoline, coal fly ash and natural pozzolan can have a very significant effect on the pore solution chemistry of concrete, depending on the dosage and composition of these supplementary cementing materials (Shehata et al., 1999). Supplementary cementing materials with low alkali content will incorporate more alkalis into hydration products than they release to the pore solution, which results in a lower alkali concentration or lower pH value in the pore solution (Duchesene, 1994). This is the basis for the use of those supplementary cementing materials to decrease the alkalinity of pore solution in concrete materials down to a safe level to suppress alkali-aggregate expansion of concrete.

When fly ash is used as pozzolanic material in concrete, through its pozzolanic properties, it chemically reacts with $Ca(OH)_2$ and water to produce C-S-H gel. The $Ca(OH)_2$ is consumed in the pozzolanic reaction and is converted into a water-insoluble hydration product. This reaction reduces the risk of leaching $Ca(OH)_2$ as $Ca(OH)_2$ which is water soluble and may leach out of hardened concrete. The incorporation of fly ash can result in considerable pore refinement (Joshi, 1997). So, after 28 days of curing, at which time little pozzolanic activity would have occurred, fly ash concretes are more permeable than ordinary Portland cement concretes. However, after 6 months of curing, fly ash concretes are much less permeable than ordinary Portland cement concretes due to the slow pozzolanic reaction of fly ash (Joshi, 1997).

In 2006, two units of 125 MW coal based power plant has started generation in Barapukuria, Bangladesh. Currently one million ton of coal is being produced per annum from this mine of which 65% is being supplied to the 250 MW thermal power plants and other 35% is being used in brick field and other domestic industries. At present, on an average 65 thousand tons of fly ash is being produced from those thermal power plants. Use of these fly ash as partial replacement of cement may also ensures the proper utilization of fly ash, in an effective way which otherwise been dumped making environmental hazard. Limited studies are reported to carry out to investigate the permeability/ transport properties of Boropukuria fly ash concrete as obtained by partial replacement of cement. This experimental program was carried out with a view to study the effects of inclusion of different quantities of Boropukuria fly ash on concrete permeability as well as strength. The study information regarding the strength and permeability characteristics of concrete containing Boropukuria fly ash would be beneficial in the utilization of these waste materials in concrete work, especially on the durability aspects.

EXPERIMENTAL PROGRAM

The experimental program was planned to study the effect of replacement of cement with supplementary cementing material fly ash on the strength and permeability characteristics of hardened concrete. Cement replacement at various percentage levels were used in this investigation to observe the effects of different fly ash levels on concrete in developing strength and permeability resistance at different curing ages.

Materials used

(a) Cement: ASTM Type-I Portland Cement was used as binding material. Chemical compositions of OPC are given in **Table 1.**
(b) Fly ash: A low calcium ASTM Class F fly ash collected from Boropukuria Power Plant, Bangladesh was used as supplementary cementitious material. Chemical analysis of the fly ash conducted by using X-ray fluorescence (XRF) study is shown in **Table 1.**
(c) Aggregate:12.5 mm downgraded crushed stone, with fineness modulus 6.58 and specific gravity 2.70, was used as coarse aggregate. Locally available natural sand passing through 4.75 mm sieve and retained on 0.075 mm sieve with fineness modulus 2.58 and specific gravity 2.61 was used as fine aggregate.

Mix design and sample preparation

Three different grades of concrete namely M38 and M28 were used in the program. Seven different mix proportions of cement fly ash (90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70) were used as cmentitious material. Cement fly ash mix ratio of 100:0 i.e. plain concrete specimens were also cast as reference concrete for comparing the properties of fly ash concrete. Fly ash concrete means the concrete made by using cement and fly ash as cementitious material with sand, stone chips and water. Relevant information of different concrete mixes is given in **Table 2.**

Table 1 : Chemical Composition (%) of OPC and FA

Constituents	Compo-sition	OPC	FA
Calcium Oxide	CaO	65.18	0.65
Silicon Di-Oxide	SiO_2	20.80	51.49
Aluminum Oxide	Al_2O_3	5.22	31.60
Ferric Oxide	Fe_2O_3	3.15	2.80
Magnesium Oxide	MgO	1.16	0.28
Sulfur Tri-Oxide	SO_3	2.19	0.19
Sodium Oxide	Na_2O	--	0.18
Loss on Ignition	--	1.70	4.2
Insoluble Residue	--	0.6	--

Table 2 : Mix Proportions and Properties of Fresh Concrete

Mixture constituent & properties	Grade of Concrete	
	M38	M28
Cement (kg/m^3)	500	435
Water (kg/m^3)	218	218
Sand (kg/m^3)	520	545
Stone Chips (kg/m^3)	1120	1150
water/cement Ratio	0.44	0.50
Slump (mm)	60	68
Air content %	1.1	1.3

A total of 200 no's of cylindrical specimen of size 100 mm diameter and 50 mm high and 300 no's of cubical specimens of 100 mm size from eight different types of fly ash concretes were cast according to the mix proportion as described for Rapid chloride permeability and strength test. The small size of specimen i.e. 100 mm cube was taken in order to accommodate large number of specimens in the limited sized curing tanks. The specimens were demoulded after 24 hours of casting and cured in plain water at 27±2°C. The concrete test specimens were designated keeping concrete grade and cement replacement level as variable. Thus M38FA40 concrete means grade of concrete is M38 and cement fly ash mix ratio is 60:40.

Test conducted

(a) Strength tests: Compressive strength of concrete specimens was tested at the ages of 3, 7, 28, 56, 90 and 180 days in accordance with the BS EN 12390-3:2009. At each case, the reported strength is taken as the average of three tests results.

(b) Rapid chloride permeability test: Cylindrical sample of 100 mm diameter and 200 mm height were prepared in accordance with ASTM C39. They were demoulded after 24 hrs and cured in plain water. After specific curing period they were cut into 50 mm thick slices. The cut cylinders were left to dry in laboratory condition for 24 hrs before application of epoxy coatings. All the specimens were epoxy coated around the cylindrical surface. At the ages of 28, 56, 90 and 180 days, the prepared cut cylinders were tested using the procedures described in the ASTM C1202. The average result of three test specimens was taken as the representative data.

RESULTS AND DISCUSSION

Compressive strength

The compressive strength of OPC and fly ash concrete of three different grades M38 and M28 has been graphically presented in **Fig.1** and **Fig.2**. Also for the ease of comparison, the relative compressive strengths are plotted in **Fig.3** and **Fig.4**. At early ages of curing, OPC concretes achieve relatively higher compressive strength as compared to fly ash concrete. Test result shows that 7 days compressive strength for OPC concrete is around 9%, 16%, 26%, 34%, 43%, 59% and 75% higher than M38FA10, M38FA20, M38FA30, M38FA40, M38FA50, M38FA60 and M38FA70 concrete respectively. At initial age of curing, upto 56 days compressive strength is seen to decrease with the increase of fly ash content in concrete when compared with no fly ash concrete. 56 days compressive strength test result of the specimens up to 40% replacement level are very similar to OPC concrete, within the range of ±9% variation. After that compressive strength of fly ash concrete starts to increase compared to OPC concrete. 90 days compressive strength test result of the specimens up to 50% replacement level are slightly higher than OPC concrete, within the range of ±12% variation.

Compressive strength is higher by 6%, 9%, 12% 8% and 1% for M38FA10, M38FA20, M38FA30, M38FA40 and M38FA50 concrete respectively; whereas the 90 days strength for M38FA60 and M38FA70 concrete is reported to be lower by 31% and 43% respectively when compared with no fly ash concrete. Cement normally gains its maximum strength within 28 days. During that period, lime produced from cement hydration remains within the hydration product. Generally, this lime reacts with fly ash and imparts more strength. For this reason, concrete made with fly ash will have slightly lower strength than cement concrete at early ages of curing and higher strength at the later ages of curing. Also fly ash retards the hydration of C_3S in the early stages but accelerates it at later stages. Conversely in cement concrete, this lime would remain intact and with time it would be susceptible to the effects of weathering, loss of strength and durability. Yamato and Sugita (1983) found that the later age strength of fly ash concrete was higher than that of the control. 180 days compressive strength data shows almost similar trend. 180 days compressive strength for M28FA10, M28FA20, M28FA30 and M28FA40 concrete are respectively 4%, 5%, 9% and 5% higher than no fly ash concrete; whereas the same value for M28FA50, M28FA60 and M28FA70 concrete are lower by 1%, 31% and 51% than OPC concrete. Similar strength values for M38FA10, M38FA20, M38FA30, M38FA40 and M38FA50 concrete are respectively 8%, 11%, 16%, 13% and 2% higher than no fly ash concrete and for M38FA60 and M38FA70 concrete are lower by respectively 25% and 39% than OPC concrete.

