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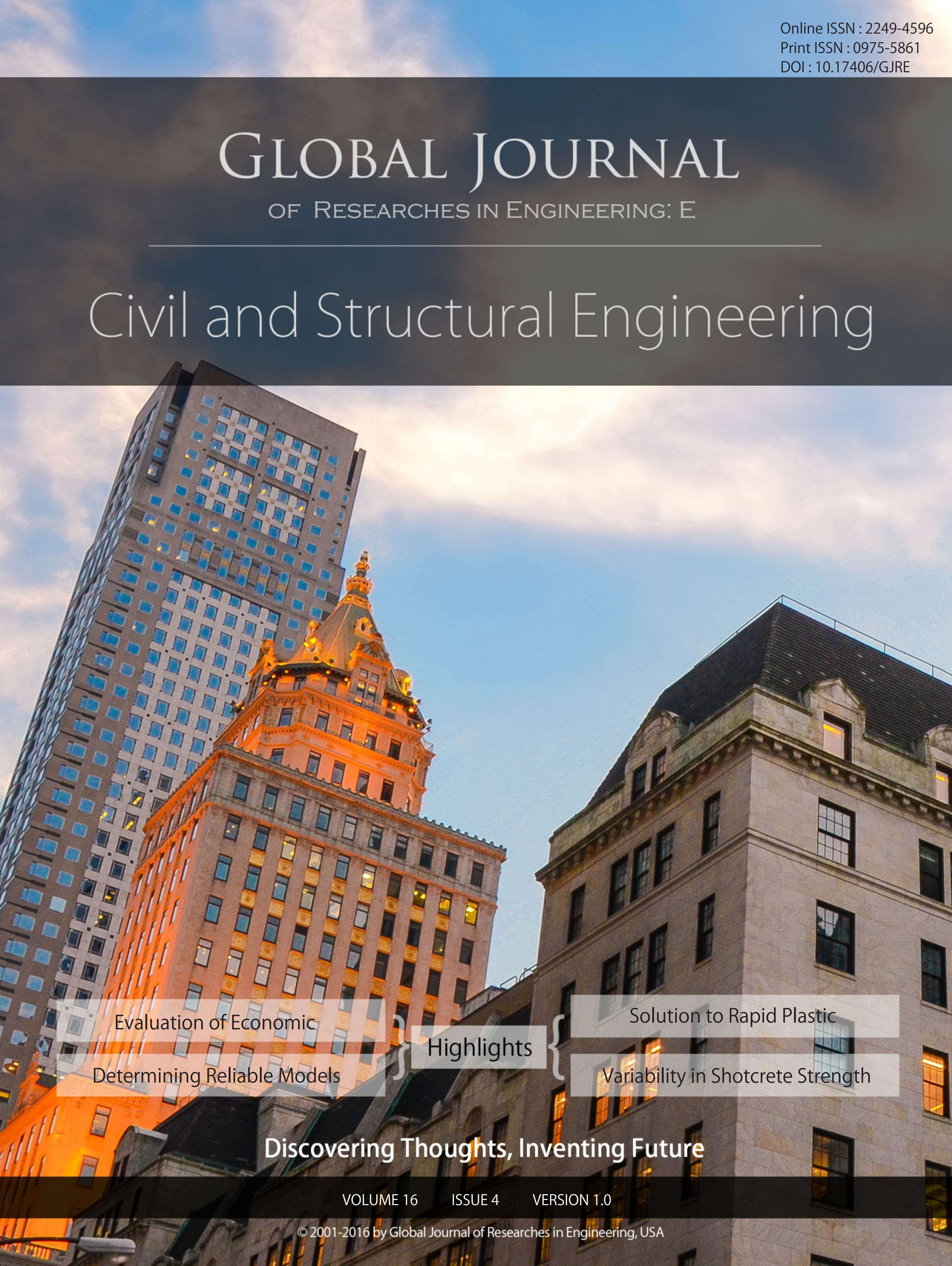

Evaluation of Economic

Determining Reliable Models

Highlights

Solution to Rapid Plastic

Variability in Shotcrete Strength

Discovering Thoughts, Inventing Future

VOLUME 16 ISSUE 4 VERSION 1.0

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Evaluation of Economic, Environmental and Safety Impact of At-Grade Railway Crossings on Urban City of Developing Country

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Md. Mehedi Hasnat [α], Dr. Md. Shamsul Hoque [σ] & Md. Rakibul Islam [ρ]

Abstract- Running through the densely populated urban areas railway has an inherent weakness of generating congestions at the at-grade crossings or level crossings (LC). It is responsible for economic losses, emission of harmful gases, and increase in accident risks for roadway traffic. Realizing these effects many of the developed countries have adopted various solutions starting from automatic gates installation to grade separation. However, developing countries have either failed to address the congestion problems caused by LCs, or yet to adopt appropriate measures to counteract them. Dhaka, the most densely populated megacity of the world has 42 level crossings in the city. This study reveals the economic losses, environmental impact and safety hazard of the busiest 7.15 kilometer railway corridor which has six level crossings. Primary field data have been utilized to find the delays and emission incurred by individual LC using available methods with slight modifications. Yearly economic losses incurred by studied LCs are estimated to be 32.95 million USD. With 1,412,128 kilograms of harmful gases (volatile organic compound, NOx and CO) emitted in a year, these LCs pose serious threats to the public health of the surrounding neighborhoods. Hazardous locations have been identified by assigning Hazard Index values. In light of these results, suitable solutions have been proposed to reduce congestion at the level crossings, and to enhance public health and roadway safety.

Keywords: level crossing, developing country, economic loss, emission, hazard index.

I. Introduction

Railway has been the most efficient way to meet the transportation demand of the mega cities throughout the world. Running through the densely populated urban areas, railway has an inherent weakness of producing congestions at the at-grade crossings (level crossing or LC). Especially near intersections, at-grade crossings create numerous conflict points for road-traffic, trains, and pedestrians. These crossings force both road traffic and trains to reduce their speed, increasing travel time, and congestion and decreasing overall efficiency of the rail network. The at-grade crossings are also a major source of traffic accidents in the urban areas, thus producing a significant threat to economy as well as to public safety.

Grade separations have been adopted in different countries to eliminate the at-grade crossings. Different criteria are used as base for the consideration of grade separation of level crossings in different countries. Australia, Germany, Great Britain, USA, Spain, Canada and various other countries used train speed as a criterion. In Japan the official regulation is followed as a grade separation criterion which states that if the product of daily vehicle traffic and the number of hours when the crossing is closed because of trains exceeds 10,000, the crossing is to be grade separated (Katz and Guttmann, 1991). Like the developed country, developing economies may not be able to adopt this solution as grade separation is very costly. Installing automatic level crossing gates, synchronizing the arrival time of trains with roadway traffic signals, appropriate platform arrangement near to the crossings are some of the less costly alternatives.

Dhaka is one of the most densely populated megacities of the world. It has a population of over 15 million with a staggering density of nearly 43,000 people per square kilometer area. Bangladesh Railway (BR) is the state-owned rail transport agency of Bangladesh. Both inter-city and suburban rail systems are operated under the state owned BR on a multi-gauge network of broad, meter and dual gauges. Presently, BR has about 2541 (1413 Approved & 1128 Un-approved) level crossing gates all over the country (Bangladesh Railway, 2008). In Dhaka, there are 29 authorized level crossings which are devised with manually operated gates. Daily on an average 90 trains travels to and from the Kamalapur Railway Station situated near the central business district (CBD). Most of the trains travel to the northern part and out of the city; only few passenger trains and DEMU trains travel south from the Kamalapur Railway Station. This creates severe congestions at the level crossings and is responsible for road-rail accidents. Some of the level crossings located in the busiest roadways are responsible for huge economic and travel time losses, and poses threat to roadway safety.

With the population growth traffic are growing faster than ever. This is high time to address the economic losses and safety issues related level

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crossings of Dhaka city. This study aims at finding out the economic losses, environmental pollution and threats to public safety associated with some of the most congested and accident prone level crossings of Dhaka. With some modifications, available methods are used to estimate the economic losses, environmental pollution and safety threats using primary field data. Also, some probable solutions are reviewed and the suitable ones are recommended.

This research paper is divided into several sections. The next section describes the available methods to estimate delays and their economic implications, which is followed by the selection of study locations and study methodology. The analyses of the study have been divided into three sections afterwards. In light of the findings some suitable solutions have been recommended in the section before the conclusion.

II. Literature Review

The literature review section focuses on the available methods to calculate vehicle delay and to estimate economic losses incurred by the at-grade crossing. The available methods of risk assessment on the at-grade crossings are also discussed here.

a) Delay Estimation of Isolated Crossing

Most of the grade crossings were somewhat isolated from traffic signalized intersections, thus making them well-suited for use of a mathematical model such as the Webster uniform delay model (Okitsu et al. 2010), which is based on classical deterministic queuing theory. Total vehicle delay caused by each blockage event is calculated using the formula below:

$$D = [AR * Q * (B + LT)]/2 \tag{1}$$

Where:

D = Total delay in vehicle-hours;
B = Duration of blockage event in hours
AR = Vehicle arrival rate in vehicles per hour;
LT = Lost time in hours
Q = Queue Duration in hours.

Queue duration is the period starting when the gates begin their descent and ending when the vehicles queued at a crossing dissipate after a gate blockage event. Queue duration is estimated based on the following formula:

$$Q = (\text{Blockage Event Duration} + \text{Lost Time}) / [1 - (\text{Arrival Rate} / \text{Saturation Flow Rate})] \tag{2}$$

A traffic delay calculation model was proposed by Hakkert and Gitelman (1997) from slight adjustment of a previous model by Rayan and Erdman (1985). That model includes:

$$T = \sum_{\substack{i=l,m \\ j=l,k}} \frac{1}{2} t_{cl_i} [t_{cl_i} + t_{rel_{i(j)}}].\lambda_j.n_{i,j} \tag{3}$$

Where, m = number of train categories for the period;
k = number of time intervals with different traffic volumes;
t_{cl_i} = blockage time caused by i-type trains;
$t_{rel_{i(j)}}$ = queue release time after i-type trains for the interval with j traffic volume;
λ_j = vehicle arrival rate at the crossing during the interval with j traffic volume; and
$n_{i,j}$ = number of i-type trains during the interval with j traffic volume.

Equation 2 provides simpler means to measure the delays than equation 3. In this study equation 2 has been used to estimate the delays of individual level crossing.

b) Estimation of Economic Cost at Grade Crossing

Economic cost incurred in grade crossings depends on several factors. Number of trains passing during the measured time (peak hour, a whole day etc.), total vehicular traffic using that crossing, blockage duration for each train event, reduction speed of vehicular traffic etc. The relationships between these factors and economic losses are linear in most cases. Hakkert and Gitelman (1997) proposed a linear regression formula for the approximate evaluation of the economic loss per crossing due to road traffic delay. The general formula is:

$$y = \alpha + \sum_{i=1}^{n} \beta_i x_i \tag{4}$$

Where, y = annual cost of vehicle delays in million NIS.
β = coefficient derived from regression analysis.
x = variables used in the estimation (daily vehicular traffic, number of crossing per day, free speed of vehicle on road etc.)

For a number of variables different values of coefficient were derived. Using equation 3, estimation of economic losses can be made by using at most five variables (Hakkert and Gitelman 1997). Without any speed data, the following equation was proposed (Hakkert and Gitelman 1997):

$$y = 0.00014x_1 + 0.010387x_2 + 0.361153x_3 \tag{5}$$

Where, x_1 = volume of daily vehicle traffic (vehicle per day, vpd)
x_2 = the number of crossing closing per day
x_3 = the number of hours per day when the crossing is closed.

Gitelman et al. (2006) used the following equation to estimate the annual cost of vehicular delays at a crossing:

$$D=260[N*d_1+(V-N)*d_2] \tag{6}$$

Where, D = annual cost of vehicular delays for 260 working days in a year.

V = daily Vehicular traffic volume

N = number of vehicles stopped at the crossing per day

d_1 = average cost of a vehicle's stopping at the crossing

d_2 = average cost of a vehicle's slowing down at the crossing

The delay costs on weekends were considered minor and hence were neglected. The economic loss sustained from traffic delays (d_1 and d_2) consisted of additional fuel consumption and other vehicle expenses (Vehicle Operating Cost), and from the time lost to vehicle occupants because of "velocity cycles" when passing the crossing (Value of Travel Time).

The same author also proposed two variant of an approximate formula for estimating economic losses incurred by grade crossing:

Y = − 0.656044 + 0.000108V + 0.0023038 trains + 0.094042 slowdown. And

Y = − 1.529568 + 0.000314V + 0.001676 trains. (for rural crossings)

Y = − 0.818024 + 0.000109V + 0.010480 trains. (for urban crossings)

Here, Y is the annual economic loss due to vehicle delays at a crossing in million NIS (New Israeli Sheqel; 1 USD = 3.78 NIS = 77.74 Bangladeshi Taka or BDT and); V refers to variable used (daily traffic volume vehicles), trains means the total number of trains, and slowdown is the average vehicle speed reduction due to a crossing in km/h.

In this research a direct approach has been adopted to estimate the economic losses in terms of vehicle operating cost (VOC) and value of travel time (VOT).

c) *Hazard Index Measurement*

A recent study identified five success factors largely responsible for the reduction in crashes, namely: commercial driver safety, locomotive conspicuity, more reliable motor vehicles, sight lines clearance, and the Grade Crossing Maintenance Rule (2).

Based on four crossing characteristics a Hazard Index (HI) equation was proposed by (Gitelman and Hakkert 1997). These characteristics included warning device, volume of vehicle traffic, and volume of train traffic and visibility conditions. Hauer (1986) proposed using an estimator T, where T is defined by:

$$T=f(x),E(x),VAR(x)); \qquad (7)$$

This method supports the maximum likelihood estimate of expected accident numbers for entities with observed accident count x, the sample mean E(x) and the sample variance VAR(x). In this manner, the influence of these characteristics on crossing safety is measured. The existing models (Taggart et al.,1987; Tustin et al.,1986) use from three to thirty factors to predict the accident potential at a crossing.

In this study New Hampshire Hazard Index (Ogden, 2007) was calculated for each of the six crossings. Calculated Hazard Index (HI) ranks crossings in relative terms; i.e. the higher the calculated index, the more hazardous the crossing. This mathematical HI helps to enhance the objectivity.

The New Hampshire Index is as follows:

$$HI=(V)(T)(P_f) \qquad (8)$$

Where, HI = hazard index

V = annual average daily traffic (AADT)

T = average daily train traffic (ADTT)

P_f = protection factor

= 0.1 for automatic gates

= 0.6 for flashing lights

= 0.8 for flashing lights with manually operated gates.

= 1.0 for signs only.

III. Selection of Study Locations

There are 42 railway level crossings and 6 railway stations in Dhaka city between Jurine and Abdullahpur of which 29 level crossings are authorized and other 13 are of unauthorized (Bangladesh Railway, 2008). 20 of these level crossings are associated with major roads and remaining 22 are associated with minor roads. For investigation, selection of crossings did not rely on an existing inventory, as it does not provide updated information about the level crossings. The major concern is to determine the economic losses, and have an estimate of the safety hazard of level crossing; following criteria are considered in selecting the study locations:

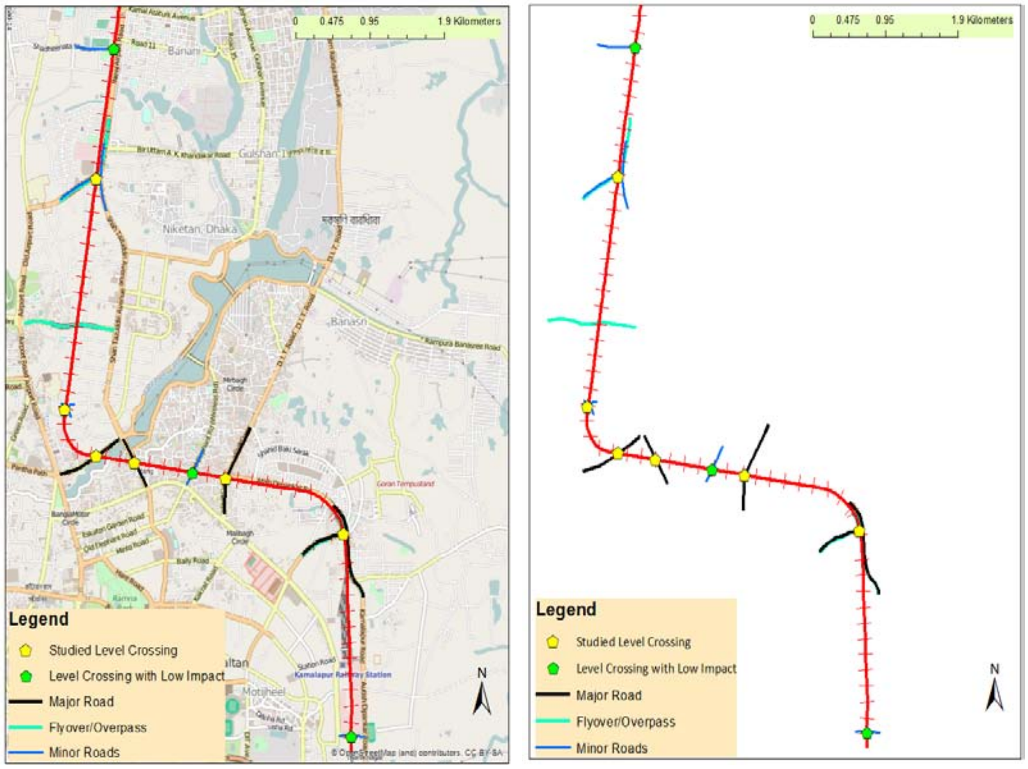

Fig. 1: Locations of the Studied Level Crossings

a. High Traffic Volume; especially those with high percentage of motorized vehicles.
b. High frequency of train traffic.
c. High duration of blockage event.
d. High rate of accidents reported in recent times.
e. High residential or commercial activities in the surrounding areas.

Based on these criteria six level crossings have been identified as critical. These level crossings sites along with the section of the railway track considered in this study have been marked in the following figure.

The selected six level crossings fall in a line starting from Mohakhali and finishing at the Kamalapur Railway Station. Length of this corridor is 7.15 km; that makes 1 LC at every 1.2 km within this densely populated area. Specially, starting from Truck Stsand to Mogbazar, there is three LC within 1.22 km of railway track. Mohakhali and Khilgaon LC have flyover (Fig. 2) running over them. But still the congestion is high in these two locations. Another flyover: Mouchak-Mogbazar flyover, is under construction which will pass over Mogbazar and Malibag LC and also will have an on and off ramps close to Karwan Bazar LC. Analyzing the aftermath of flyovers at Mohakhali and Khilgaon will help to assess the near-future scenarios at Mogbazar, Malibag and Karwan Bazar LC when Mouichak-Mogbazar flyover will be in operation.

IV. Study Methodology

The vehicle delay for the peak hours; (morning peak of 3 hours and evening peak of 3 hours, total 6 hours) is calculated for each blockage event and for each direction recorded during a single working day. Equation 1 is used to calculate the delay. The total daily (24 hours) vehicle delay is then estimated. The vehicle delay for the off-peak hours (18 hours) is taken to be half of the total peak 6 hour delay.

This mathematical model relies on only a few parameters, such as motor vehicle traffic, duration of the blockage, and the saturation flow for departing vehicles once the blockage is removed. This makes it easy to calculate delay for a given direction of traffic. The formula fits in a cell of a computer spreadsheet.

Primary field data were collected for the frequency and duration of the crossing gate blockage events in May 2015. It was observed that vehicles continued to traverse through the crossing when the warning lights flashed; in some events vehicles were found to traverse until the gate arm had fully closed the crossing. As soon as the gate arm began to rise, the vehicles in the queue began to traverse through the crossing. Therefore, for the delay analysis, the gate blockage event duration is considered to be the time when the gate arm was completely down until the gate arm begins to rise. Most of the time, a single train was observed to traverse through the crossings during the blockage events. In some cases, two trains traversed through the crossing on different tracks in different/same directions during a single blockage event.

Vehicular arrival rate is the number of vehicles arriving at the grade crossing within an identified time period. The arrival rate is based on the traffic count data collected with from field in May 2015 at each crossing over a 6-hour period (morning peak 3 hours and evening peak 3 hour). As the traffic stream consisted of different types of vehicles, to have the vehicular rate Passenger-car-equivalent (PCE) factor was used. However, for delay estimation in vehicle-hour at the rail crossings during a gate blockage event, the number of vehicle arrivals during the hour when the gate was down was recorded as the vehicular arrival rate. Delay in vehicle-hour was calculated for a single event and multiplied by the total number of gate blockage events observed during the peak 6 hours.

The maximum flow rate of the vehicles of a lane group observed during the traverse immediately after the gate blockage event is the saturation flow rate. Any start-up lost time prior to queue dissipation after the end of a gate blockage event is excluded in saturation flow rate. For the six different grade crossings different values of saturation flow were observed. Saturation flow rate was calculated in PCU per hour.

The time difference between the gates starts to rise and saturation flow stabilizes is the lost time. From the observation it was found that it took as long as 30 seconds to restore the normal traffic flow after the gate arm starts to rise. The lost time was added to the total blockage event duration.

The queue length was determined at the end of blockage event duration plus the lost period. Maximum total queue is the maximum number of vehicles waiting at the crossing during a single event. From the field the maximum queue length for each event was observed and recorded.

V. Economic Losses and Emission Cost of Delay

Delay for each crossing is measured by using equation 1. Vehicle Operating Cost (VOC) and Value of Travel Time (VOT) are well established measure of economic loss incurred by traffic congestion. In this study direct approach is used to calculate VOC and VOT from the calculated delay. The established VOC and VOT for different types of vehicles are extracted from RHD (Roads and Highways Department) Road User Cost (2004-2005). Table 1 shows the volume in PCU (Passenger car unit) with their delays and estimated losses in terms of VOC and VOT.

Table 1: Characteristics and Economic Losses of Investigated at Grade Crossings. (for 90 daily train events)

Sl	Location	AADT (PCU/hr)	Average BED per Closing (second)	Delay (veh-hr) in a Year[a]	Total Delay (veh-hr) in a Year [b]	Annual VOC in USD	Annual VOT in USD	Total Yearly Economic Loss[a] in USD	Total Yearly Economic Loss[b] in USD
1	Mohakhali	79099	172	1038977	1558465	1,922,275	4,283,667	6,205,943	9,308,914
2	Truck Stand	57279	200	302786	454179	144,808	253,454	398,263	597,394
3	Karwan Bazar	86414	222	1156900	1735350	1,145,876	2,117,879	2,291,753	3,437,629
4	Mogbazar	104465	219	1882394	2823591	2,869,598	6,106,272	8,987,478	13,463,805
5	Malibagh	84207	117	259078	388617	213,200	585,178	798,378	1,197,567
6	Khilgaon	111185	182	1447123	2170685	784,958	1,538,557	2,323,515	3,485,272
Total				6,087,258	9,130,887	7,080,715	14,885,007	21,965,722	32,948,583

All the costs at 2015 prices.

a = based on 260 working days and Peak 6 hours of the day.

b = for peak and off peak hour combined

The total vehicle-our lost in a year (in 260 working days) is 9.13 million. In monetary value the total loss in VOC and VOT combined is 32.95 million USD. The highest loss is suffered at Mogbazar LC with 13.46 million USD in a year. The Mohakhali LC is in the second and Khilgaon LC is in the third position with 9.31 million USD and 3.49 million USD losses in a year respectively. Interesting to mention that, both of these level crossings have flyover passing over them. The flyovers were supposed to reduce the at-grade congestion and reduce the travel time and economic losses. Instead, these two locations suffer more losses than the remaining three LCs. Another flyover is under construction which will pass over the Mogbazar and Malibag flyover. Due to the on-going construction works congestion is high in Mogbazar LC.

The emissions from the vehicles waiting in the queue during the closing period of the level crossing gates have been calculated. Three of the most common and harmful gases emitted from motor vehicles are considered: Volatile Organic Compounds (VOC), Carbon Monoxide (CO), and Nitrous Oxides (NOx) are considered in emission cost estimation. Idle vehicle emissions have been considered in the estimation (EPA, 1998). Table 2 summarizes the total emissions in kilograms and their costs for the six level crossings.

Table 2: Emissions and Emission Cost of Studied Level Crossings

Sl.	Location	Annual Emission in Kg			Annual Emission Cost (USD)
		VOC (Volatile Organic Compound)	CO (Carbon Monoxide)	NOx (Nitrous Oxides)	
1	Mohakhali	20470	206519	13989	289,426
2	Truck Stand	1605	28401	1569	36,318
3	Karwan Bazar	16116	287370	19526	378,180
4	Mogbazar	32193	562674	28541	712,683
5	Malibagh	2196	37748	3563	52,828
6	Khilgaon	7744	135840	6064	169,519
Total		80324	1258552	73252	1,638,954

Total yearly emission cost for six level crossings is 1.64 million USD. Emission is highest at Mogbazar LC. That is because the percentage of motorized vehicles are high in this level crossing and also the waiting time and queue length is higher in this level crossing due to the on-going flyover construction. These emissions have serious adverse effect on public health (Krzyżanowski 2005, Künzli et al. 2000, Wjst et al. 1993). Starting from various respiratory diseases these are responsible for cancer if exposed for a long period of time. The emissions not only affect the passengers and riders, but also have severe effect on the people living close to the level crossing junctions. Studies have proven that proximity to traffic sources escalates the risk for asthma and asthma exacerbations on the residents (Salam et al. 2008). As one of them most densely populated urban area in the world the risks are even higher in Dhaka. Specially, at Karwan bazar, Truck Stand, and Khilgaon which have relatively high population density in the surrounding areas compared to the other three level crossings, are more vulnerable to air pollution.

VI. Hazard Index

Hazard index is measured based on New Hampshire equation (equation7) with slight modification. As visibility is an important criteria in urban areas and from the field observation and questionnaire data the visibility was found to be responsible for several collision; this factor is included in this study.

V_f = Visibility factor
= 0.5 for good visibility
= 1 for poor visibility
= 1.25 for very poor visibility.

With V_f the modified equation becomes:

$$HI = (V)\ (T)\ (P_f)\ (V_f) \tag{9}$$

The HI of the studied level crossings is given in Table 3.

Table 3: Hazard Index (HI) of Studied Level Crossings

Grade Crossing	Traffic in PCU/hr[a]	AADT[b]	ADTT	Protection Factor, P_f	Visibility Factor, V_f	HI	DEF	Max. Queue Length (meter)
Mohakhali	3190	79099	90	0.8	1	5695125	7.727	180
Truck Stand	2310	57279	90	0.8	1.25	5155070	6.528	120
Karwan Bazar	3485	86414	90	0.8	1	6221790	7.012	220
Mogbazar	4213	104465	90	0.8	1.25	9401865	6.528	210
Malibagh	3396	84207	90	0.8	1	6062897	7.012	195
Khilgaon	4484	111185	90	0.8	1.25	10006637	7.727	170

a = Traffic volume is the sum of all approaches of the crossing, measured from 10 am to 11 am.
b = Conversion to AADT is done by using expansion factors (Grabber and Hoel, 2014)
[HEF = 17.11, MEF = 1.395, DEF]

As seen from the Table 3, most hazardous location is Khilgaon LC and the least hazardous location among the seven is Truck Stand LC. Both the level crossings have same values of P_f and V_f, but as more road-way traffic passes in the Khilgaon LC it has higher values of HI. Mohakhali LC is the fifth hazardous location among the seven. This is an interesting finding, although Mohakhali and Khilgaon both have flyover running over them which were built to reduce the at grade congestion. Even though, Khilgaon is the most vulnerable location for road way accident. A new flyover Mouchak-Mogbazar flyover is under construction, which will pass over the Mogbazar and Mailbag LC.