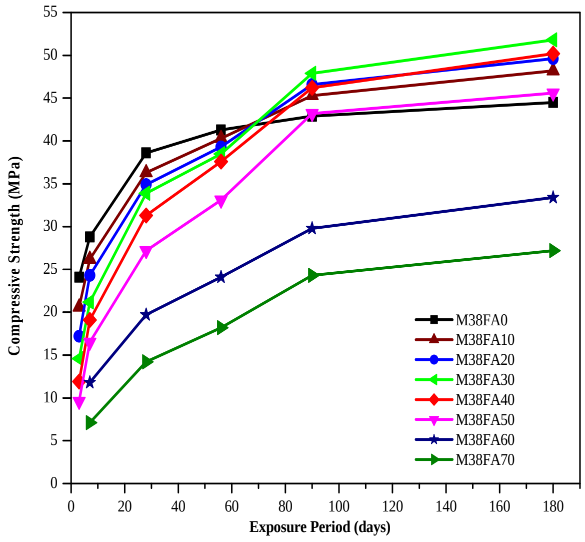

Fig.1 : Compressive Strength - Exposure Time Relation for M38 Fly Ash Concretes

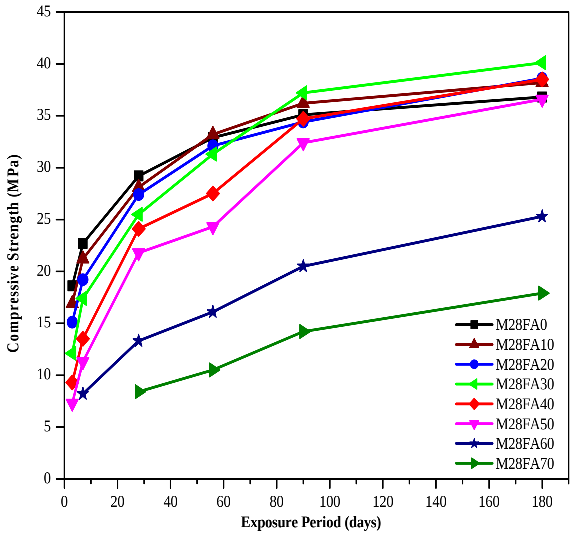

Fig.2 : Compressive Strength - Exposure Time Relation for M28 Fly Ash Concretes

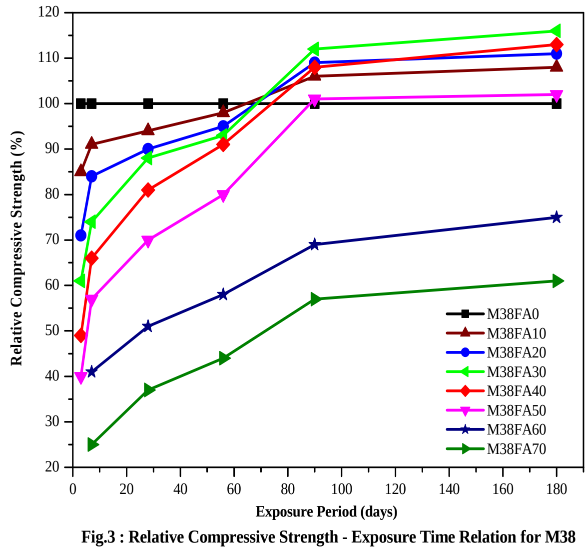

Fig.3 : Relative Compressive Strength - Exposure Time Relation for M38 Fly Ash Concretes

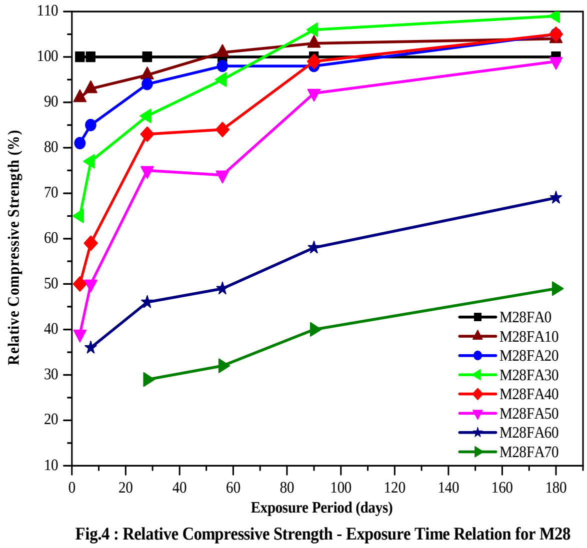

Fig.4 : Relative Compressive Strength - Exposure Time Relation for M28 Fly Ash Concretes

Rate of strength gaining for different types of concrete is observed to vary with the grade of concrete and is higher for the higher grade of concrete. Among all the concrete studied, 180 days compressive strength is increased by about 4%, 5%, 9% and 5% for concrete M28FA10, M28FA20, M28FA30 and M28FA40 respectively as compared to OPC concrete; whereas the same value is found to increase by around 8%, 11%, 16% and 13% for concrete M38FA10, M38FA20, M38FA30 and M38FA40 respectively compared to the strength of no fly ash concrete. Also for higher grade concrete, relative strength gaining was observed to be higher for the similar span of curing age. In case of 180 days of curing, compressive strength compared to 28 days of curing of similar concrete was observed that 8%, 11%, 22% and 23% higher for M28FA10, M28FA20, M28FA30 and M28FA40 concrete and 14%, 21%, 28% and 32% higher for M38FA10, M38FA20, M38FA30 and M38FA40 concrete. So it can be concluded that strength gaining is relatively faster for higher grade concrete as compared to lower grade concrete.

Rapid chloride permeability

Rapid chloride permeability value for OPC and fly ash concrete for 28, 56, 90 and 180 days curing period are graphically presented in **Fig.5** and **Fig.6**. At the initial age of curing RCPT values are higher for fly ash concrete compared to OPC concrete. In case of OPC concrete, amount of passing charge is observed as 4240 and 6295 coulombs for M38 and M28 grade concrete; whereas the similar value for fly ash concretes of cement replacement level of 20%, 30%, 40% and 50% are 4512, 4621, 4766 and 5280 coulombs for M38 grade concrete and 7295, 7465, 7870 and 8013 coulombs for M28 grade concrete at the curing age of 28 days. But for longer age of curing, fly ash concrete show better resistance against chloride ion penetration. After 180 days of curing, rapid chloride permeability values are respectively 43%, 38%, 34%, 30%, 24% for M38FA10, M38FA20, M38FA30, M38FA40, M38FA50 concretes and 62%, 59%, 50%, 48%, 51% for M28FA10, M28FA20, M28FA30, M28FA40 and M28FA50 concretes respectively as compared to the 28 days RCPT values of OPC concrete of similar grade. The incorporation of pozzolanic materials improved the resistance to chloride penetration of concrete as confirmed by other researchers (Janotka, 2000). A close observation of the data shows that fly ash concrete has relatively better resistance against chloride ion penetration and hence the use of fly ash in structural concrete may inhibits the risk rebar corrosion.

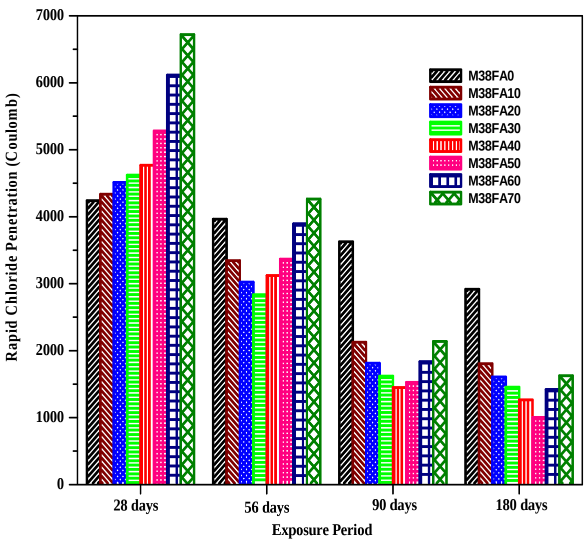

Fig.5 : Rapid Chloride Penetration - Exposure Time Relation for M38 Fly Ash Concretes

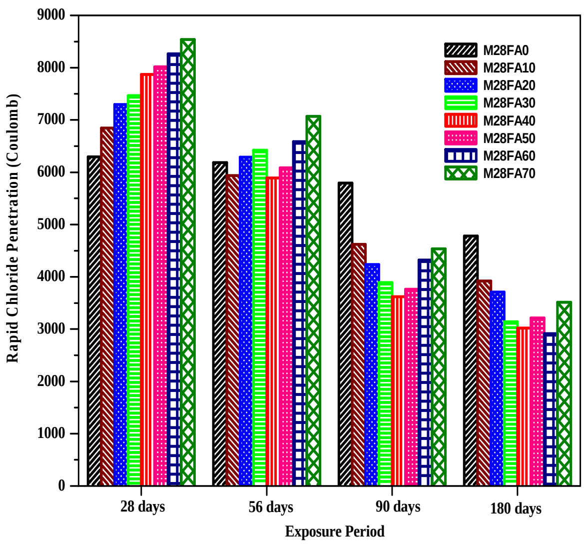

Fig.6 : Rapid Chloride Penetration - Exposure Time Relation for M28 Fly Ash Concretes

Relative RCPT values of fly ash concrete compared to OPC concrete is observed to vary with the grade of concrete and replacement level of fly ash with cement. At an age of 90 days of curing, rapid chloride permeability values are 50%, 55%, 60%, 58% lower for M38FA20, M38FA30, M38FA40, M38FA50 concretes respectively and 27%, 33%, 38%, 35% lower for M28FA20, M28FA30, M28FA40, M28FA50 concretes respectively as compared to OPC concrete of similar grade. Also after 180 days of curing, RCPT values for 20%, 30%, 40%, 50% replacement level concrete are 45%, 50%, 57%, 66% lower respectively for M38 grade concrete and 22%, 34%, 37%, 33% lower respectively for M28 grade concrete as compared to OPC concrete of similar grade. This is due to high fineness of fly ash. It can react with the products liberated during hydration, forming secondary C-S-H gel that fills all the pores inside concrete and makes it more impermeable (Sarkar et al, 1995). So it reduces the amount of charge passed through the concrete. The study result also shows that as the amount of fly ash used in concrete is increased, charge flow through the concrete sample is decreased. This is due to the reduction of the pore spaces inside the concrete specimen that makes the concrete dense and compact and as a result the amount of charge flow is decreased.

CONCLUSIONS

Based on the results of the investigation conducted on different fly ash concrete made with various level of cement replacement as mentioned and cured for varying curing period up to 180 days, the following conclusions can be drawn:
(1) At early ages of curing, the rate of gain in compressive as well as tensile strength of fly ash concrete specimens is lower as compared to the corresponding strength of OPC concrete.
(2) Fly ash concrete mix having various cement replacement level up to 50% exhibited satisfactory results from both compressive strength and RCPT point of view.
(3) The optimum fly ash content is observed to be 30% of cement. Fly ash concrete with 30% cement replacement shows around 13% higher compressive strength than OPC concrete after 180 days curing.
(4) Chloride penetration resistance for fly ash concrete is observed to be improved as compared to OPC concrete. Fly ash concretes with 40% cement replacement level shows around 50% lower rapid chloride permeability value as compared to OPC concrete.
(5) Higher grade concrete showed higher strength gaining and lower rapid chloride permeability as compared to lower grade concrete.
(6) Fly ash concrete is reported as environmentally friendly. Use of fly ash as partial replacement of cement in any concrete work markedly reduces the cost of cement which otherwise been dumped that create environmental hazard and also provides lower impact on environment by reducing CO_2 emission, judicious use of resources etc.