The following figure identifies the most vulnerable level crossings in terms of combined value of economic losses and emission costs, and Hazard Index values.

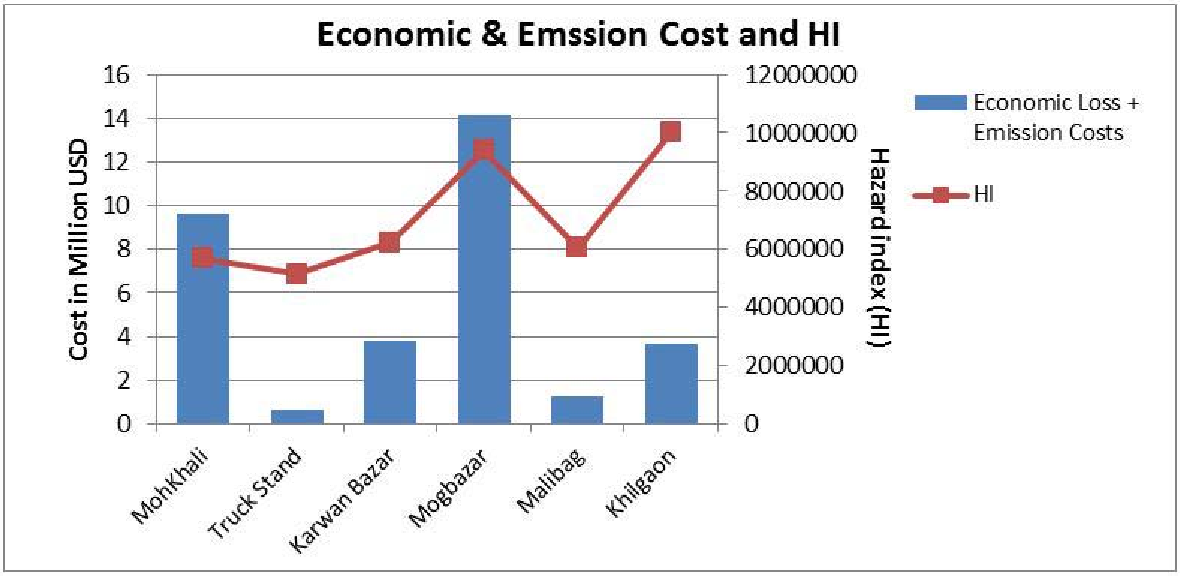

Fig. 2: Economic and Emission Costs and Hazard Index of Level Crossings

The values are high for Mohakhali and Mogbazar LC. As it was mentioned earlier, both of these level crossings have flyover running over them, still these two level crossings suffer the most. The daily vehicle traffic is higher in these locations which also escalates the risk of accidents. At Karwan Bazar and truck Stand LC the visibility is very poor. Slums and shops are located very close to the tracks from Truck Stand to Karwan Bazar LC. At the Mogbazar LC corner plots are occupied by large buildings (Fig. 3).

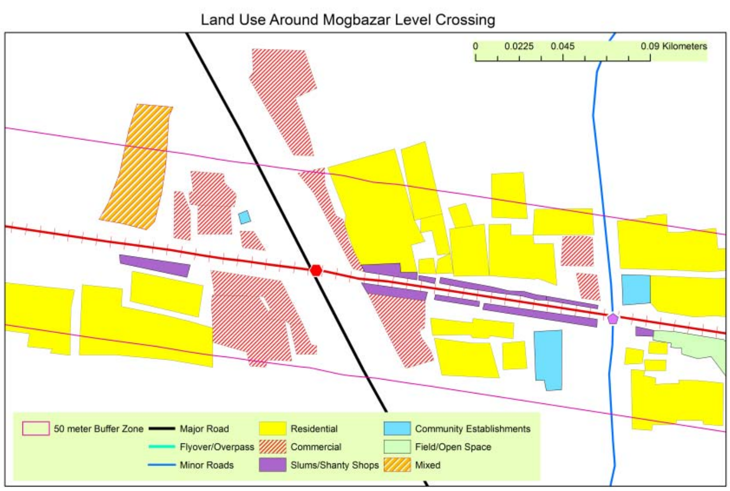

Fig. 3a: Hazardous Level Crossings

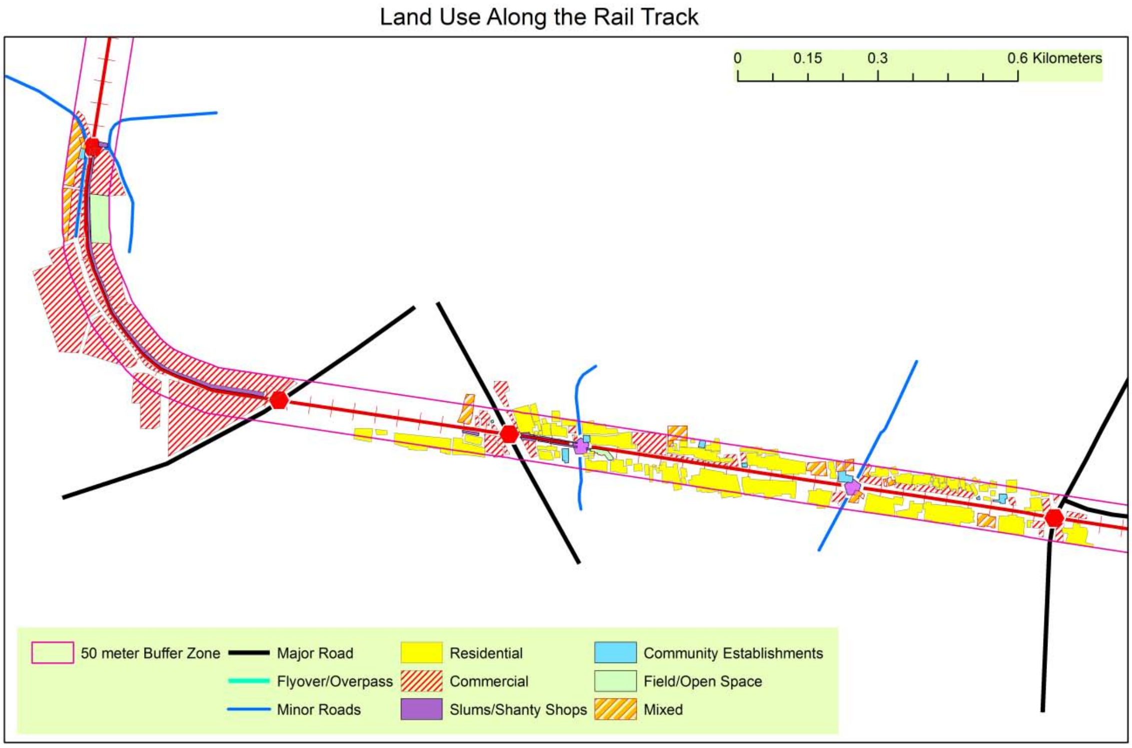

Fig. 3b: Hazardous Level Crossings

In very recent times, several accidents took place in this sort section. Slums and hawkers are also found in the surrounding area of Khilgaon LC. These increase the accident probability in many folds. According to national dailies, 238 people have lost their lives in level crossing related accidents only inside Dhaka city from January 2014 to September 2014. Accident rates are higher for Mogbazar, Karwan Bazar and Khilgaon LC.

VII. Recommendations

To mitigate the congestion and safety problems associated with the grade crossing various countries have adopted, and still adopting the solution of grade separated road-rail crossing. In different countries, different criteria are set to determine the warrant of grade separation. Most widespread parameter defining the need of grade separation is operating speed of trains. Grade separation is warranted if the trains operate at 160 kmph or higher speed (Katz and Guttman, 1991). In Israel the criteria decisive parameter is the product of daily vehicle traffic and the number of trains per crossing per day. These values vary from state to state and lie in the range of 20,000 to 35,000 and 50,000 to 75,000 for a rural and urban crossing respectively (Hakkert and Gitelman, 1997). In India a value of 100000 of this product (known as traffic moment) is used as a threshold to prioritize the sites for grade separation (UNESCAP 2000). In Japan, the criteria for grade separated crossing is set to be product of daily vehicle traffic and the number of hours when the crossing is closed because of trains; if that product exceeds 10,000, the grade separation is warranted (Katz and Guttman, 1991).

Elimination of all the level crossing is the only true way to address the economic losses and the safety issues (VicGov, 2009). It has been suggested to be the most effective measure of ensuring safety and reducing the risk of collision at level crossings (LCSC, 2013). However, due to the built up urban areas elimination of all level crossings altogether may not be feasible. From the analysis, grade separation is warranted for all the 7 level crossings. Following table summarizes the criteria for grade separation used in different countries and the corresponding values for the selected seven level crossings.

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Table 4: Grade Separation Criteria for Selected Level Crossings

A= Train Moment*	Israeli Criteria (A ≥ 75,000 for Urban)	Indian Criteria (A ≥ 100,000)	B= Product of Daily Traffic (PCU) and closing time (hr)	Japanese Criteria (B > 10,000)	Train Speed (Kmph)
4,912,281	Y	Y	234701	Y	≤ 30
3,557,169	Y	Y	197601	Y	≤ 30
5,366,552	Y	Y	330937	Y	≤ 30
6,487,599	Y	Y	395203	Y	≤ 30
5,229,500	Y	Y	169959	Y	≤ 30
6,904,912	Y	Y	348813	Y	≤ 30
6,477,030	Y	Y	395819	Y	≤ 30

* *Daily Traffic (PCU) times the Daily No. of Trains*

In terms of vehicular traffic and train traffic, all the level crossings need grade separation as found from Table 4. Although the train velocity is low and thus does not poses any significant threat to the roadway traffic. But again, due to the high roadway traffic and poor methods of gate operation, the trains are compelled to run at a speed lower than the average to avoid any collisions. Thus, this also delays the trains and reduces the efficiency of train movement.

Grade separation is the engineering process of separating roadway traffic modes and railway traffic by way of building a tunnel or a bridge. It reduces road congestion and its bi-products (Guzman et al. 2015). Removal of the level crossing through the construction of a road overpass might have the potential to reduce headways to a significant amount, but in order for the additional line capacity benefits to be realized all other level crossings on the line would also have to be replaced by road overpasses. To adopt this in Dhaka all the level crossing must be replaced by road over-pass or underpass. Installing overpass only in selected locations will not solve the problem as it is evident from the study of Mohakhali and Khilgaon level crossing. While grade separation is the most effective alternative, it is also an extremely costly solution. For example, in Australia, the cost of removing all level crossings in Victoria has been calculated to cost between USD 60 billion and USD 80 billion (NPV) (Lucas, 2009). The Committee for Melbourne estimates USD 100 million per level crossing removal from the Melbourne metropolitan area (CfM, 2011). With 50 years of life time annual cost of a road over-pass is 32.753 Million INR (11.656 Million INR for the year of 2000) or 0.5 Million USD (United Nations ESCAP 2000). Building a crossing grade separation in Israel was estimated to be NIS (New Israeli Sheqel) 2.2 million to NIS 66 million per site. The analogous published estimates for the United States are USD 1.56 million to USD 4.2 million (Rozek et al. 1988) and for Sweden are 3.6 million to 10.8 million Swedish kroner (Asp et al. 1986) (all values converted to 2015 prices).

Automatic barrier is used in many railways (USA, UK, Australia, Germany etc.). With a life time of 15 years the annual cost of an automatic barrier is USD 26,120 (in 2015 price) (United Nations ESCAP 2000). Considering lower cost than grade separation this solution can prove to be useful for Dhaka. With synchronization of the in-train devices the gate closing time can be reduced and accident probability can be minimized.

Several regulatory reforms in the operation of railway can be considered to reduce congestions at the level crossings. A study on the typical railway firm of Japan found some effective regulatory methods to reduce congestion without reducing the firm's cost reducing efforts based on price cap (PC) regulation (Kidokoro 2006). This study, PC regulation with a cap contingent on transportation quality (inverse of congestion rate), was found to relieve congestion without distorting cost-reducing efforts (Kidokoro 2006). The study also found that PC regulation, with fixed investment levels and allowing cost pass-through for investments, can correct the congestion without damaging cost-reducing efforts, ensuring low elasticity of substitution among inputs and proper determination of the target investment levels by the regulator (Kidokoro 2006). Using micro-simulation models, Mitrovik et al. (2012) found that optimizing light rail transit (LRT) schedule with preemption to LRT can reduce at grade congestion. In Dhaka, the railway is operated by Ministry of Railway (MoR) not by any private organization. To learn from Japan, the MoR must conduct a detail study to best meet the demand by reducing congestion in cost-effective way.

Modification of platform arrangements and warning methods can reduce the gate closing time and accident probability. A study by Guzman et al. (2015) proposed that congestion at station level crossings is not caused by the level crossing intersection closure operation, but rather by trains at the platform and/or arriving, forcing the intersection to remain closed for long intervals. At an Arrival Side Platform (ASP) platform,

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a train travelling east to west or up-line, triggers the intersection closure, arriving at the ASP platform before crossing the level crossing intersection, passenger's disembark and board. During this process, the intersection remains closed to all road and pedestrian traffic; the train then proceeds through the level crossing opening the intersection to road traffic. But that is not the case for a Departure Side Platform (DSP). In DSP the passenger boarding and onboarding is done after the train has crossed the level crossing. By installing DSP the congestion can be reduced by a significant amount (Guzman et al. 2015). For the case of Truck Stand LC this method can significantly reduce the gate closing time.

VIII. Conclusions

This study focused on the economic, environmental and safety impact of level crossings inside densely populated urban city. From available methods, simple estimations have been made by minor modification to meet the actual scenario. Field data have been used to estimate the economic losses in terms of VOT and VOC, the environmental effect in terms of emissions and safety threats in terms of Hazard Index. By quantitatively stating all the problems associated with at grade rail crossings, most vulnerable sites have been identified. Also, reviewing the available solutions, some suitable solutions have been proposed in this study.