REFERENCES

Ampadu, K. O. and Torii, K. 2002, Chloride Ingress and Steel Corrosion in Cement Mortars Incorporating Low-Quality Fly Ash, *Cement and Concrete Research*, Vol.32, pp.893 – 901.

Barker, D.J., Turner, S.A., Napier-Moore, P.A., Clark, M. and Davison, J.E. 2009, CO_2 capture in the cement industry, *Energy Procedia,* Vol. 1, pp. 87–94.

Duchesene, J. and Berube, M.A. 1994, The Effectiveness of Supplementary Cementing Materials in Suppressing Expansion due to ASR: Another Look at the Reaction Mechanism, Part 2: Pore Solution Chemistry, *Cement and Concrete Research,* Vol.24, No.2, pp. 221-230.

Hossain, K.M.A. and Lachemi, M. 2004, Corrosion resistance and chloride diffusivity of volcanic ash blended cement mortar, *Cement and Concrete Research*, Vol.34, No.4, pp.695–702.
IEA (International Energy Agency), 2006, *Energy Technology Perspectives: Scenarios & Strategies to 2050,* Paris.
Janotka. I. and Krajci, L.2000, In: Malhotra VM (ed) Proceedings of the fifth CANMET/ACI *International Conference on Durability of Concrete*, SP-192, pp. 223.

Joshi, R.C. and Lohtia, R.P. 1997, Fly Ash in Concrete – Production, Properties and Uses, *Advances in Concrete Technology*, Vol.2. Gordon and Breach Science Publishers, India.

Metz, B., Davidson, O., Bosch, P., Dave, R. and Meyer, L. 2007, *Mitigation, in Intergovernmental Panel on Climate Change, Fourth Assessment Report, Climate Change,* Cambridge University Press, UK.

Sarkar, S.L., Kumar, A., Das, D.K. and Banerjee, G. 1995, Utilization of fly ash in the development of cost effective cementitious product, In: The Fifth Canmet/ACI *International Conference on Fly Ash, Silica Fume, Slag, and Natural Pozzolans in Concrete,* Milwaukee, pp. 439-458, USA.

Shehata, M. H., Thomas, M. D. A. and Bleszynski, R. F. 1999, The Effects of Fly Ash Composition on the Chemistry of Pore Solution in Hydrated Cement Pastes, *Cement and Concrete Research*, Vol. 29, No. 12.

Thomas, M.D.A. and Jones, M.R. 1996, A Critical Review of Service Life Modelling of Concretes Exposed to Chlorides, *Concrete in the Service of Mankind: Radical Concrete Technology*, (eds. R.K. Dhir and P.C. Hewlett), E.&F.N. Spon, pp. 723-736, London.

Yamato, Takeshi., and Sugita, Hideaki., 1983, Shrinkage and Creep of Mass Concrete Containing Fly Ash, Fly Ash, Silica Fume, Slag and Other Mineral By- Products in Concrete, ACI SP 79, pp.87-102.

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CONSTRUCTION PRODUCTIVITY IMPROVEMENT USING PROCESS MODELLING

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ABSTRACT

The construction industry of the twenty-first century is well positioned to progress through improvements in equipment and methods of construction. Mechanization is evolving into automation, as manufacturers of construction and positioning equipment work to integrate their technologies to enhance the construction performance and productivity. While construction materials are planned and procurement of materials is arranged, unfortunately the achievements don't meet with the expectations. There are some reasons for these unexpected achievements, such as unpredictable breakdown of equipment, idle time, unanticipated demand for resources, operator efficiency, and non-availability of materials. Although these factors are unpredictable, their frequency can be evaluated through modelling with time and helps to increase the construction productivity. The study provides application and some examples of different modelling approaches especially the simulation modelling, which helps to the construction manager by balancing of equipment, labour, materials and financial resources to improve the construction productivity.

Keywords: Construction industry, Equipment, Construction productivity, Simulation modelling

INTRODUCTION

The construction industry of the twenty-first century is well positioned to progress through improvements in equipment and methods of construction. Mechanization is evolving into automation, as manufacturers of construction and positioning equipment work to integrate their technologies to enhance the construction performance and productivity. (Jonasson et al., 2002). Productivity improvement in construction work are driven by a group of factors; for example, Factors related to construction process, safety factor, site layout, factors related to construction resources (labour, equipment and materials), factors related to external environment and conditions, and factors related to management. A major element of causing low performance in construction is the presence of lost time in construction sites. In construction sites typically only half the working day is used effectively. Much can be blamed on poor organization, where redoing work, workers moving about and machine breakdowns commonly account for up to 75% of the lost time (Olomolaiye et al., 1998). This paper focuses on how process modelling can improve the construction productivity. So, several techniques of process modelling are described in this paper specially the "Simulation Modelling" and how it helps to improve productivity in construction. The process modelling can be done by simulation, linear programming, expert system etc. By analysing process modelling construction manager can find out the right way to carry out the operation efficiently and optimizing the use of resources, hence improve the productivity.

PROCESS MODELING

Model is a representation of a real world entity but not the "real thing" itself. In general the process of modelling, in particular simulation modelling, includes analysis, abstraction, simplification and approximation (Friedman 1996). The models can analyse alternative construction procedures with time as the dynamic element by defining the task, process and associated resources. The primary factor for modelling is the efficient use of the resources by optimizing the resources in construction processes. Based on the operational consideration, a construction process can be defined as a collection of activities. Activity is a readily identifiable component of a construction process, which cannot start until its required resources are allocated to it (Shi, 1999). So activity consumes resources and helps to produce the output.

APPROACHES OF PROCESS MODELLING

For process modelling there are several types of techniques are available; simulation modelling, linear programming, expert systems of modelling etc.

SIMULATION MODELLING

Simulation involves generation of a real situation using a model, which represents the real system as nearly as possible. So, simulation is the duplication of the real system through a model, which can be manipulated easily, and this manipulation can be used to gather knowledge on the real system.

Computer simulation is an effective tool that can be used in the construction industry to analyse the performance of construction process. The technique can be applied to compare different alternatives for management decision making at relatively low cost and with a faster rate compared to real situations. It is suitable in complex situations where other mathematical modelling cannot be applied easily. Computer based simulation models have developed on several themes, (Slaughter 1999) first, the characterization of the cyclic activities in construction. These cyclic activities are modelled through subordinates or 'modules'. For example, simulation models 'CYCLONE' And 'MicroCYCLONE' has been used to many simulation analyses. A second theme for construction simulation model is the expansion of 3-D graphical representation to include the construction processes in the model.

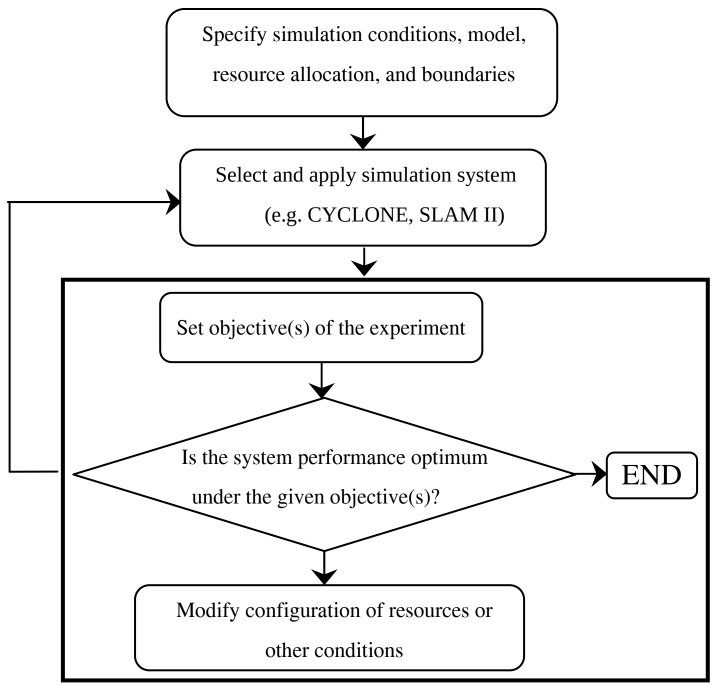

Fig. 1. Structure of simulation system (AbouRizk et al., 1994)

In an ideal simulation system the user provides initial resources and boundaries and the simulation condition. After that simulation provides the overall performance of the construction system, resource allocation to optimize their performance. The basic structure of simulation has shown in Fig. 1. Computer simulation can simulate a construction process on the operational level by addressing the random nature, resource driven characteristics and dynamic interactions during operation. It has been proven to be an effective tool for planning and improving the performance of a construction process (Shi 1999).

Simplified Simulation

Simulation models allow a concise representation of repetitive activities and the explicit formulation of resource flows. Several simulation techniques or systems are developed to simplify the model formulation of the construction processes, such as – RESQUE, CYCLONE, SLAM II, INSIGHT, Stroboscope etc. (Senior 1998). Different simulation system has different representation procedure. The CYCLONE is the most popular construction process simulation system because it uses small number of basic modelling elements.

Dynamic Process Simulation

A dynamic simulation is different from a steady-state simulation in that a dynamic simulation predicts how process variables change with time when moving from one steady-state to another or, during a transient upset; a steady-state simulation only shows the values of the variables when the plant is in a steady-state. When a dynamic simulation is run in "real time", the dynamic response of the variables in the simulation should be exactly the same as the dynamic response of the actual variables in the process plant. Through the computer based dynamic process simulation models, the detailed tasks of construction processes can be examined. It can be act as a tool for assessing the applicability of specific designs or technologies to particular projects (Slaughter 1999). An example of dynamic simulation has given below for material handling in site (Olomolaiye et al., 1998).

The elements involved in the crane handling of different types of material, for example- concrete, brick, formwork and reinforcement, can be considered as portions of time in a continuous working cycle with each characterized by a distribution having a mean value, reflecting patterns of change in the quantity and order of materials handled, servicing time, breakdowns and idling. In simulating materials supply the work done to date with each material type is expressed as a percentage of the total quantity of materials of that type to be moved, as shown in in Eq. (1).

New work done = Old work done + Δt * (rate of work) (1)

Where start work done = 0 and Δt is considered as time interval. Work done starts at 0% and completes at 100%. The rate of work done is the percentage of total stock delivered on each cycle,

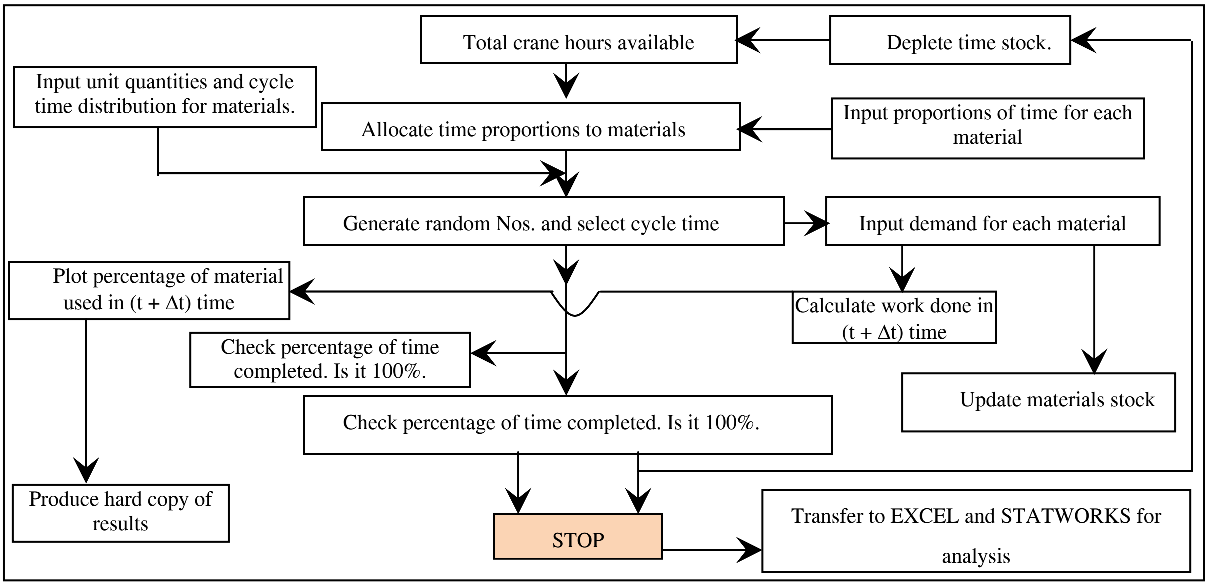

Fig. 2. Flow chart of dynamic simulation applied to materials handling (Olomolaiye et al., 1998)

divide by the time to load and deliver the material, this is selected from a distribution representing real data obtained from work study observation. The values are selected randomly. The diagrammatical system for material handling is shown in Fig. 2.

The incremental simulation time interval Δt are input, together with the quantity for each material type and the proportion taken up with this material in the cycle time. The output information consists of the percentage of each material used at any given time. By monitoring the performance of each type, the impact of making changes can be examined.

Activity Based Construction Simulation

Activity Based Construction (ABC) modelling uses one single element (e.g. activity) for modelling general construction processes instead of multiple elements as required by current simulation systems (Shi, 1999). The concept of activity based construction model is targeted to reduce the tediousness, complexities and error-proneness during modelling. ABC is a static representation of a construction process. The simulation algorithm provides a mechanism to experiment the ABC model so that the dynamic behaviours of the construction process can be observed by tracing the movement and interactions of simulation entities in the model. Simulation entities flow through a simulation model, which are identifiable by their states and locations during a simulation. It can be resource entity and processing entity (Zhang et al., 2002). Activities are the basic elements that ABC- Sim directly deals with during a simulation experiment. The dynamic behaviour of a construction process is portrayed by detailing the changes of the state of activities. The ABC Sim algorithm involves three stages: Select activity for construction, advance simulation and release simulation entities. The process is illustrated in Fig. 3.

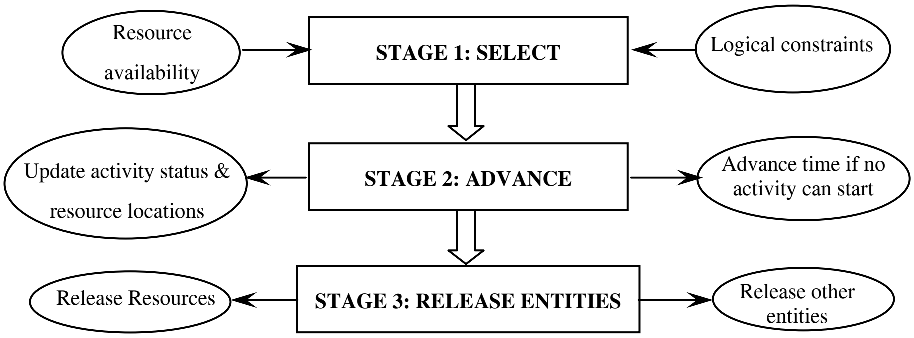

Fig. 3. Three stage ABC- Sim Algorithm (Shi, 1999)

Example: Concreting Process

A process for the placement of floor slab concrete is adopted by ABC modelling and simulation. In this process, the concrete is produced at the offsite batch plant, and transport to job site by transit mix trucks. The fresh concrete arriving at the job site is moved to the placement of area by a hoist, held temporarily in a storage hopper, and then distribute by using rubber tired buggies, which is illustrated in Fig. 4.

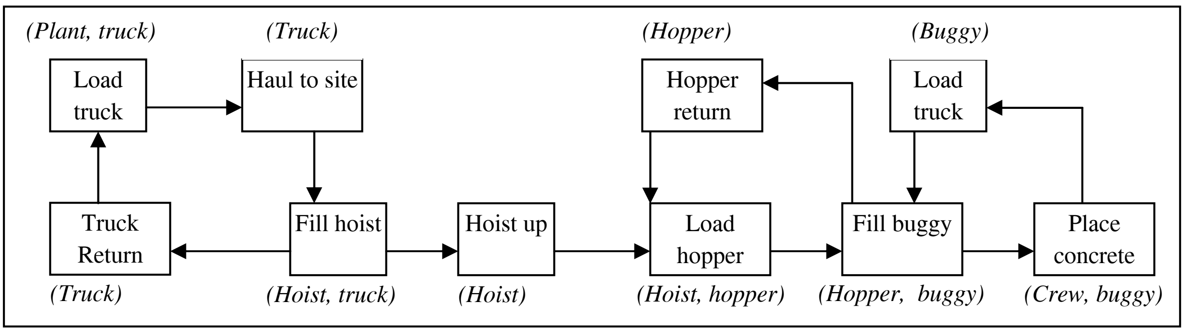

Fig. 4. ABC Model of concreting Process (Shi 1999)

This process consists of 10 activities and requires six kinds of resources: plant, truck, hoist, hopper, buggy, and crew and form 3 loops. ABC–Mod and ABC-Sim create a unique and easy to use for construction modelling and simulation method which is addressed as ABC in general. ABC can provide all of the modelling and simulation functionality requirements for construction.

Genetic Algorithm Optimized Simulation

A Genetic Algorithm (GA) is a heuristic optimization method that operates through determined, randomized search. The set of possible solutions for the optimization problem is considered as a population of individuals. The degree of adaptation of an individual to its environment is specified by its fitness .The simulation models generally, are capable to analyse the performance of a process, during the inputting the set resources into the model. A trial and error approach is used to experiment the model with various combinations of resources to improve the solution or output of the simulation. This trial and error approach is a time consuming and does not give guarantee of an optimal solution. The genetic algorithm with simulation model is suitable to get an optimum set of resources that optimize both cost and production, under various work conditions and resource availability limits. There are five steps for resource optimization by GA simulation. These steps are shown in Fig. 5.

LINEAR PROGRAMMING

Linear programming is the most popular type of mathematical programming model. Basically linear programming (LP) involves mathematical formulation of an objective function together with a set of associated constraints within which the objective should be achieved and solving the formulation to obtain an optimum solution (Olomolaiye et al., 1998). In construction engineering, linear programming acts as a technique to allocate or use limited resources among a number of competitive construction activities by maximizing benefit or minimizing loses in their use. In linear programming (LP) model the objective function can be a maximization problem, for example- profit of a certain operation, or a minimization problem, for example cost of a project, distance travelled for truck and equipment. Through linear programming we can determine the optimum number of the combination of the equipments (number truck and loader for earth moving operation) by minimizing the cost of operation.

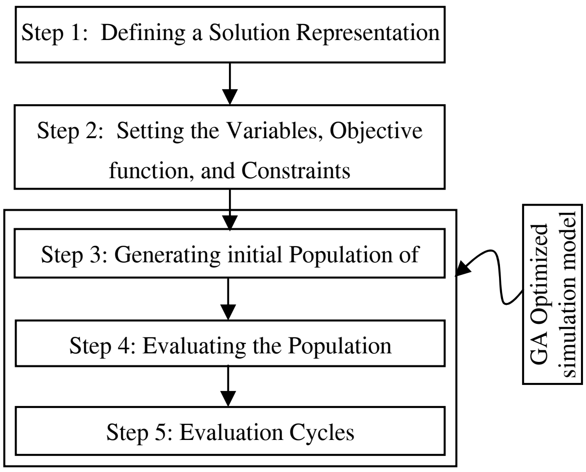

Fig. 5. Steps for resource optimization by GA simulation.

EXPERT SYSTEMS

An expert system consists of a knowledge base structured logically and stored in a computer. This knowledge can be accessed by the computer program, called the shell (Olomolaiye et al., 1998). The shell conduct the modelling by using questions and answered by the user, in the format of "Yes", "No" or "Don't know". The simplified concept of Expert System has illustrated in Fig. 6.

Expert system can be used in construction industry for carnage selection, claims analysis, earth moving equipment selection, layout of temporary construction facilities etc. Though no expert system has been developed in the areas of materials management, company management, constructability evaluation and quality control, several planning, engineering, management and operational tasks are candidates for expert system formulation (Mohan 1990).

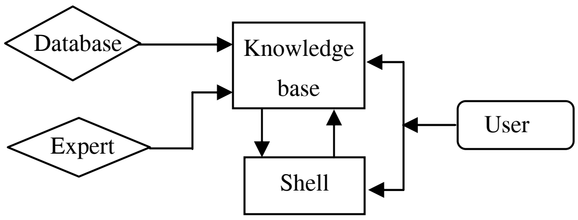

Fig. 6. Simplified concept of an Expert System (Olomolaiye et al., 1998)

CONCLUSION

Computer simulation is an effective tool that can be used in the construction industry to analyse the performance of construction processes. Looking to the future, the more powerful modelling environments are coming into the construction industry, not the least of which is the type of virtual reality system that will move from design visualization into construction planning and management (Paulson, 1995).