9.13 million vehicle-hours are lost in a single year in six level crossings. The economic value of lost travel times and vehicle operating cost is 32.95 million USD or 25.62 billion BDT per year. Total yearly emission cost for six level crossings is 1.64 million USD or 1.275 billion BDT per year. Yearly 1412128 kilograms of harmful gases (volatile organic compound, NOx and CO) are emitted during the delays in six level crossings. Khilgaon LC has the highest HI followed by Mogbazar and Karwan Bazar LC.

From all the analysis Mogbazar LC has been identified as the most vulnerable LC as the economic costs, emission values and HI are higher than most of the other level crossings analyzed in this research. Surely, this LC draws the primary attraction for improvement to reduce congestion and economic losses. Mohakhali LC and Khilgaon LC have flyover running over them, but still do not manage to control the congestions to a significant level. Similarly, Mogbazar LC and Malibag LC may face similar consequences as another flyover is under construction in this corridor.

From this study it is obvious that all of the six level crossings require grade separation. But with limited resources and already developed urban establishments this is not the suitable solution for Dhaka. Using automatic barriers, rearrangements of ASP and DSP or adoptions of regulatory measures are some of the recommended solutions.

For staged improvement of the congestion scenario a more detailed research with cost-benefit studies of alternative solution is required. This study has identified the present situation of six level crossings in terms of economic losses and road-rail safety indicators.

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Statistical Analysis of the Variability in Shotcrete Strength

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Abstract- The variability in the strength of sprayed concrete was investigated and compared to that of counterpart lab-cast concrete. Statistical parameters were utilised in order to analyse the results based on a statistical approach. Two types of sprayed concrete were investigated; plain and fibre reinforced. The variations in the results were examined within the same typeof sprayed concrete and between the two types. The statistical analysis indicated that the strength of the placed sprayed concrete had larger variations compared to lab-cast concrete. The number of replications of test specimens that is required to ensure an acceptable error at certain level of confidence was calculated for various error values and levels of confidence. It was found that while two cubes of lab-cast concrete could be enough to keep the error below 10% at 95% confidence level, 16 cores of sprayed concrete would be necessary. If only three specimens of sprayed concrete were tested, then the expected error could be as high as 25% and 20% at 95% and 90% confidence levels, respectively.

Keywords: strength variation; sprayed concrete; shotcrete; in-situ strength, concrete cores; fibre-reinforced-concrete; statistical analysis; coefficient of variation; standard deviation; quality control.

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Keywords: strength variation; sprayed concrete; shotcrete; in-situ strength, concrete cores; fibre-reinforced-concrete; statistical analysis; coefficient of variation; standard deviation; quality control.

I. Introduction

Sprayed concrete, also known as shotcrete, is a cement-based mixture which is projected pneumatically at a high velocity onto a target surface. Compared to cast- in-place concrete, the sprayed concrete offers significant advantages. It reduces the amount and time for formwork installation and removal. Indeed, in many cases it eliminates the need for formwork altogether when shooting against existing surface. This advantage is extremely valuable in situations when formwork is cost prohibitive or deemed impractical [1-2].

Sprayed concrete has traditionally been used for repair works and for temporary construction in mining and tunneling to ensure the safety of workers. However, technological advancements, made it a viable construction material for new construction [2-3].

The utilisation of fibre reinforcement in concrete and sprayed concrete is rapidly expanding due to the potential economic and technical benefits. Many deficiencies of plain concrete and sprayed concrete could be alleviated by using fibre reinforcement. For example, polypropylene fibres are capable of improving the ductility of concrete by enhancing properties such as its flexural toughness, fatigue and impact resistance [4-10].

The physical and mechanical properties of properly applied sprayed concrete could be comparable or superior to those of conventionally cast concrete of same composition [2]. However, it is extremely difficult to produce sprayed concrete with the same composition of specified cast concrete due to the nature of the spraying process. The process of applying sprayed concrete generally ensures that most of the aggregates and cementitious materials combine to form a mixture, which adheres well to the substrate. Unfortunately, considerable amount of materials strikes the surface but does not adhere to the substrate. This is known as the rebound and it greatly influences the composition of the in-situ sprayed concrete. The latter could also be altered during the application process due to other variables such as using accelerator, fibre addition, poor application techniques, skills of the nozzleman and overwatering. Consequently, the properties of the placed sprayed concrete could have properties that are significantly different from the specified properties. Particularly, compressive strength [11-15].

Compressive strength is the primary material property specified for sprayed concrete. It is usually considered not only as a measure of its ability to carry loads but also as an indicator of its quality. Furthermore, the compressive strength of the placed sprayed concrete could be considered as the critical criterion used for design, and therefore needs to be accurately determined.

There are many testing methods available in the market for assessing the strength of in-situ sprayed concrete. Although each method has its advantages, most of them suffer from inherent negative aspects including limited range, inaccuracy and inconsistency. In addition, some of them are impractical [3, 16-17]. However, drilling cores from the in-situ sprayed concrete is considered one of the best methods to use in

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determining the compressive strength [12]. This technique is widely used since it is simple and economical. Guidelines and recommended procedures for coring, testing, and interpreting results of core specimens are well established and documented by several standards, codes and research reports such as ACI 214 R-02 [18], BS EN 13791 [19], ACI 214.4R-03 [20], ASTM C42 [21], BS 1881 [22], BS EN 12504-1 [23], The Concrete Society Technical Report CSTR 11 [24], Neville [25] and Chen et al. [26]. However, the results obtained from testing extracted cores are often noticeably scattered [14, 27]. The variation in the strength obtained for cores taken from sprayed concrete is often mentioned in the literature in general context but, unfortunately, it is rarely quantified on the basis of statistical analysis. Without significant statistical analysis the limited data available from placed sprayed concrete are regarded as unreliable [16]. The main objective of this research, therefore, was to investigate the variability in the strength of cores drilled into placed sprayed concrete and quantify it based on a statistical approach.

II. Materials, Mix Proportions and Production of Specimens

a) *Materials*

The binder used in this investigation was Portland cement (CEM1), conforming to BS EN 197-1 (2000). The coarse aggregate was quartzite natural gravel of 10-mm nominal maximum size. It had a specific gravity of 2.64, bulk density of 1585 kg/m3 and water absorption of 0.60 percent. The fine aggregate was Quartzite sand complying to zone M of BS EN 12620 (2002), with specific gravity and water absorption of 2.68 and 0.10 percent, respectively. Fibrillated Polypropylene fibres (PPF) with a nominal length of 18mm and an average diameter of 55μm was used, where applicable. More information about this fibre is given elsewhere [4].

b) *Mixes and mix proportions*

Two types of concrete were sprayed in this study; plain and fibre reinforced concrete (FRC). The mixes were initially optimised from laboratory tests. The cast and pre-sprayed compositions of the mixes are given in Table 1. The water content for the lab-cast concrete was constant at 160 kg/m (i.e. w/c ratio of 0.40). However, for sprayed concrete it was decided during spraying by the nozelman according to the ease of 'shotability' of each mix.

Table 1: Lab-cast and pre-sprayed mix proportions (kg per m^3)

Mixes	*Method*	*CEM1*	*Gravel*	*Sand*	*Fibre*
Cast-N	Lab-cast	400	948	948	-
Shot-N	Sprayed	400	948	948	-
Cast-F	Lab-cast	400	948	948	2.0
Shot-F	Sprayed	400	948	948	2.0

III. Production and Testing of Specimens

a) *Lab-cast concrete specimens*

A conventional rotary drum concrete mixer was used for mixing. The coarse aggregate, cement and sand were first mixed in dry state for one minute before adding about half of the mixing water. After two minutes of mixing, the remaining mixing water was added. Mixing was continued for another three minutes before adding the polypropylene fibres, where applicable, carefully into the running mixer to avoid clumping. Mixing was continued for a further five minutes to achieve uniform mixture. After casting, the lab-cast concrete specimens were compacted using a vibrating table. The specimens were, then, finished and covered with wet hessian and polyethylene sheets overnight. They were then de-moulded after 24 hours and cured in a fog room with curing conditions conforming to BS 1881: Part 111: 1983 (20±2°C and RH 97±3%) until testing.

b) *Sprayed concrete specimens*

Sprayed concrete panels were produced by dry process, which was more appropriate for this study due to economical and practical reasons. A dry-process pneumatic spraying machine with rotary feed wheels, 38-mm nozzle and material hose was used.

All ingredients except water were first mixed in dry state in a conventional concrete mixer. Where applicable, PPF fibre was added after two minutes of dry mixing, which then continued for another two minutes. The dry mix was then fed through the hopper of the spraying machine, which conveyed the mix pneumatically through the material hose to the nozzle where water was added through the water ring.

Wooden square moulds of 1200-mm side and 100-mm depth, shown in Figure 1, were manufactured specially for this project. Before spraying, the moulds were positioned as vertically as possible (within 5 to 10°). Every effort was made to minimise the variations in the spraying process. For example, the spraying distance between the nozzle and the target-surface and the spraying angle were kept around one meter and 90°, as shown in Figure 2.

Figure 1: Wooden moulds for sprayed concrete panels

After completing spraying, each panel was marked and covered with polyethylene sheet for 2 days, after which the panels were loaded carefully on trucks and transported to the laboratory for curing, coring and testing. On arrival, all sprayed panels were kept in the fog room to be cured, in the same conditions as the counterpart lab-cast concrete.

Figure 2: Production of sprayed concrete panels

By the age of 14 days, cores were taken from the panels of each type of concrete for compressive strength testing. Cores were inspected for any imperfect parts or sand pockets, marked and kept cured in the same fog room.

Twenty cores were drilled from each type of sprayed concrete. The number has been decided to minimise the effect of variation. Celik et al. [16] suggested that sample sizes of 18 or more are preferred for statistically significant data sets for minimizing the

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effect of variation within the results of compressive strength.

c) *Compressive strength tests*

Compressive strength of the drilled cores from the sprayed concrete and the hardened concrete cubes was determined according to BS 1881: Part 116: 1983, at the age of 28 days. The tests were carried out using a digital automatic testing machine of a 3000 kN capacity. The results of the compression tests are given in Table 2.

Table 2: Results from compressive strength test (MPa)

Sample	Plain		Fibre reinforced		Overall	
	Shot-N	Cast-N	Shot-F	Cast-F	Shot	Cast
1	29.96	69.28	25.30	76.35	-	-
2	32.82	70.42	26.59	77.89	-	-
3	33.74	74.51	26.72	79.54	-	-
4	36.13	75.30	30.51	80.47	-	-
5	38.78	76.24	32.69	82.69	-	-
6	38.89	77.11	36.12	83.29	-	-
7	39.95	77.86	37.55	83.54	-	-
8	40.79	78.17	38.46	83.84	-	-
9	41.97	78.43	39.34	84.09	-	-
10	44.07	78.45	40.68	85.37	-	-
11	44.26	79.74	42.31	86.41	-	-
12	45.58	80.68	42.83	86.45	-	-
13	46.37	81.24	44.92	87.02	-	-
14	46.95	81.25	45.82	87.23	-	-
15	47.41	81.96	47.53	88.30	-	-
16	49.35	82.33	52.16	89.01	-	-
17	50.06	82.52	52.97	89.51	-	-
18	53.76	82.73	53.11	90.52	-	-
19	55.48	84.05	64.15	91.54	-	-
20	69.59	85.25	70.01	92.08	-	-
Mean (MPa)	44.3	78.9	42.5	85.3	43.4	82.1
SD (MPa)	9.0	4.2	12.0	4.4	10.5	5.4
CoV (%)	20.4	5.4	28.1	5.2	24.2	6.5

SD= Standard Deviation; CoV= Coefficient of Variation

IV. Results and Discussion

a) Variability in sprayed and lab-cast concrete

The average 28-day strength of all sprayed concrete specimens was 43.4 MPa. The calculated standard deviation (SD) was 10.5 MPa and the coefficient of variation (CoV) was 24.2%. The corresponding values for the lab-cast concrete were 82.1 MPa, 5.4 MPa and 6.5% for the average strength, SD and CoV, respectively.

The value of the CoV for the lab-cast concrete observed in this study (6.5%) is between the 5.5% and 7.0% limits of the fair class recommended by ACI 214 R-02 [18] for concretes with strength of more than 35MPa, but outside 4.5% to 5.5% band for good concrete for lab trial batches. However, the CoV value reported in this study is similar to what Cussigh et al. [28] reported for high-performance concrete. Indeed, the CoV recorded for the lab-cast concrete compare favourably to the values reported by Aït-Mokhtara et al. [29] for high performance concretes with strength range between 68 and 84 MPa. The standard deviation of the results of the lab-cast concrete indicates good quality control over the production of the concrete specimens, as it falls nicely 20 between 4 to 6 MPa, which is considered acceptable in the UK [30]. The values of the coefficient of variation show further evidence of good quality control. The coefficient of variation of 6.5% is at the lower end of the range (between 5 and 10%) suggested by Day et al. [30] for concrete with a reasonable quality control.

On the other hand, the standard deviation and coefficient of variation of the results of the sprayed concrete not only are much higher than those of the counterpart lab-cast concrete, but also are much higher than the acceptable values for good quality concrete. Considering the upper limits suggested by Day et al. [30], the SD of 10.5 MPa is about 75% higher than the upper limit of 6 MPa. In addition, the CoV of the sprayed concrete (24.2%) is double the upper limit of 10%. Even when compared to more relaxed limits, the 24.2% overall CoV is about 60% higher than the 15% suggested by Swamy and Stavrides [31] for good quality control of concrete. When compared to the limits given by ACI 214 R-02 [18] for concretes with strength of more than 35MPa, the CoV of the sprayed concrete is 70% higher than the maximum limit of 14% for general construction testing.

The observed variability in the compressive strength of cores taken form in-situ sprayed concrete could be attributed to several factors that might possibly affect the compressive strength either during sampling or testing procedures. For example, concrete cores are susceptible to damage caused by the drilling operation or removing the cored specimens. This damage could be in the form of macro or microcracking and/ or weakening the bond between the cement matrix and aggregate particles at the surface of the core. It is also inevitable that drilling cuts through coarse aggregate particles, resulting in them being not fully bonded to the concrete matrix [16, 32-35].