While construction materials are planned and procurement of materials is arranged, unfortunately the achievements don't meet with the expectations. There are some reasons for these unexpected achievements, such as unpredictable breakdown of equipment, idle time, unanticipated demand for resources, operator efficiency, and non-availability of materials. Although these factors are unpredictable, their frequency can be evaluated through modelling with time and helps to increase the construction productivity.

Generally the modelling has experimented for the repetitive or cyclic processes. Now a day's research is going on non-repetitive activities, or focusing on different types of resources (Slaughter, 1999).

This paper provides application and some examples of different modelling approaches especially the simulation modelling, which helps to the construction manager by balancing of equipment, labour, materials and financial resources to improve the construction productivity.

LIST OF REFERENCES

Abourizk, S. and Shi, J. 1994. Automated Construction Simulation Optimization. *Journal of Construction Engineering and Management*, ASCE, 21(3): 257-266.

Paulson and Boyd C. 1995. *Computer Application in Construction.* New York: McGraw-Hill.

Friedman, L.W. 1996. *The Simulation Metamodel*. Kluwer Academic Publishers, Norwell, Mass.

Jonasson, S.; Dunston, P. S.; Ahmed, K. and Hamilton, J. 2002. Factors in Productivity and Unit Cost for Advanced Machine Guidance. *Journal of Construction Engineering and Management*, ASCE, 128(5): 367-374.

Mohan, S. 1990. Expert systems applications in construction management and engineering. *Journal of Construction Engineering and Management*, ASCE, 116(1): 87-99.

Olomolaiye, Paul O.; Jayawardane; Ananda, K.W. and Frank, C.H. 1998. *Construction Productivity Management.,* England: Longman, Harlow, Essex.

Senior, B.A. and Halpin, D.W. 1998. "Simplified Simulation System for Construction Projects", *Journal of Construction Engineering and Management*, ASCE, 124(1): 72-81.

Shi, J. (1999). Activity Based Construction (ABC) Modeling and Simulation Method. *Journal of Construction Engineering and Management*, ASCE, 125(5): 354-360.

Slaughter and E. Sarah. 1999. Assessment of construction processes and innovations through simulation *Construction Management and Economics,* 17(3): 341-350.

Zhang, H.; Shi, J.J. and Tam, C.M. 2002. Iconic Animation for Activity Based Construction Simulation, *Journal of Computing in Civil Engineering,* ASCE, 16(3): 157-164.

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SUSTAINABILITY OF METRO RAIL IN THE CONTEXT OF DHAKA CITY

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ABSTRACT
The 400 years old Dhaka city is turned into a jam prone city due to its unplanned urban transport planning. At present the road way comprises only 8% of its total area in Dhaka city. As a result we have very limited option to change the geometric condition of roadway. According to Strategic Transport Plan, 2005 it was suggested to implement 3 BRT (Bus Rapid Transit) and 3 Metro Rail routes in this city within 2024. However, there is a lot of quandary among the decision makers and general public about the sustainability of this Metro Rail. Sustainability issue is also highlighted in the fact that it is underground or elevated. To evaluate the sustainability parameters extensive primary and secondary data is collected. Extensive questionnaire survey was also done by the researchers. To get representative sample, data was collected from various age group, occupation group, income group, education group, travel pattern group and so forth.The key issue of the paper is to evaluate the existing public transport facilities and compare it with Metro Rails that are in operation around the world. Finally, it is found sustainable in Dhaka city in context of energy, land, construction, economic and safety. Also some recommendation is given for efficient management of Metro Rail in Dhaka city.

Keywords: Sustainability, Demand, Higher Capacity, Public Transport, Metro Rail

INTRODUCTION

Public transport means the safe, convenient and cheap mode of transportation system. But in modern age urban dwellers demand rapid, reliable mode of public transport with higher passenger carrying capacity. That's why the Mass Rapid Transit has brought under the light in many countries in the world. Dhaka, the capital, administrative and commercial nucleus of Bangladesh**,** is subjected to severe traffic congestion, insufficient traffic management, high accident rates and increasing air pollution problems. The Dhaka Metropolitan Area (DMA) has a population of 11.875 million and Dhaka city among them 45.6% are women and 54.4% are men (Population & Housing Census, 2011). Currently urban transportation in DMA mostly depended on road based transport system such as car, bus, auto-rickshaw, non-motorized rickshaw etc. The deteriorating traffic conditions are affecting the city's efficiency and are being considered as a major barrier for her economic growth and development. This has prompted to the introduction of Mass Rapid Transit (MRT) like Metro Rail in order to improve the public transport system of the city which was also reflected in Strategic Transport Plan (STP, 2005) for Dhaka city.

Though Dhaka's area is less than 1% of the country's total land area, it has about 10% of the total population and 30% of the total urban population (Rahman, 2008). Among the various causes of congestion and air pollution, the mixed movement of traffic is the foremost one. According to STP (2005) about 51% of the total trips in Dhaka city are shared by non motorized modes and motorized transport modes contribute to the rest 49% trips. Extents of trips that are made by walking are considerable and 22% of all the total trips. Rickshaw is the most prevailing among the non motorized transport modes and represents 29% of all trips and bus represents only 31% of all trips (Das 2009). The high dependence on non-motorized rickshaw and a low dependence on public transport is a symptom of ham-fisted transport operations.

In the previous decades various kinds of master plan, expert's opinion as well as guidelines was suggested to improve the existing scenario of Dhaka city. However, very few suggestions saw the light of optimism. Therefore, it is essential to find out alternative sustainable solutions and the solutions should be oriented towards Mass Rapid Transit (MRT) options. Without MRT, it is quite impossible to provide sustainable transportation system of a city with huge population. Bus Rapid Transit and Metro Rail have been successful and very popular transit option in many developed and developing cities and is being increasingly utilized by many other cities (Guha, 2011) .Therefore, in this paper details investigation about the sustainability parameter of metro rail is done in the context of Dhaka city.

METHODS

Data has collected by using both manual and automatic method (vedio camera). Most of the data are collected by conducting field survey, carried out directly by the researcher. Moreover, some information is collected from Strategic Transport Plan (STP, 2005) and Preparatory Survey Report on Dhaka Urban Transport Network Development Study in Bangladesh (DHUTS, 2010) .Secondary sources are used to evaluate the sustainability of metro rail in Dhaka city. The physical surveys have been conducted at different bus stoppages as well as at other locations along the survey route on demand of various transportation modes, frequency of bus services, passenger carrying capacity etc. The field surveys also included an extensive passenger opinion surveys about the existing hazards along the selected corridor, the travel time, the existing hazards along the selected corridor, various vehicular perimeter, comfort assessment etc. To get representative sample, data is collected from various age group, occupation group, income group, education group, travel pattern group and so forth. These data is processed by making customize data entry and decoding program and analyzed by using SPSS PC software.

RESULTS AND DISCUSSIONS

Paradigm of other Countries

In the present world**,** about 172 cities have the Metro Rail in their urban transportation system. World's largest MRT systems by annual ridership can be seen from the Table 1. Metro systems are being developed or expanded in several developing cities, such as Bangkok, Santiago de Chile, Kuala Lumpur, Delhi, Mumbai, Kolkata, Sao Paulo, Buenos Aires, Mexico City, Cairo, Dubai, Ankara, Manila, Beijing, Shanghai, Taipei, Hong Kong and many other parts of the world. There is extensive Metro Rail activity in some cities and substantial future activity is under planning or underway in many other cities (presently in 38 cities) (Hoque, 2012).

Metro Rail is the most common international term for subway and heavy rail transit. Compared to other modalities of public transport system, grade-separated metro is the most expensive form of mass rapid transit, but has the highest passenger carrying capacity. It is fully segregated, usually elevated or underground urban railway. The track and electric vehicles are similar to suburban railways although stations are closely spaced. Trains may have 6-10 cars, with a total capacity of up to 3000 passengers, in some cases trains are operated over an extensive network. From the above discussion it is clearly revealed that according to the recommendation of STP, 2005 MRT Line 6 can be suitable for Dhaka city, as there are plenty of examples of other countries, which are successfully operating Metro Rail.

Table 1: Largest Metro Rail around the World

World's Largest MRT Systems
(by annual ridership: 2006-2008)

1.	Tokyo Subway	- 3.174 billion (2008)
2.	Moscow Metro	- 2.573 billion (2008)
3.	Seoul Subway	- 2.047 billion (2008)
4.	New York City Subway	- 1.624 billion (2008)
5.	Mexico City Metro	- 1.460 billion (2008)
6.	Paris Métro	- 1.388 billion (2007)
7.	Hong Kong MTR	- 1.309 billion (2008)
8.	Beijing Subway	- 1.200 billion (2008)
9.	London Underground	- 1.197 billion (2007)
10.	Shanghai Metro	- 1.122 billion (2008)
11.	São Paulo Metro	- 945.8 million (2008)
12.	Cairo Metro	- 700.0 million (2002)
13.	Madrid Metro	- 690.0 million (2007)
14.	Guangzhou Metro	- 601.0 million (2008)
15.	Singapore Mass Rapid Transit	- 571.0 million (2007)
16.	Caracas Metro	- 510.2 million (2008)
17.	Vienna U-Bahn	- 498.1 million (2008)
18.	Toronto Transit Commission	- 459.0 million (2007)
19.	Taipei Metro	- 450.0 million (2008)
20.	Berlin U-Bahn	- 446.5 million (2008)
21.	Barcelona Metro	- 422.0 million (2008)
22.	Montreal Metro	- 382.5 million (2008)
23.	Rome Metro	- 331.0 million (2008)
24.	Milan Metro	- 318.0 million (2006)
25.	Athens Metro	- 278.0 million (2006)

Route

Among the three metro lines out of six mass transit lines as recommended by strategic transport plan (STP, 2005), the Line 6 is found to be most affordable based on the feasibility study carried out by JICA.

According to proposal (STP, 2005), the Metro Line 6 connects between Pallabi in the north of the city and Saidabad in the south with the total length of 16 km. However, as per JICA study total length of proposed line is 22 km from Uttara-3 to Saidabad including 6 km of extension (Figure 1). Taking into account future urbanization of Dhaka city, JICA has recommended its extension from Pallabi to Uttara-3 area, where RAJUK has undertaken large housing developments (DHUTS, 2010).As the proposed route is nearly 22 kilometers it will surely provide accessibility to a huge number of passengers. Client-oriented transport system is an imperative quality to make any transport project sustainable. Therefore, a wide coverage of the route ensures the sustainability of Metro Rail in Dhaka city.

Initial Operation Planning

As per JICA, the estimated capacity of the proposed MRT Line 6 in 2025 is 64,000 pphpd (Passenger per Hour at Peak Hour Both Direction) (DHUTS, 2010). If around 70% of the passengers will go from north to south**,** it is estimated about 40,000 pphpd in 2025. At present**,** the capacity of a three lane road is 4,500 Passenger per Hour at Peak Hour each Direction (Field Survey, 2012).Therefore**,** if the project will implement it will be definitely sustainable, because the main power of sustainable transport system is its user which is robustly present in the selected route. Now some features of metro rail (MRT Line 6) is mentioned below:

Table 2: Initial Operation Planning (DHUTS, 2010)

Number of Stations	16
Number of Terminals	2
Stop Time at Stations	40 seconds
Train Composition	10 cars
Average Speed	35 Km/hr
Maximum Speed	80 Km/hr
Commercial Length	22 Km
Turn Around Time in Each Terminal	4 min
Crash Load	250/m^2 (AW3)

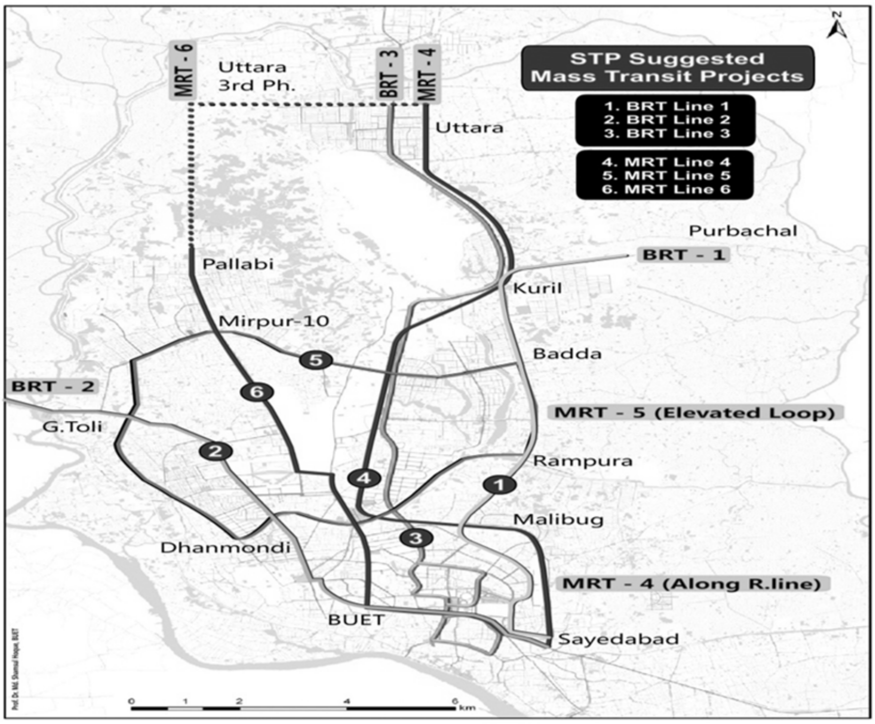

Figure 1: Alignments of three MRT and three BRT (STP, 2005)

Challenges in Providing a Sustainable Transport System

Implementation of any metro route is always a tough job. As Dhaka city is an unplanned city, there are more challenges to be faced. First of all, the whole route should be straight in nature without any sharp curve. Secondly, enough space should be needed for boarding alighting facilities at the station. Therefore, land acquisition for station will be a hard task. On the other hand, proper connecting facilities towards the station are mandatory. And the final and most crucial question is if it is underground or elevated. A lot of factors are depending on the implementation phase of Metro Rail. It is true a number of impediments exist to provide a sustainable transport, however, once if it is constructed, it will be an inseparable part of the urban dwellers of Dhaka city.

Elevated or Underground

Underground Metro Rail always needs continuous power supply for lighting, operation, maintenance, stations and so on. Also it needs standard security, air circulation and proper ventilation system. Sufficient drainage round the year is also a vital requirement of any underground Metro Rail (Hoque, 2012). Like airplane "Fail Safe" is a mandatory policy for this type of underground structure. Fail-safe designs are designs that incorporate various techniques to mitigate losses due to system or component failures. The design assumption is that failure will eventually occur but when it does, the device, system or process will fail in a safe manner (Wikipedia, 2011). Therefore, at least two power substations are necessary, one for operation and one for emergency situation. Moreover, in the proposed route lots of high rise buildings exist. Therefore, it is not easy to construct underground Metro Rail through this buildings and underground facility lines. On the other hand, for elevated Metro Rail, only limited power is needed for operation. Other operational and maintenance cost in comparison to underground is very much limited. From the above discussion, it is very much clear that elevated Metro Rail is best suited and more demandable to Dhaka city.

Preliminary Financial Evaluation

Financial evaluation has done considering 4 separate cases. Case 1 delineates no subsidy to the capital cost, case 2: 10% of the capital cost is invested as share capital from Bangladesh Government, case 3: In addition to case 2, RAJUK will contribute construction and system cost for additional costs from Pallabi to Uttara Phase 3, and case 4: Infrastructure cost among the project costs will be granted to the MRT company. Elaborately observing the results of the financial feasibility study two separate outcomes is revealed. It is found that without any government subsidy, FIIR (Financial Internal Rate of Return) of the project indicates to be 1.71%. On the other hand, when the government and RAJUK invest some of the project cost, FIIR becomes to be 3.2% (DHUTS, 2010). If the government induces soft loan such as Yen Loan to the project, it is financial very much possible to implement the project.

Preliminary Economic Evaluation

From the economic feasibility study it is disclosed that the investment of USD 7,491 million will produce annual economic benefits of USD 1,309 million in 2025. Moreover, the Benefit Cost (BC) ratio is computed to be 2.23. Finally, EIIR (Economic Internal Rate of Return) is computed to be 25.7% (DHUTS, 2010). All the data reveals that this project will be economically feasible. Financial and economic feasibility are the key tool to measure sustainability of any transport project. Therefore, metro rail is going to be a successful venture in the heart of Dhaka city.

Sustainability Curve of Metro Rail

According to BRTA**,** the number of Bus, Car and Rickshaw in 2009-10 is 1243, 19557, 216985 respectively in Dhaka city. This huge number of Car and Rickshaw is the main cause of the traffic congestion in Dhaka city. However, the passenger carrying capacity of these two vehicles is too low. A comparison of various vehicles is tabulated below. From table 3**,** it is clear that only Rapid Rail Transit have the highest passenger carrying capacity. Though Metro Rail is an expensive venture, there are many elements to make this reliable and passenger friendly service. First of all**,** it has millions of users in this city to use this service. Furthermore**,** to reduce our road congestion**;** we have no other option left without Metro Rail. There is always an issue that if this type of expensive projects will be sustainable or not. But if we observe its sustainability curve**,** it is clear to us that its sustainability is always increasing at an increasing rate since 1863. Therefore**,** from the sustainability point of view**,** it will surely cope with the economy of our country.

Table 3: Comparison of various vehicles with metro rail

Model	Capacity	Number of Bogeys	Headway (Min)	Capacity (pass/hr/direction)
Taxi	7	-	-	-
Van	11	-	-	-
Bus	75-80	-	0.67	5000-9000
Streetcar	99-139	3	2	8000-15000
Light Rail Transit	74-200	3	1.5	12000-20000
Rapid Rail Transit	210-360	3-10	2	40000-62000

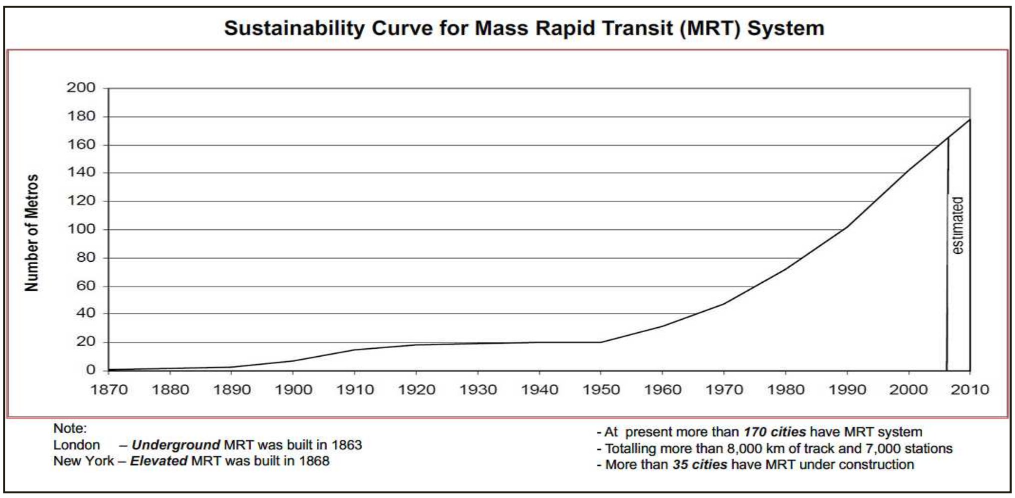

Figure 2: Sustainability Curve of Metro Rail

CONCLUSION

From the study, it was found that MRT system like metro rail is not only indispensable but also feasible in developing countries like Bangladesh. It is revealed that the proposed 22 km route is sufficient enough to provide accessibility to a large commuter group and initial operation plan is technically sound enough to provide a sustainable, comfortable, faster, safe and secured ride. It is also found that a plenty of hindrances may arise to implement this project such as straight alignment, continuous power supply, complication in elevated construction, proper drainage provisions and so on. However, this study depicts that this project is financially and economically beneficial for the government in context of FIIR, EIIR, and BC ratio. Therefore, once the challenges during construction phase can be solved, it will surely a sustainable and durable project which reduce the severe congestion in Dhaka city as well as earn handsome amount of revenue for the government each year. Finally, it is seen from the sustainability curve that all around the world this venture provides faster and safer ride to urban dwellers. Therefore, once it will construct it will be the best gift to our future generation.