Indeed, the effect of any aggregate loosened by the cutting operation could explain the lower average strength obtained for sprayed concrete cores in this study. Particularly, when compared to that of the counterpart lab-cast concrete.

The lower average strength obtained for concrete cores is also observed for concrete placed using conventional placing methods and, thus, it is not necessarily a result of the spraying process. De Stefano et al. [36] reported that the in-situ concrete not only usually has low strength, but it is also highly variable, even within a single building.

Fig. 3 presents the histogram of all results obtained from the compressive strength tests for lab-cast and sprayed concrete. The figure shows that the results are almost normally distributed and fit well with the superimposed normal distribution curves of the same mean and standard deviation as the compressive strength results of each type of concrete; i.e. lab-cast and sprayed. However, the distribution of the latter is spread over a wider range of about 40 MPa (30 to 70 MPa) compared to only 20 MPa for the lab-cast concrete (70 to 90 MPa). This would be particularly significant when considered in the light of the values of the average strength in both cases. In addition, the curve in the case of lab-cast concrete is steep due to the low standard deviation (5.4 MPa) whereas for the sprayed concrete, it is flat because of its higher standard deviation (10.5 MPa).

The difference in the shapes of the two curves demonstrates that the strength results are more spread for sprayed concrete, indicating that less strength values fit within one standard deviation from the mean strength; i.e. confirming higher variations. Thus, sprayed concrete has a higher probability that measured strength values could be far from the mean strength.

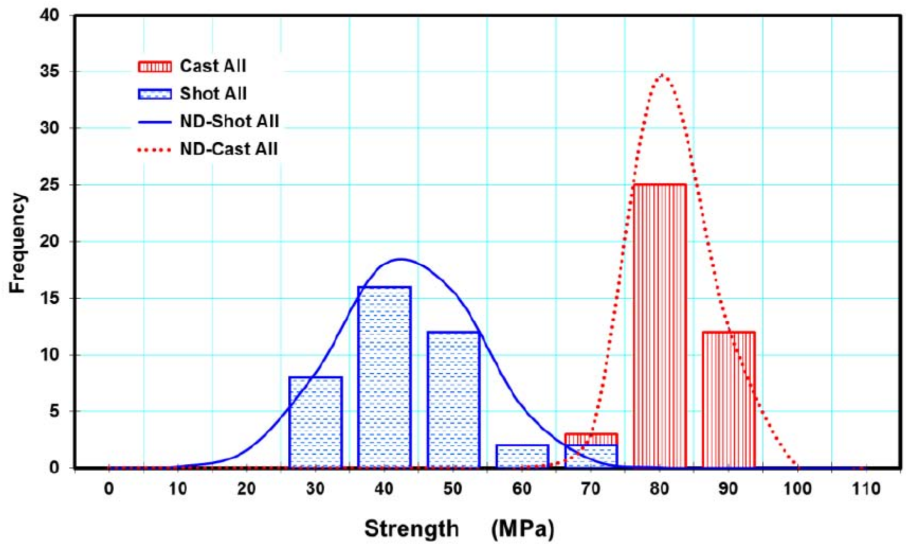

Figure 3: Distribution of strength (All results)

The SD and CoV obtained in this study are slightly higher than the values reported by Zhang [14] for cores taken form test panels in a tunnel shotcrete project. The reported SD and COV for compressive strength at 28 days were 8 MPa and COV of 17%, respectively. However, these values are for wet-mix sprayed concrete, which is known to have a better quality control of the produced sprayed concrete compared to the dry-mix used in the current study. Nonetheless, the values of coefficient of variation obtained in this study or reported in the literature for sprayed concrete are significantly higher the recommended values for compressive strength of concrete. These high values of coefficients of variation for sprayed concrete strength obtained in this study and reported studies in the literature - despite the difference in the materials and methods used- indicate higher variability in the strength of sprayed concrete when compared to limits that have been derived and set originally for cast concrete. Therefore, there could be a need to amend standards, regulations and code of practice to reflect this higher variability and account for it when judging the quality of sprayed concrete.

b) Plain lab-cast and sprayed concrete

The plain (i.e. no fibre reinforcement) sprayed concrete had an average 28-day strength of 44.3 MPa, with a SD of 9.0 MPa and a CoV of 20.4%. The lab-cast concrete, on the other hand, has corresponding values of 78.9 MPa, 4.2 MPa and 5.4% for the average strength, SD and CoV, respectively.

Fig. 4 presents the histogram of the results obtained from the compressive strength tests for lab-cast and sprayed plain concrete. As with the overall results (Fig. 3), the Figure shows that the results are almost normally distributed for both types of concrete. The distribution of the sprayed concrete strength, however, is dispersed over a wider range compared to the cast concrete. This is reflected in the shape of the superimposed normal distribution curve of each type of concrete. The curve of the lab-cast concrete is steeper due to the lower standard deviation (4.2 MPa) compared to that of the sprayed concrete (9.0 MPa), which has a flatter curve, indicating that less strength values fit within one standard deviation from the mean strength. The standard deviation of the sprayed plain concrete not only is higher than that of the counterpart lab-cast plain concrete but also is much higher than the acceptable values for good quality of concrete. The standard deviation of 9.0 MPa is 50% higher than the upper limit of 6 MPa, suggested by Day et al. [30]. Equally, the value of the CoV of the sprayed plain concrete (20.4%) is double the upper limit of 10% and almost four-times higher the 5.4% coefficient of variation of the lab-cast plain concrete. The latter, is just below the 5.5% limit given by ACI 214 R-02 [18] for good concrete produced in laboratory. However, the 20.4% CoV of the sprayed plain concrete is significantly higher than the maximum limit of 14% for general construction.

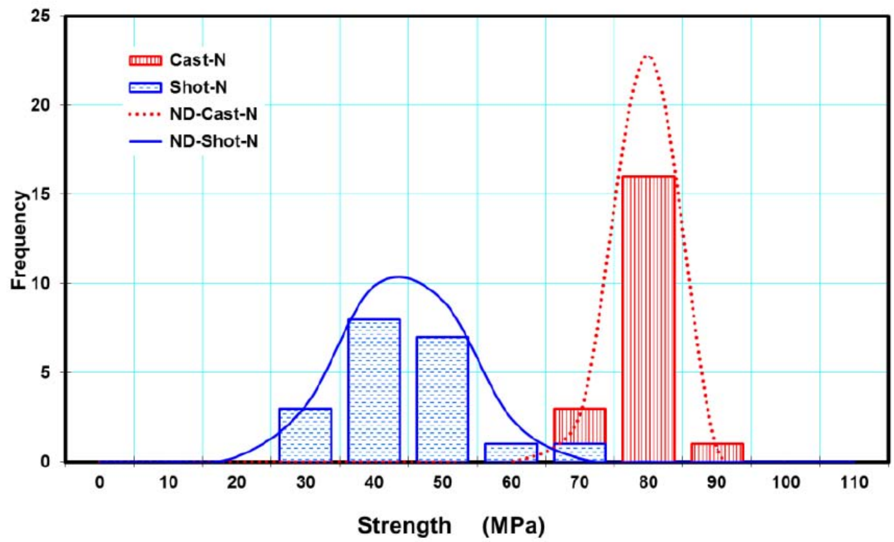

Figure 4: Distribution of strength of plain cast and sprayed concrete

c) Fibre-reinforced lab-cast and sprayed concrete

The fibre-reinforced concrete (FRC) produced using the spraying process had an average 28-day strength of 42.5 MPa, with a SD of 12.0 MPa and a CoV of 28.1%. The lab-cast concrete has corresponding values of 85.3 MPa, 4.4 MPa and 13 5.2%, respectively.

The histograms of the results obtained for lab-cast and sprayed FRC are presented in Fig. 5. The figure shows that the results are almost normally distributed for both types of concrete. Again, the distribution for sprayed concrete is dispersed over a wider range compared to the cast concrete. The 4.2 MPa standard deviation of the lab-cast concrete caused its curve to be steeper than that of the sprayed concrete, which has a 12.0 MPa standard deviation. The latter, is almost 3 times higher than that of the counterpart FRC produced in the lab (i.e. lab-cast) and is much higher than the acceptable values for good quality of concrete. The standard deviation of 12.0 MPa doubles the upper limit of 6 MPa, suggested by Day et al. [30]. Furthermore, the value of the coefficient of variation of the sprayed FRC (28.1%) would appear huge when compared to the upper limit of 10%, recommended by Day et al. [30] or the 15% limit suggested by Swamy and Stavrides [31]. Indeed, the 28.1% CoV of sprayed FRC is more than double the 14% limit in ACI 214 R-02 [18] for concrete produced in general construction conditions.

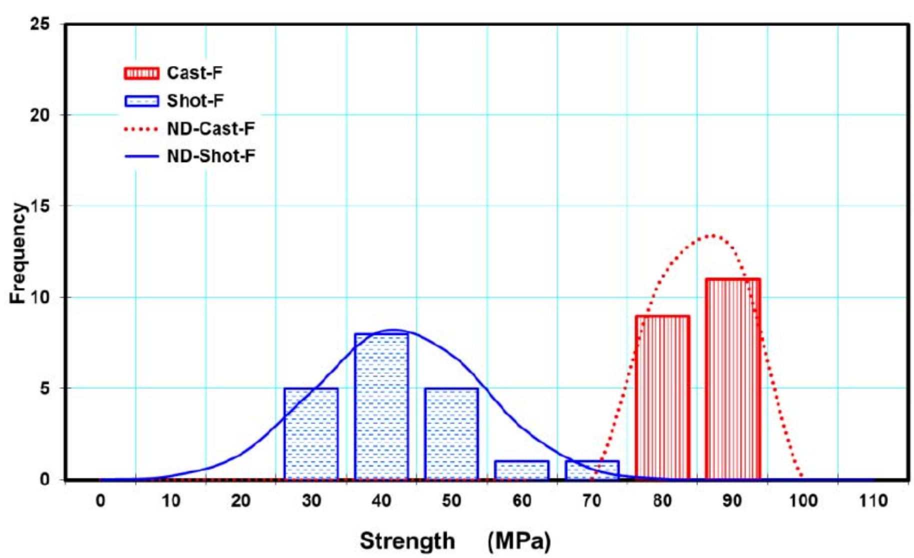

Figure 5: Distribution of strength of fibre reinforced cast and sprayed concrete

Comparing Figures 4 and 5 for sprayed plain and FRC revealed similarity in the characteristics of histograms and the superimposed normal distribution curves for both types. However, there have been distinct differences between the statistical parameters calculated for sprayed plain and FRC. The SD and CoV obtained for the sprayed FRC were higher than those of the sprayed plain concrete. The standard deviation of

12.0 MPa for sprayed FRC is 33% higher than the 9.0 MPa for the sprayed plain concrete. Similarly, the value of the coefficient of variation of the sprayed FRC (28.1%) is about 40% higher than that of the sprayed plain concrete. Coupling these two statistical parameters together it could be suggested that the results indicate higher variability in the results of the sprayed FRC when compared to sprayed plain concrete. This can be attributed to the inclusion of the fibre into the mixture, which could be seen as an introduction of additional variable. Indeed, the introduction of the fibre into sprayed concrete could impart several other variables, such as fibre rebound, local fibre de-bonding and collated fibre spots. Thus, adding fibres increased sources of variability in the strength results of sprayed concrete.

d) Normal probability plots

Figs. 6 and 7 present the normal probability plots of the strength results for lab- cast and sprayed concrete for the two types of concrete used in this study; i.e. plain and FRC, respectively. In each Figure, two straight lines representing best fit trends, have been drawn through the plotted points. It can be seen that the vast majority of the points representing the results for lab-cast and sprayed concrete are close to straight lines, indicating that the results are close to normal distribution with small departure. However, the departure from the normal distribution is clearer in the case of sprayed concrete. This is also reflected in the calculated coefficient of correlation for the best fit lines presenting cast and sprayed concrete. In the case of the latter, the coefficient of correlation for sprayed plain and FRC are 0.94 and 0.96, respectively. The corresponding coefficient of correlation for lab-cast concrete are 0.96 and 0.98, respectively. Relationships with coefficient of correlation over 0.95 is usually acceptable [11].

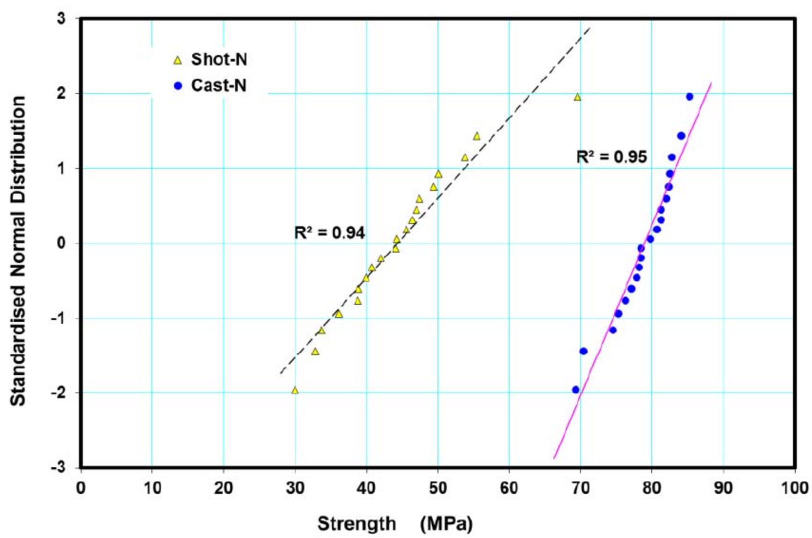

Figure 6: Normal probability plot of plain cast and sprayed concrete

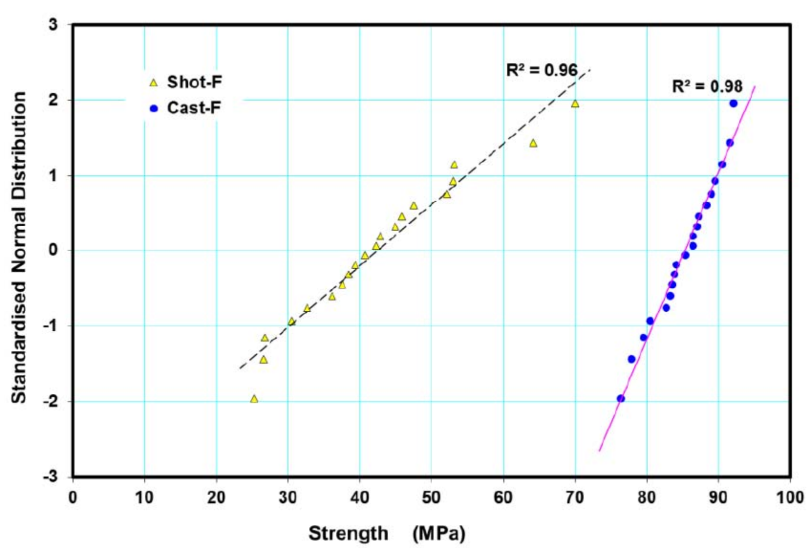

Figure 7: Normal probability plot of fibre reinforced cast and sprayed concrete

e) Minimum number of test replications

The statistical analysis of the strength of sprayed concrete indicated that the strength of the placed sprayed concrete had large variations. Therefore, for good practice, it might be necessary to increase the number of replications to ensure an acceptable error at certain level of confidence.

The CoV of the test results, shown in Table 2, could be used to determine the minimum number of replications, n, required in order to guarantee that the percentage error in the average strength is below a specified limit, e, at a specific level of confidence, as given by Equation 1 below [31, 37]:

$$n = t^2 v^2 / e^2 \tag{1}$$

where:

v = coefficient of variation

t = value of t-student distribution for the specified level of confidence and is dependent on the degree of freedom, which is related to the number of tests.

Considering a large sample size, the value of "t" approaches 1.645 and 1.282 at 95% and 90% levels of confidence, respectively [38-40]. The equation is used to calculate the number of samples required to keep the error under various limits between 10 and 30%, at 95% and 90% levels of confidence. The results is presented in Table 3.

It can be seen that the number of required replications increases as the level of confidence increases but, understandably, decreases if higher percentage error is accepted. However, the increase in the number of required replications in the case of sprayed concrete is significantly higher than that is required for lab-cast concrete.

Table 3: Number of replications required to keep the error under a specific limit

Error (*e* %)	95 % Level of confidence		90 % Level of confidence	
	Shot-All	Cast-All	Shot-All	Cast-All
<10	16	2	10	1
<15	7	1	5	1
<20	4	1	3	1
<25	3	1	2	1
<30	2	1	2	1

For example, two cubes of lab-cast concrete could be enough to keep the error below 10% at 95% confidence level, but 16 cores of sprayed concrete would be necessary to keep the error below 10% at the same confidence level. At least 7 specimens would be required to establish the strength of placed sprayed concrete with an error of less than 15%, at 95% level of confidence.

The European specification for sprayed concrete [41] recommend that the strength of placed sprayed concrete to be determined as the average value from 3 samples. It can be seen from Table 3 that if only three specimens of sprayed concrete were tested, then the percentage error could have been as high as 25% and 20% at 95% and 90% confidence levels, respectively. It is, therefore, suggested to review the current regulations and guidelines to increase the required number of replications to offset large variations and ensure higher confidence in the strength of the placed sprayed concrete. Alternatively, new limits for SD and CoV should be developed for good quality sprayed concrete, rather than relying on limits that have been originally derived from testing cast concrete specimens.

V. Conclusions

For the materials and techniques used in this investigation, the following conclusions could be made:

1. The variability in the strength of sprayed concrete was significantly higher than that of counterpart lab-cast concrete. The standard deviation and coefficient of variation of the results of sprayed concrete (10.5 MPa and 24.2%, respectively) not only were higher than those of the counterpart lab-cast concrete (5.4 MPa and 6.5%, respectively) but also were outside the common acceptable limits for good quality concrete.
2. Compared to the case of sprayed concrete, the histograms of the results obtained for lab-cast concrete is steeper due to lower standard deviation (5.4 MPa compared to 10.5 MPa) and narrower range. The strength results are more spread for sprayed concrete than those of lab-cast concrete, indicating that less strength values fit within one standard deviation from the mean strength; i.e. higher variations.
3. The normal probability plots for lab-cast and sprayed concrete were close to straight lines, indicating that the results are close to normal distribution with small departure. The departure, however, was clearer in the case of sprayed concrete.
4. For sprayed concrete, it could be necessary to increase the number of test replications to ensure an acceptable error at certain level of confidence.

While two cubes of lab-cast concrete were enough to keep the error below 10% at 95% confidence level, 16 cores were necessary for sprayed concrete.

5. It is recommended to review current regulations and guidelines in order to account for the large variability that exists intrinsically in the strength results of cores drilled into sprayed concrete. It is suggested that new acceptance levels should be developed for sprayed concrete rather than using limits that were originally derived from testing lab-cast concrete. Alternatively, the required number of replications could be increased to offset the large variations and ensure higher confidence in the strength of the placed sprayed concrete. The latter, however, could have practical and economical implications.

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Solution to Rapid Plastic Deformation and Short Service Life of Flexible Pavements in Bangladesh using Cement Stabilization

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Abstract- The main objective of this research is to provide a solution to the rapid plastic deformation of flexible pavements due to moisture effect and heavy loading thus increasing the service life of flexible pavements. It is a common phenomena in Bangladesh that pavements undergo critical damage due to uncontrolled traffic flow, heavy loading and weather effect. Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in rainfall, high temperatures and humidity. Most parts of the country receives at least 2000mm of rainfall per year (weatheronline.co.uk)and the major parts of the country is comprised of sand and silty clay soil which tend to collapse when soaked and thus inducing damage to the sub-base layer of the pavements. The solution requires stabilization of sub-grade soil of flexible pavement using Portland Cement. The method considers three different percentage of cement content by weight (10%, 12% and 14%) with constant water-solid ratio(0.156) and finally recommends 10% cement content to be the optimum selection for stabilization.

Keywords: bangladesh, soil-cement, cement stabilization, sub-grade stabilization, flexible pavement.

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Strictly as per the compliance and regulations of :

Solution to Rapid Plastic Deformation and Short Service Life of Flexible Pavements in Bangladesh using Cement Stabilization

Md Ibtesam Hossain [α] & Md Wasim Ather [σ]

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Keywords: bangladesh, soil-cement, cement stabilization, sub-grade stabilization, flexible pavement.

I. Introduction

Pavements in Bangladesh are generally constructed with unbound coarse aggregated sub-grade layer. As a result, when saturated and under heavy traffic load, gradation of the unbound aggregate breaks and weakens the sub-base layers of the pavement. Saturation can also reduce the dry modulus of both the asphalt layer (30% or more) and the base and sub-base modulus (50% or more). As water is one of the principle cause of premature pavement failure, the service life of pavements have become much shorter which leads to greater degree of road accidents and maintenance cost. This is where stabilization comes into play. According to TRL Overseas road note 31 (1993), stabilization can enhance the properties and pavements in following ways: 1) A considerable amount of their strength is retained when they are saturated. 2) Surface deflection is reduced. 3) Erosion resistance is increased. 4) The stabilized layer cannot be contaminated by other materials in other layers. 5) The effective elastic module of granular layers, constructed above stabilized layer, are increased.

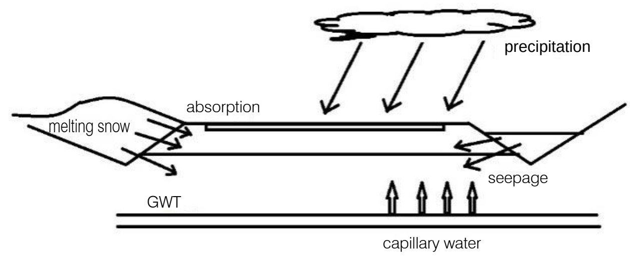

Fig. 1: Main Sources of Water in Pavement

The research evaluated Portland Cement and Lime as stabilizer. This two stabilizer is selected as they are economically available in Bangladesh. But, before choosing any of them, particle size distribution and atterberg limit test is required and commonly used to gain a preliminary assessment of the type of stabilizing agent needed for specific soil type. Also, climate have significant effect on the choice of stabilizer. As for Bangladesh, the moisture content of pavement materials is very high and so it is important to ensure that the wet strength of the stabilizer is adequate. In this condition, cementitious binder is usually preferred although asphalt and asphalt/cement is also considerable. On the other hand, Lime is suitable for cohesive soils, particularly when used as an initial agent to dry out the materials. Lime can also work with silty soils if pozzolan is added to promote cementing reaction. Lime stabilization requires clay content greater than 25-30% but in most part of the country clay content is not adequate enough for lime stabilization. Though lime stabilization with pozzolan can be done for low clay content (e.g. 7% caly content) soil, the research chose cement stabilization for the following reason: Most commonly used pozzolan is fly ash, a finely divided residue that results from the combustion of pulverized coal in power plant boilers, which is transported from the combustion chamber by exhaust gases but in Bangladesh, fly ash is not economically available and only used in cement industries and as a result, cement stabilization stands above from other stabilizations in

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this country. Cement stabilization refers to stabilize soil with Portland cement and the primary reaction is with the water available in the soil which leads to the formation of cementitious material. These reactions occur almost independent of the nature of the soil and for this reason, Portland cement can be used to stabilize a wide variety of materials.

The research begins with soil classification. It involves:

1) *Grain Size Analysis:* It is done to determine the percentage of different grain sizes contained within soil. The mechanical or sieve analysis along with hydrometer analysis is done to get the distribution of particles.

Equipment used: Balance, Set of sieves, Cleaning brush, Hydrometer, Sedimentation cylinder, control cylinder, thermometer, beaker, timing device.

2) *Atterberg Limit Test:* This test is done for determining the Liquid Limit (LL) and Plastic Limit (PL) of the sample soil. The liquid Limit (LL) is arbitrarily defined as water content, in percent, where soil is put up on a standard cup and cut by a groove of standard dimensions. Soil will flow together at the base of the groove at a distance of 13mm (1/2 inch) when subjected to 25 shocks from the cup being dropped 10mm from a standard LL apparatus operated at 2 shocks per second. The plastic Limit (PL) is the water content, in percent, when soil can no longer be deformed by rolling into 3.2mm (1/8 inch) diameter threads without crumbling.

Equipment used: Liquid limit device, Porcelain (evaporating) dish, Flat grooving tool with gage, Eight moisture cans, Balance, Glass plate, Spatula, Wash bottle filled with distilled water, drying oven set at 105°C.

Liquid Limit (LL) = 36%

$$PI = 0.73(LL-20)$$
$$= 11.68$$

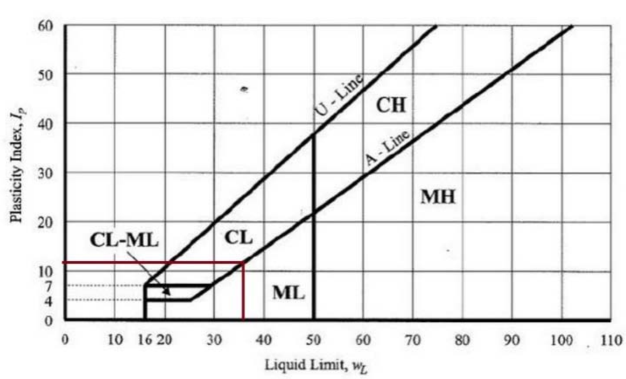


Fig. 2: Plasticity Chart

From the figure it can be said that it is type CL-ML.

Sieve #200 passing = 5% < 50%; so the soil is coarse grained soil.

#4 passing = 91.93% > 50%; so the soil is sandy.

Amount of sand = 91.93%

Amount of gravel = (100-91.93)% = 8.07%

Finally, the soil type is SC-SM and it is silty, clayey sand. (as amount of gravel is <15%)

Cement stabilization is ideally suited for well graded aggregated soil which has required amount of fines to effectively fill the available void space. General guidelines for cement stabilization are that the Plasticity Index (PI) should be less than 30 for sandy materials. A more specific general guideline based on the fines content is given in the equation below which defines the upper limit of PI for selecting soil for cement stabilization

$$PI \leq 20 + \frac{50 - (\text{\% smaller than 0.075mm})}{4}$$

$PI \leq 20 + (50-5)/4$

$PI \leq 31.25$; so the soil can be cement stabilized as we got PI = 11.68

II. Sample Preparation

Soil is dried and sieved (to remove large lumps, stones, leaves and other impurities) before it is mixed with cement and compressed into blocks. Once soil has been dried and sifted it is mixed thoroughly with cement of three different percentage of 10%, 12% and 14% by weight. After mixing, water is added little at a time keeping the water solid ratio of 0.156 for proper workability with optimum moisture content. The prepared mixed is then placed into the mould. Mould was placed on a firm , level surface. The mixture was placed in three layers of approximately equal volume and each layer was rod with 25 uniform strokes of tamping rod over the cross section of the mould.. For layers 2 and 3, the rod shall penetrate into 25mm into the underlying layer. Any left voids was closed by lightly tapping on the sides of the mould with the rod. After the top layer has been ridded, the surface was struck off with trowel and covered with saran wrap to prevent evaporation. Then the specimens were stored undisturbed for 24 hours in such a way as to prevent moisture loss and to maintain within a temperature range of 15°C to 27°C. Finally, specimens were removed from mould between 20 and 48 hours and transferred carefully to the place of curing and testing. Each block was set on edges and spaced far enough apart. The blocks were sprinkled with fine water spray three times a day and during the first 4 days of curing, blocks were covered with plastic because the slower the blocks dry, the stronger they will be.