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REFERENCES

Bhuiyan, L A. 2007. Study on Bus Operation in Dhaka City. *Air Quality Management Project (AQMP);* Department Of Environment, Government of Peoples Republic of Bangladesh

Dhaka Urban Transport Network Development Study in Bangladesh. 2010. JICA.

Hoque, MS.2012. Urban Transportation and Metro Rail. *Bandhan:A Monthly Publication of Akij Cement,* Volume 21, pp. 6-11.

Strategic transport plan for Dhaka. 2005. *Dhaka Transport Co-ordination Board,* Government of Peoples Republic of Bangladesh.

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DESIGN OF BUILDINGS BASED ON CLIMATE CHANGE

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ABSTRACT
Climate change and its impact on the design of buildings are currently subject to concern. Large resources have been put into development of models for predicting future climate changes. However, considering the huge investment in buildings combined with their expected long service life, only few resources have been put into adaptation strategies for buildings. In line with other countries, Bangladesh is at the beginning of developing a strategy to address the effect of climate change on a broad scale. The present paper is based on one of the pre studies for this work and focuses only on the impact on the design of buildings. It is shown how performance requirements for buildings may be taken as a starting point for a systematic evaluation of which climate related data are needed as a background for the design of buildings. Among the conclusions is that the lack of knowledge about the uncertainty of the relevant climate parameters is in itself a problem, and that the building sector should be more active in presenting its need for knowledge about specific climate related parameters

INTRODUCTION

A great part of the value of our infrastructure is bound in buildings. Satisfactory performance of those buildings can only be achieved by proper considerations to climate effects. The load-bearing structures of buildings are usually expected to last for at least 100 years. Climate change is therefore a serious problem in relation to design and renewal of buildings.

Many studies on climate change aim at developing models by which climate change scenarios are developed. Part of that is to establish a relation between climate key parameters, such as global warming, and the driving forces, i.e. greenhouse gases. This paper does not challenge these studies but take the results (Intergovernmental Panel on Climate Change, 2001) as the starting point for considerations related to decision making in the design of buildings. The idea in this contribution is to start with the performance requirements for buildings and then evaluate which climate parameters that do influence the design of buildings. Next step is to look for changes in the relevant climate parameters as presented in climate scenarios, and finally to evaluate the impact (threats and opportunities) and potential adaptation strategies to be used in the design of buildings, including changes in buildings codes and regulations. This approach differs from the approach in which impact from flooding, wind, rain and overheating are considered as a background for strategies for adaptation to climate change. Both studies are substantial and take the change in climate parameters as the starting point for evaluations of the impact on buildings. Although the most important parameters, which have been identified, are equivalent to those identified in this study, it is found that the performance requirements approach offers a more systematic way to identify climate related parameters of importance to the design of buildings.

The work presented here is based on two initiatives. Some research which addresses the effect of climate change on different sectors (buildings, farming, traffic, etc). The present paper is based on one of the pre-studies for this work and focuses only on the impact on the design of buildings. Part of the work has also been done in relation to a screening of the effect of climate change.

PERFORMANCE RELATED CLIMATE PARAMETERS

Building performance in relation to climate parameters may be characterized as indicated in Table-1.The table illustrates that buildings should offer a safe place to stay, with no danger of collapse, even during extreme storms. They should be comfortable to live in, i.e. provide us with thermal comfort, whether the weather is warm or cold, have a good indoor air quality, and facilitate the use of the surroundings when the weather is for that. They should also be durable with moderate maintenance costs. It should be noted that lack of thermal comfort and bad air quality may be life threatening for vulnerable people. In such cases, these criteria shall be characterised as safety criteria. It should also be noted that the design of a building aims at achieving a building which satisfies all the demands of the client. The climate-related performance requirements are only part of these demands, which also consist of requirements to the use of the building, to architecture, etc.

Table 1. Climate parameters in relation to performance of buildings

Performance requirements	Building subject	Climate related parameters to be considered
❍ Safety (life)	❍ Load-bearing structure, including foundation (strength)	❍ Maximum wind speed ❍ Ground water level (maximum and minimum)
❍ Comfort	❍ Building envelope (rainproof, temperature insulated) ❍ Indoor environment (temperature, air quality) ❍ Surroundings (building integration with the surroundings)	❍ Maximal rainfall ❍ Outdoor temperatures (maximum - heat waves, minimum, average winter temperatures) ❍ Relative humidity ❍ Toxic releases as from biological activity, such as mould or house-dust mites
❍ Durability	❍ The whole building	❍ Relative humidity ❍ Air temperature ❍ Ultra-violet radiation ❍ Frost-thaw cycles ❍ Attacks from insects such as termites or House Longhorn. ❍ Dry rot

THE DESIGN SITUATION

Part of the design process is to distinguish between different classes of consequences such as loss of life or health, lack of comfort, economic loss or opportunities for better comfort or economic savings. These consequences call for a differentiation of the safety levels, where loss of life or health, being the most serious, must be prevented at a high level, while some (temporary) loss in comfort or some increase in maintenance costs may be accepted if the climate change should develop more seriously than expected.

Climate change, with its changing conditions for satisfying a specific performance requirement, means that a certain standard of a building may not in the future satisfy the performance requirements which were satisfied in the original design.

Part of the background knowledge is also that in some cases it may be much more expensive to upgrade a building after having finished the construction than it would have been if that standard had been part of the original design. A typical example of that is when a load-bearing structure must be strengthened. In other cases upgrading can be done at almost no costs, as when a window, which cannot last any longer, is substituted with at better insulated window.

Even if one aims at adapting to climate change, the outcome of the design decision process may not prove to be adequate. The chosen standard may have been too high which means that part of the investment is wasted. It may also be chosen so that an upgrading turns out to become necessary, so that one ends out with an initial investment as well as costs for an upgrading. In this case it might be so that it had been better to save the initial investment and wait for more reliable information on the relevant climate parameter and then upgrade. The decisions are of course most difficult for the load bearing structures with their long expected life time, and easier for parts of the building envelope which regularly are renewed. These considerations should only be taken as illustrations of how uncertainty associated to climate change parameters makes decisions on initial investments in higher standards more complicated. The key question is: When shall we act, and how far should we go in meeting the threats or make use of the opportunities?

A systematic treatment of risk assessment and decision making may be found in (Willows and Connell (Eds), 2003) and (Lisø, 2006). However, it looks as if the more advanced tools cannot be too much help until the quality of input data is better. This means that the lack of knowledge about the uncertainty of the relevant climate parameters is in itself a problem. Whether an initial investment is a good idea basically depends on the uncertainty concerning relevant parameters in the climate data and how large the investment is in relation to the potential benefit. This decision situation is illustrated in Table 2.

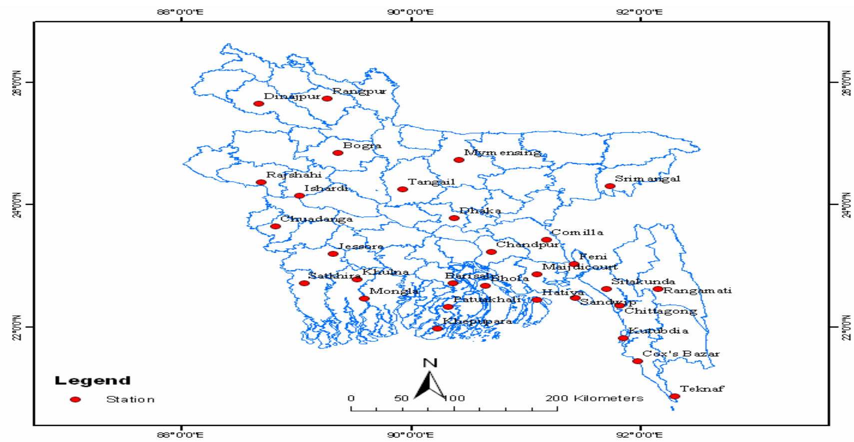
Table 2. Decision situations

	Small uncertainty on climate data	Large uncertainty on climate data
Small investment in relation to the potential benefit	Go for it	Maybe
Large investment in relation to the potential benefit	Maybe	Wait

CLIMATE DATA FOR BANGLADESH

Temperature Trend

Long term changes of near surface air temperature over Bangladesh have been studied using the available historical data collected by the Bangladesh Meteorological Department (BMD). Maximum and minimum daily temperature data of last sixty years (1948-2007) collected from 34 stations of BMD located all over the Bangladesh have been used in this study. It has been found that daily maximum temperature shows a positive trend of increase at a rate of 0.621 ± 0.491 0C per 100 year. The maximum increase occurred during November at a rate of 2.7 0C per 100 year. However, daily minimum temperature shows more significant trend of increase at a rate of 1.536 ± 0.461 0C per 100 year. The maximum increase occurred during February at a rate of 3.4 0C per 100 year. Daily mean temperature shows positive trend of increase at a rate of 1.026 ± 0.403 0C per 100 year. It has been clearly found that temperature of winter season (December to February) has been raised much higher rate than that of summer season (June to August).



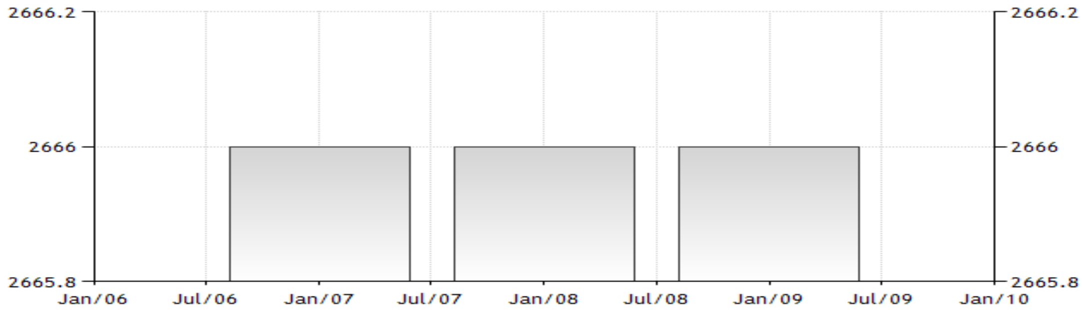
[Fig.1] Thirty four ground base measuring stations of Bangladesh Meteorological Department (BMD)

Reference: Analyzing changes of temperature over Bangladesh due to global warming using historic data by A K M Saiful Islam

Rainfall & Precipitation Trend

Heavy rainfall is characteristic of Bangladesh. With the exception of the relatively dry western region of Rajshahi, where the annual rainfall is about 160 centimeters, most parts of the country receive at least 200 centimeters of rainfall per year Because of its location just south of the foothills of the Himalayas, where monsoon winds turn west and northwest, the region of Sylhet in northeastern Bangladesh receives the greatest average precipitation. From 1977 to 1986, annual rainfall in that region ranged between 328 and 478 centimeters per year. Average daily humidity ranged from March lows of between 45 and 71 percent to July highs of between 84 and 92 percent, based on readings taken at selected stations nationwide in 1986 & 2007. So we have to consider the maximum rainfall for environment impact perspective.