Fig. 1: Soil Cement Mixing and Moulding

Fig. 2: Final Sample of Soil-Cement Block

The samples were taken and tested for compressive strength in 7th 14th and 28th days. Blocks were carefully placed within the machine without shock and load is implied with a constant rate within a range of 0.140 MPa to 0.350 MPa per second until failure occurs. Sub-Section example is given below:

Table 1: Summary of Soil-Cement Block Stabilized with 10% Cement Content

Time (days)	Area (square inch)	Load (lb)	Stress (psi)
7	4	634	159
14	4	745	186
28	4	900	225

Table 2: Summary of Soil-Cement Block Stabilized with 12% Cement Content

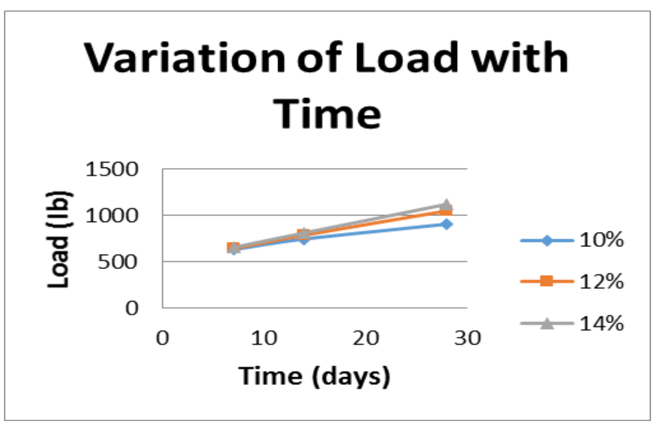
Time (days)	Area (square inch)	Load (lb)	Stress (psi)
7	4	639	160
14	4	784	196
28	4	1047	262

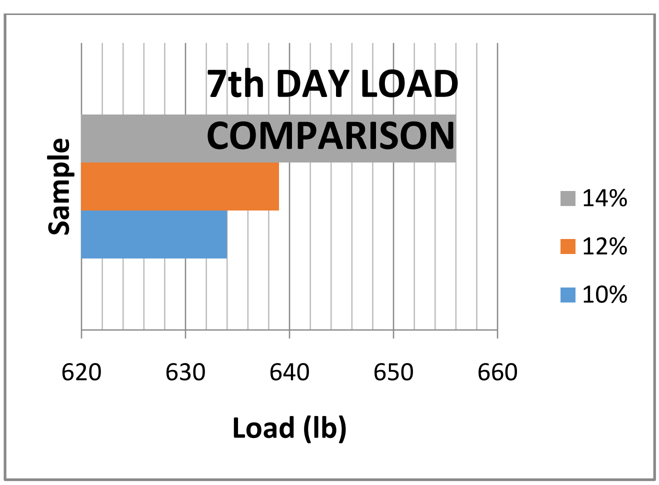
Table 3: Summary of Soil-Cement Block Stabilized with 14% Cement Content

Time (days)	Area(square inch)	Load (lb)	Stress (psi)
7	4	656	164
14	4	812	203
28	4	1119	280

Table 4: Analyze of Load Properties of Soil-Cement Block Stabilized with 10, 12 & 14% Cement Content

Time (days)	Load (lb)		
	Cement Content 10%	Cement Content 12%	Cement Content 14%
7	634	639	656
14	745	784	812
28	900	1047	1119





III. Conclusion

Load bearing capacity of different percentage of cement content in soil-cement is evaluated in this research. Three different percentage 10% 12% and 14% by weight is selected for testing. As the research goal was to find a solution to plastic deformation and shortened service life of flexible pavements, stabilized sub-grade layer provides increased load bearing capacity thus minimizing the damage taken. Generally, the load bearing capacity of Bangladesh varies from 300-500 lb. After stabilizing, the experiment shows that the 7 days load (634 lb) of minimum cement content (10%) is greater than the capacity of conventional practice. Also, the overall maintenance need has been found to be 70,913.82 million taka for the year 2012-2013, 20099.14 million taka for the year 2013-2014, 13322.68 million taka for the year 2014-2015 and 11470.38 million taka for the year 2015-2016 and 10358.24 million taka for the year 2016-2017 (Ministry of communication, Roads and Highways Department, Bangladesh). A large amount of money from a tight budget is spent on the maintenance and thus the author recommends using stabilization to lessen or even mitigate the current crisis. Stabilization with 10% cement content by weight is recommended as it will be cost effective and satisfies general load carrying capacity. Stabilization requires a more detailed and sophisticated verification protocol for which a structured mixture design protocol is included. The mixture design protocol for each stabilizer includes an initial approximation of the appropriate stabilizer content either based on an empirical database or a screening test. This is followed by strength testing where the critical conditions expected in the field are simulated in the laboratory. Since it is normally beyond the scope of stabilizer selection and testing to mimic moisture and environmental variations over the year, a critical condition is normally simulated by partially saturating the sample. The method and degree of this 'moisture conditioning' process is based on experience and varies among design agencies.

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Effect of Some Factors on the Dynamic Response of Reinforced Cylindrical Shell with a Hole on Elastic Supports Subjected to Blast Loading

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Nguyen Thai Chung α & Le Xuan Thuy σ

Abstract- This paper presents the finite element algorithm and calculation method of reinforced cylindrical shell with a hole under blast loading. Using the programmed algorithm and computer program written in Matlab environment, the authors solved a specific problem, from which examining the effects of structural and loading parameters to the dynamic response of the shell.

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I. Introduction

Dao Huy Bich and Vu Do Long [1] used the analytical method to analyze the dynamics response of imperfect functionally graded material shallow shells subjected to dynamic loads. Nivin Philip, C. Prabha [2] analyzed static buckling of the stiffened composite cylindrical shell subjected to external pressure by the finite element method. Nguyen Thai Chung and Le Xuan Thuy [3] used the finite element method to analyze the dynamic of eccentrically rib-stiffened shallow cylindrical shells on flexible couplings under blast loadings. Lin Jing, Zhihua Wang, Longmao Zhao [4], Gabriele Imbalzano, Phuong Tran, Tuan D. Ngo, Peter V.S. Lee [5], Phuong Tran, Tuan D. Ngo, Abdallah Ghazlan [6] analyzed dynamic response of the composite shells and cylindrical sandwich shells under blast loading. Yonghui Wang, Ximei Zhai, Siew Chin Lee, Wei Wang [7] succeeded in analyzing the dynamic responses of curved steel-concrete-steel sandwich shells subjected to blast loading by the numerical method. Anqi Chen, Luke A. Louca and Ahmed Y. Elghazouli [8] analyzed dynamic behaviour of cylindrical steel drums under blast loading conditions. However, studies on the calculation of shell structure under the effect of the shock waves are few, especially of the shells with a hole.

In order to develop the study approach to the shallow cylindrical shells, in this paper, the authors set the algorithm and computer program to analyze the dynamics of rib-stiffened shallow cylindrical shells with abatement holes under the effect of the shock wave loads. Couplings on the shell borders are elastic supports with the tension- compression stiffness k.

II. Computational Model and Assumptions

Considering the eccentrically rib-stiffened shallow cylindrical shell on elastic supports, being described by springs with stiffness k. The shell is subjected to a layer shock wave. Because the shell is shallow, the shock-wave presssure affecting can be considered to be uniformly distributed over the surface of the shell (Figure 1).

The assumptions: Materials of the shell are homogeneous and isotropic; the rib and shell are linearly elastically deformed and have absolutely adhesive connection; loading process works, no cracks appearing around the hole.

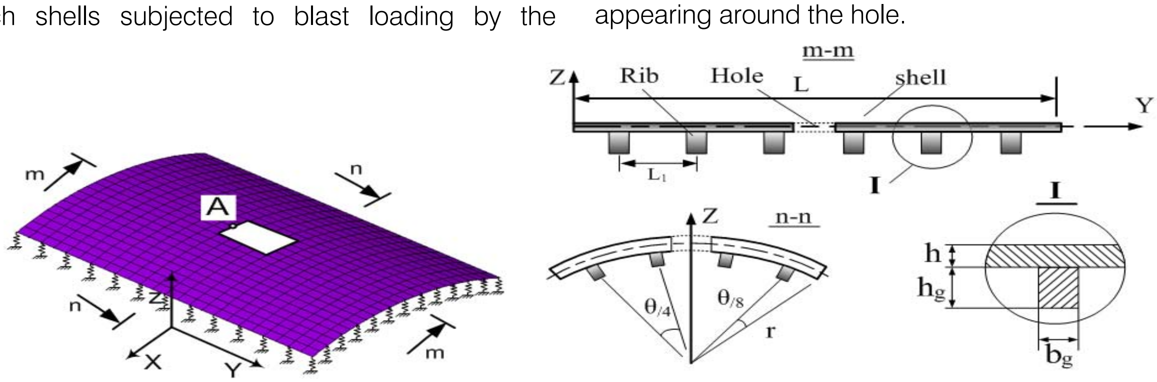

Figure 1: Problem model

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III. Finite element Model and basic Equations

a) Types of elements to be used

The shell is fragmented by 4-node flat shell elements, which means that the shell is a finite combination of 4-node flat elements, is a combination of membrane elements and plate elements subject to bending and twisting combination (Figure 2).

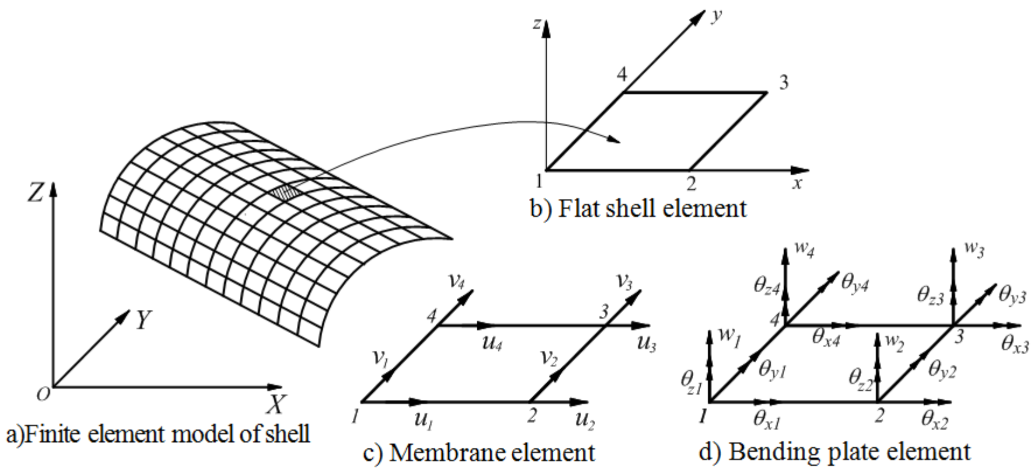

Figure 2: General shell element model

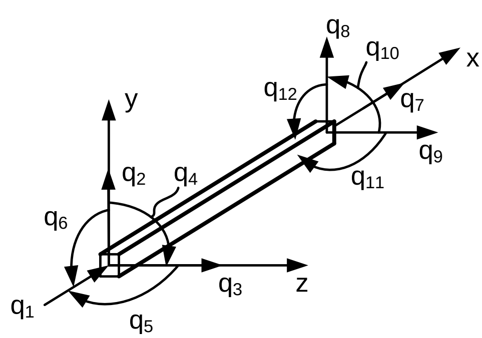

Figure 3: Beam elements

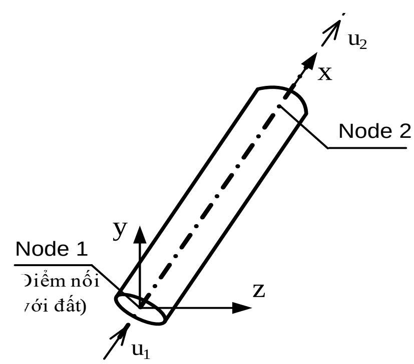

Figure 4: Bar elements

The stiffened ribs are divided into 2-node spatial beam elements, each node has 6 degrees of freedom (Figure 3). The linearly elastic supports are described by bar elements, that are under tension and compression along its axis denoted by *x*, each node of the element has one degree of freedom (Figure 4) [9],[10].

b) Flat shell element describes the shell

Each node of the shell element is composed of 6 degrees of freedom: u_i, v_i, w_i, θ_{xi}, θ_{yi}, θ_{zi}. Displacement of any point of the element can be written as [9]:

$$\begin{gathered} u(x,y,z,t)=u_0(x,y,t)+z\theta_y(x,y,t), \\ v(x,y,z,t)=v_0(x,y,t)-z\theta_x(x,y,t), \\ w(x,y,z,t)=w_0(x,y,t), \\ \theta_x=\theta_x(x,y,t),\ \theta_y=\theta_y(x,y,t),\ \theta_z=\theta_z(x,y,t) \end{gathered} \qquad (1)$$

where u, v, and w are the displacements along x, y and z axes, respectively; superscript "o" denotes mid plane displacement; and θ_x, θ_y, and θ_z are rotations about the x - axis, y - axis and z - axis, respectively.

Strain vector components are:

$$\varepsilon_x=\frac{\partial u}{\partial x},\ \varepsilon_y=\frac{\partial v}{\partial y},\ \gamma_{xy}=\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}, \qquad (2)$$

Relationship stress - strain can be written as

$$\{\sigma\}=[D]\{\varepsilon\}, \qquad (3)$$

where [D] is a matrix of relationship stress - strain.

Using Hamilton's principle for the elements [12]:

$$\delta H_e=\delta\int_{t_0}^{t_1}(T_e-U_e+W_e)dt=0\,, \qquad (4)$$

where $H_e=T_e-U_e+W_e=H_e\left(\{q^e\},\{\dot{q}^e\},t\right)$ is the Hamilton function, T_e is the kinetic energy of the element, U_e is the total potential energy of the element, W_e is total external work due to mechanical loading of element e, $\{q^e\},\{\dot{q}^e\}$ are vector of nodal displacements, and vector of nodal velocities, respectively.

Considering the case not mention the damping, from (4) leads to the following:

$$-\frac{d}{dt}\left\{\frac{\partial H_e}{\partial\{\dot{q}^e\}}\right\}+\frac{\partial H_e}{\partial\{q^e\}}=\{0\}\,, \tag{5}$$

The kinetic energy T_e of the elements is determined by the expression [9]:

$$\begin{aligned} T_e &= \frac{1}{2}\{\dot{q}^e\}^T\left(\int_{V_e}\rho[N]^T[N]dV_e\right)\{\dot{q}^e\} \\ &= \frac{1}{2}\{\dot{q}^e\}^T[M]_e^s\{\dot{q}^e\}, \end{aligned} \tag{6}$$

where [N] is function matrix of flat shell elements [9], [10], V_e is element volume, $[M]_e^s$ is element mass matrix, ρ is specific volume of materials.