The Average precipitation in depth (mm per year) in Bangladesh was 2666.00 in 2009, according to a World Bank report, published in 2010. The Average precipitation in depth (mm per year) in Bangladesh was reported at 2666.00 in 2008, according to the World Bank. Average precipitation is the long-term average in depth (over space and time) of annual precipitation in the country.



[Fig. 2] Precipitation Graph of recent five years 2006-2010

Table 3. Precipitation of other close neighbour country of Bangladesh

Country	Precipitation in depth (mm per year)
India	1083
Nepal	1500
Myanmar	2091

Among them India & Nepal has snow fall but in Bangladesh there is no sort of snow fall. But we can see that though Bangladesh is free from snow fall but it has higher precipitation value than others. It is a great matter to concern.

Wind Speed Trend

- Wind speeds appear to be higher in the east of the country than the west.
- Wind speeds in the coastal areas appear to be higher than inland.
- Wind speed exhibits a strong seasonal cycle, lowest in the winter and higher in the summer
- Annual average wind speed 2.5 m/s

The final report of WEST indicates that the average monthly wind-speed is relatively high during the months of April through August and low during September to March. The average annual wind speed values at 25 meter height for the seven stations vary from 2.96 m/sec to 4.54 m/sec. The highest average annual value (4.54 m/sec) was observed in Kuakata and the lowest value (2.96 m/sec) was observed in Teknaf and Noakhali.

Sea level Trend:

Floods that occur practically every year cause the water levels to rise by 13 centimetres to 2 metres. Only if more than 50% of the country is flooded, a flood will be called ‘heavy’.

However, while the blame for the rise in sea level (it is around 5.4 mm per year) is almost always ascribed purely to the rising sea levels due to global warming, in actual fact the sea is rising at only 1.4 mm/year, a rate which it has stayed the same in the Bay of Bengal for over forty years, and the majority of the problem is caused because the area in question is a river delta, and the ground is subsiding by about 4 mm/year.

Table 4. Climate data for Bangladesh (2071-2100), based on IPCC Previous Study & Data Analysis

Average temperature	+ 3.4°C
Yearly rainfall	+ 9%
Summer rainfall	-15%
Maximum 24 hour rainfall	+ 21%
Average wind speed	+ 4%
Maximum wind speed (storms)	+ 10%
Maximum see level at the west coast	+ 0.45m – 1.05m

By comparing the information in Table 4 with the information in Table 1 it can be seen that the provided data only contain data for some of the parameters needed in the design of buildings. One also misses the statistical information on these parameters, but that is the nature of scenarios, since they prescribe a point perspective rather than an interval at a certain level of confidence. As indicated above this means that the more sophisticated tools for risk analysis cannot be applied.

The missing data are not simple to derive. Concerning the average temperature increases, but this is not sure, because more rain will fall during the winter. Concerning the level of ground water, it might be so that the minimum level becomes smaller due to less rainfall during the summer, and the maximum level will increase because the winter rainfall increases. But again, it may not be the case. Only more sophisticated models can give us the necessary information. Also design data for heat waves are missing in Table 4, and when it comes to comfort in general and to durability one again misses more detailed information about minimum winter temperatures, relative humidity, ultra-violet radiation and frost-thaw cycles. Table 1 also shows the need of data on changed biological activity dependent on changed climate. It is clear that the building sector is interested in other species than the farming or the forestry sectors. This information can only be provided in a co-operation between meteorologists, biologists and building experts. It becomes obvious that standard metrological parameters as they are presented in table 4 are not sufficient input for building design. The building sector should be more active in presenting its need for specific parameters.

CLIMATE CHANGE ADAPTATION IN BANGLADESH

In comparing Table 1 and Table 4 it can be seen that climate change will give rise to threats as well as opportunities in the design of buildings. Those which are considered the more important are discussed below.

Wind loads

The above mentioned scenario indicated increased wind loads of about 20 % (load depends on the square of the wind speed). Wind load is a critical loading case for most buildings, so higher wind load calls for stronger structures. Compared to the safety margin of load bearing structures in buildings, a 20 % increase in the wind load ought not be critical. However, a heavy storm in 1991, which just reached the design wind of today. It was also found that the damaged buildings had strengths at about half of what is required according to the standard. A 20% increase in wind loads (10 % in extreme wind speed) is therefore supposed to result in a situation for which adaptation actions must be developed.

There are several possibilities for such actions. One is that the client demands a better quality control in new building projects to be sure that the strength will be as prescribed. Another possibility is that the insurance companies will demand the strength documented as a condition for keeping the premium at the present level. A third possibility is to increase the loads prescribed in standards. This will, as also pointed out by (Sanders and Phillipson, 2003) lead to a conflict with the tradition to base the magnitude of wind loads on historical data using an advance statistical approach to reach a specified level of formal safety.

For existing buildings the challenge is to identify types of weak buildings and strengthen them before they are damaged. This is an expensive process, but probably far less expensive than rebuilding damaged buildings after a storm worse than the 1991& 1998-storm. The indirect damages on buildings from fallen trees have been considerable. It is not likely that trees will become more resistant simultaneously with the increase in wind loads. The means that we should be better to evaluate when a tree may represent a threat to a building and to chop it down before it damages the building.

Ground water level

A changed ground water level may have an implication on the design of the foundation as well as floors and walls of the basement. If the drainage is insufficient a higher level of ground water (also a false ground water level after a heavy rainfall) may undermine the structural safety, and a lower groundwater level may lead to increased settlements and cracks in the walls of the building dependent on the type of soil below the foundation.

Heat waves

Already today many people find warm summer days hard to overcome. With more severe heat waves, higher income and cheaper technology an uncontrolled spontaneous investment in inefficient, electricity driven cooling equipment might be the result. Cooling could also lead to uncontrolled condensation which may give rise to mould and house-dust-mites. There is no exact research on that perspective. Similar idea and a substantial discussion on adaptation strategies aiming at improved indoor climate performance in different types of buildings may be found in “Beating the heat: Keeping UK buildings cool in a warmer climate. (Hacker et al., 2005).”

Extreme rainfalls

More extreme rainfalls may threat with overrun of gutters and water running into the basement from the surroundings. Water penetrating the building envelope is a main cause for deterioration of building materials. Better water protection, larger gutters, adequate drainage and surface regulation near the buildings are some of the measures to take into account.

Milder climate

In Bangladesh the traditional view is that buildings protect us from an unpleasant outdoor climate, and a few days a year we may enjoy the surrounding gardens and parks. The future climate may offer quite different opportunities for an integration of buildings with the surroundings, which may add considerably to the comfort from spring to autumn. In last few years Bangladesh faces serious heat in summer and excessive cold in winter. Undoubtedly this condition will more severe in future. One might also look forward to a smaller bill for heating during the winter, but it is not clear when we may prescribe cheaper heating systems with lower capacity.

Deterioration of building materials

Table 1 shows the relevant parameters. The challenge is that the effect on different building materials is different for each parameter, and the magnitude of the effect is even not know sufficiently well in many cases. A discussion on the behaviour of different building materials can be found in (Graves and Phillipson, 2000).

RESEARCH NEEDS

The study has revealed a number of building research items to be considered with the view to strengthen the decision making for a future with a warmer climate. They are:

- On which basis may the prescription of performance criteria, regulated by building codes, change its basis from historical climate data to future data?
- How is the distribution of strength of structures in existing buildings and how may weak buildings be identified and strengthened in an economical way?
- How will the future climate influence the durability of the different building materials?
- Architecture for a warmer climate (natural ventilation, integration with the surroundings)

CONCLUSIONS

- Performance criteria for buildings seem to be an adequate starting point for evaluation of climate change impacts on buildings.
- The lack of knowledge about the uncertainty of the relevant climate parameters is in itself a problem.
- The building sector should be more active in presenting its needs for specific climate related parameters.
- The most important threats on buildings are storm damages, warm and toxic indoor climate and short durability of some building materials.
- The use of data from climate scenarios as basis for prescribed loads on buildings is in conflict with the existing tradition of using historical data and a sophisticated statistical approach.
- The present knowledge is not sufficient to allow for advanced cost benefit analysis as a basis for investments in climate adaptation measures.

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REFERENCES

IPCC (2007) Climate Change 2007: *"The physical science basis: IPCC Working Group I Fourth Assessment Report: Summary for Policymakers", IPCC*, Geneva.

A K M Saiful Islam, *"Analyzing Changes of Temperature Over Bangladesh due to Global Warming Using Historic Data."*

World Bank (2000), *"Bangladesh: Climate Change & Sustainable Development"*, p. 40.

Mia, N.M. (2003) *"Variations of temperature of Bangladesh", In Proceedings of SAARC Seminars on Climate Variability In the South Asian Region and its Impacts*, SMRC, Dhaka.

Clark, Joseph A. 2001. "*Energy Simulation in Building Design"*, Second edition. London: Butterworth - Heinemann.

Chowdhury, M.H. K. and Debsharma, S.K. (1992), *"Climate change in Bangladesh – A statistical review", Report on IOC-UNEP Workshop on Impacts of Sea Level Rise due to Global Warming, NOAMI*, held during 16-19 November 1992, Bangladesh.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers. 2001a. *ANSI/ ASHRAE/ IESNA Standard 90.1-2001, "Energy Efficient Design of New Buildings except Low-Rise Residential Buildings"* Atlanta: ASHRAE.

Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability*. Cambridge: Cambridge University Press.