The total potential energy U_e is determined by:

$$U_e = \frac{1}{2}\{q^e\}^T[K]_e^s\{q^e\}\,, \tag{7}$$

In which $[K]_e^s$ is stiffness matrix of flat shell elements.

Total external work due to mechanical loading is determined by:

$$\begin{aligned} W_e &= \frac{1}{2}\int_{V_e}\{q^e\}^T\{f_b^e\}dV_e + \\ &+\frac{1}{2}\int_{S_e}\{q^e\}^T\{f_s^e\}d\ _e\{+Aq^e\}^T\{f_c^e\}, \end{aligned} \tag{8}$$

with A_e is element area, $\{f_b^e\}$-volume force vector, $\{f_s^e\}$-surface force vector, $\{f_c^e\}$- concentrated force vector of the elements [9], [10].

Substitute (6), (7), (8) into (4), (5), we have the differential equation describing the vibration of the shell element in matrix form as follow:

$$[M]_e^s\{\ddot{q}^e\}+[K]_e^s\{q^e\}=\{F^e\}, \tag{9}$$

where $\{q^e\}$ is the vector of nodal displacements, $\{F^e\}$ is the mechanical force vector.

In the (X, Y, Z) coordinate system:

$$\begin{aligned} [M']_e^s &= [T]_e^T[M]_e^s[T], \\ [K']_e^s &= [T]_e^T[K]_e^s[T] \end{aligned} \tag{10}$$

$[T]_e$ is the coordinate axes transition matrix [9].

b) Space Beam Element Describes the Rib

Displacement in any node of the bar with (x, y) coordinates is identified as follows [9]:

$$\begin{aligned} u &= u(x,y,z,t) = u_0(x,t)+z\theta_y(x,t)-y\theta_z(x,t) \\ v &= v(x,y,z,t) = v_0(x,y,t)-z\theta_x(x,t), \\ w(x,y,z,t) &= w_0(x,t)+y\theta_z(x,t) \end{aligned} \tag{11}$$

where, the subscript "0" represents axis x (y = 0, z = 0), t represents time; u, v and w are the displacements along x, y and z; θ_x is the rotation of cross section about the longitudinal axis x; and θ_y and θ_z denote rotations of the cross section about y and z axes.

The strain components:

$$\begin{aligned} \varepsilon_x &= \frac{\partial u}{\partial x}=\frac{\partial u_0}{\partial x}+z\frac{\partial\theta_y}{\partial x}-y\frac{\partial\theta_z}{\partial x}, \\ \gamma_{zx} &= \frac{\partial u}{\partial z}+\frac{\partial w}{\partial x}=\frac{\partial w_0}{\partial x}+y\frac{\partial\theta_x}{\partial x}+\theta_y, \\ \gamma_{xy} &= \frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}=\frac{\partial v_0}{\partial x}-z\frac{\partial\theta_x}{\partial x}-\theta_z. \end{aligned} \tag{12}$$

Node displacement vector: $\{q\}_e^b = \{q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8, q_9, q_{10}, q_{11}, q_{12}\}^T$ (13)

Element stiffness matrix is set up from 4 types of component stiffness matrices [9], [11]:

$$\underbrace{[K]_e^b}_{12x12}=\underbrace{[K_x]_e}_{2x2}+\underbrace{[K_r]_e}_{2x2}+\underbrace{[K_{xy}]_e}_{4x4}+\underbrace{[K_{xz}]_e}_{4x4} \tag{14}$$

where, $[K_x]_e=(k_x^{ij})$, $[K_r]_e=(k_r^{ij})$, i, j = 1,2; $[K_{xy}]_e=(k_{xy}^{lk})$, $[K_{xz}]_e=(k_{xz}^{lk})$, l, k = 1÷4, are tension (compression) stiffness matrix, torsion stiffness matrix, bending stiffness matrix in the xy plane, and bending stiffness matrix in the xz plane, respectively.

$$[K]_e^b = \begin{bmatrix} k_x^{11} & 0 & 0 & 0 & 0 & 0 & k_x^{12} & 0 & 0 & 0 & 0 & 0 \\ 0 & k_{xy}^{11} & 0 & 0 & 0 & k_{xy}^{12} & 0 & k_{xy}^{13} & 0 & 0 & 0 & k_{xy}^{14} \\ 0 & 0 & k_{xz}^{11} & 0 & k_{xz}^{12} & 0 & 0 & 0 & k_{xz}^{13} & 0 & k_{xz}^{14} & 0 \\ 0 & 0 & 0 & k_r^{11} & 0 & 0 & 0 & 0 & 0 & k_r^{12} & 0 & 0 \\ 0 & 0 & k_{xz}^{21} & 0 & k_{xz}^{22} & 0 & 0 & 0 & k_{xz}^{23} & 0 & k_{xz}^{24} & 0 \\ 0 & k_{xy}^{21} & 0 & 0 & 0 & k_{xy}^{22} & 0 & k_{xy}^{23} & 0 & 0 & 0 & k_{xy}^{24} \\ k_x^{21} & 0 & 0 & 0 & 0 & 0 & k_x^{22} & 0 & 0 & 0 & 0 & 0 \\ 0 & k_{xy}^{31} & 0 & 0 & 0 & k_{xy}^{32} & 0 & k_{xy}^{33} & 0 & 0 & 0 & k_{xy}^{34} \\ 0 & 0 & k_{xz}^{31} & 0 & k_{xz}^{32} & 0 & 0 & 0 & k_{xz}^{33} & 0 & k_{xz}^{34} & 0 \\ 0 & 0 & 0 & k_r^{21} & 0 & 0 & 0 & 0 & 0 & k_r^{22} & 0 & 0 \\ 0 & 0 & k_{xz}^{41} & 0 & k_{xz}^{42} & 0 & 0 & 0 & k_{xz}^{43} & 0 & k_{xz}^{44} & 0 \\ 0 & k_{xy}^{41} & 0 & 0 & 0 & k_{xy}^{42} & 0 & k_{xy}^{43} & 0 & 0 & 0 & k_{xy}^{44} \end{bmatrix} \quad (15)$$

Similarly, element mass matrix is also established from 4 types of volume matrix:

$$\underbrace{[M]_e^b}_{12x12} = \underbrace{[M_x]_e}_{2x2} + \underbrace{[M_r]_e}_{2x2} + \underbrace{[M_{xy}]_e}_{4x4} + \underbrace{[M_{xz}]_e}_{4x4} \quad (16)$$

$$[M]_e^b = \begin{bmatrix} m_x^{11} & 0 & 0 & 0 & 0 & 0 & m_x^{12} & 0 & 0 & 0 & 0 & 0 \\ 0 & m_{xy}^{11} & 0 & 0 & 0 & m_{xy}^{12} & 0 & m_{xy}^{13} & 0 & 0 & 0 & m_{xy}^{14} \\ 0 & 0 & m_{xz}^{11} & 0 & m_{xz}^{12} & 0 & 0 & 0 & m_{xz}^{13} & 0 & m_{xz}^{14} & 0 \\ 0 & 0 & 0 & m_r^{11} & 0 & 0 & 0 & 0 & 0 & m_r^{12} & 0 & 0 \\ 0 & 0 & m_{xz}^{21} & 0 & m_{xz}^{22} & 0 & 0 & 0 & m_{xz}^{23} & 0 & m_{xz}^{24} & 0 \\ 0 & m_{xy}^{21} & 0 & 0 & 0 & m_{xy}^{22} & 0 & m_{xy}^{23} & 0 & 0 & 0 & m_{xy}^{24} \\ m_x^{21} & 0 & 0 & 0 & 0 & 0 & m_x^{22} & 0 & 0 & 0 & 0 & 0 \\ 0 & m_{xy}^{31} & 0 & 0 & 0 & m_{xy}^{32} & 0 & m_{xy}^{33} & 0 & 0 & 0 & m_{xy}^{34} \\ 0 & 0 & m_{xz}^{31} & 0 & m_{xz}^{32} & 0 & 0 & 0 & m_{xz}^{33} & 0 & m_{xz}^{34} & 0 \\ 0 & 0 & 0 & m_r^{21} & 0 & 0 & 0 & 0 & 0 & m_r^{22} & 0 & 0 \\ 0 & 0 & m_{xz}^{41} & 0 & m_{xz}^{42} & 0 & 0 & 0 & m_{xz}^{43} & 0 & m_{xz}^{44} & 0 \\ 0 & m_{xy}^{41} & 0 & 0 & 0 & m_{xy}^{42} & 0 & m_{xy}^{43} & 0 & 0 & 0 & m_{xy}^{44} \end{bmatrix} \quad (17)$$

In the (X, Y, Z) coordinate system:

$$[K']_e^s = [T]_e^T [K]_e^b [T], \quad [M']_e^b = [T]_e^T [M]_e^b [T].$$

c) Bar Element Describes the Elastic support

Node displacement vector and stiffness matrix of bar element is [9]:

$$\{q\}_e^{sp} = \{u_1, u_2\}^T, \; \underbrace{[K]_e^{sp}}_{2\times 2} = k_{sp}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \quad (18)$$

where, k_{sp} is the tension- compression stiffness of elastic support.

d) Governing equations and solving method

The connection of bar elements and space beam elements into the flat shell elements forming the rib-stiffened shell – elastic support system is implemented by direct stiffness method and Skyline diagram under the general algorithm of Finite element method [9],[10]. After connecting and getting rid of margins, the governing equations of the rib-stiffened shell – elastic support system is:

$$[M]\{\ddot{q}\} + [K]\{q\} = \{F\}, \quad (19)$$

In the case of taking the damping into account the equation (19) becomes:

$$[M]\{\ddot{q}\}+[C]\{\dot{q}\}+[K]\{q\}=\{F\}, \qquad (20)$$

where:

$[M]=\sum_e [M]_e^s+\sum_e [M]_e^b$ - overall mass matrix (after getting rid of margins);

$$[K]=\sum_e [K]_e^s+\sum_e [K]_e^b+\sum_e [K]_e^{sp}$$

- overall stiffness matrix (after getting rid of margins).

$[C]=\alpha[M]+\beta[K]$ - overall damping matrix, α, β are Rayleigh damping coefficients [10].

Equation (20) is a linear dynamic equation and may be solved by using the Newmark's direct integration method. Based on the established algorithm the authors have written the program called Stiffened_SC_Shell_Withhole in Matlab environment.

IV. Numerical Examination

a) The effects of abatement hole

Considering the shallow cylindrical shell whose plan view is a rectangular, generating line's length *l* = 3.0m, opening angle of the shell θ = 40°, the radius of curvature is r = 2.0m, shell thickness th = 0,02m. The shell material has elastic modulus E = 2.2×10^{11} N/m², Poisson coefficient ν = 0.31, specific volume ρ = 7800kg/m³. The eccentrically ribbed shell with the height of ribs h_g = 0.03m, thickness of ribs th_g = 0.006m, the shell with 4 ribs is parallel to the generating line, 6 ribs is perpendicular to the generating line, the ribs are equispaced. The ribs' material has E = 2.4×10^{11}N/m², ν = 0.3, ρ = 7000kg/m³. Considering the problem with two cases:

- Case 1 (*basic problem*): The shell has a square (a x a) abatement hole in the middle position, with a = 0.3 m;

- Case 2: The shell has no hole (a = 0).

Acting load: the shock waves act uniformly to the direction of normal on the shell surface according to the law: $p(t)=p_{max}F(t)$, $F(t)=\begin{cases}1-\frac{t}{\tau}: & 0\le t\le\tau \\ 0: & t>\tau\end{cases}$, p_{max} = 3.10^4 N/m², τ = 0.05s.

Conditions of coupling: Four sides of the shells with couplings are limited to move horizontally and leaned on elastic supports with the tension- compression stiffness k = 3.5×10^4 kN/m.

Case 1: The shell has a square abatement hole with the side a = 0.3 m (Basic problem):

Using the established Stiffened_SC_Shell _ with hole program, the authors solved the problem with the calculating time t_{cal} = 0.08s, integral time step Δt = 0.0005s. The results of deflection response and stress at the midpoint of the hole edge (*point A*) are shown in Figures 5, 6.

Case 2: The shell has no hole:

Results in Figures 7 and 8 respectively are deflection response and stress at the midpoint of the shell.

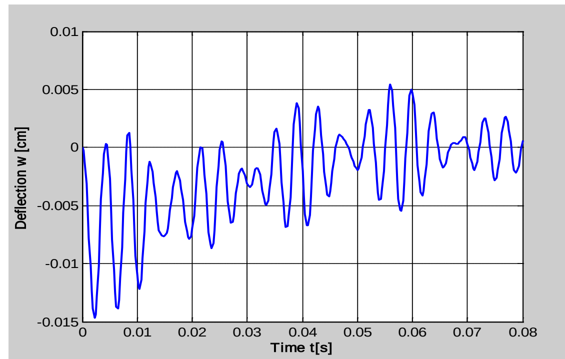

Figure 5: Displacement response w at point A

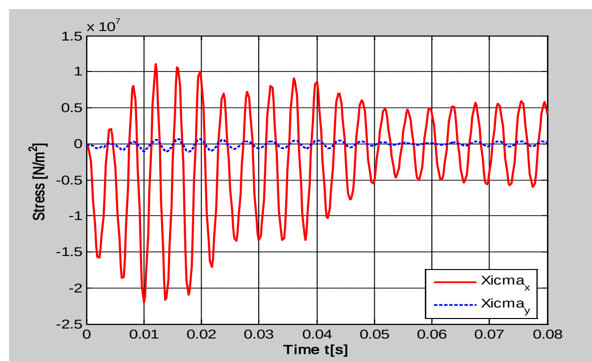

Figure 6: Stress response σ_x, σ_y at point A

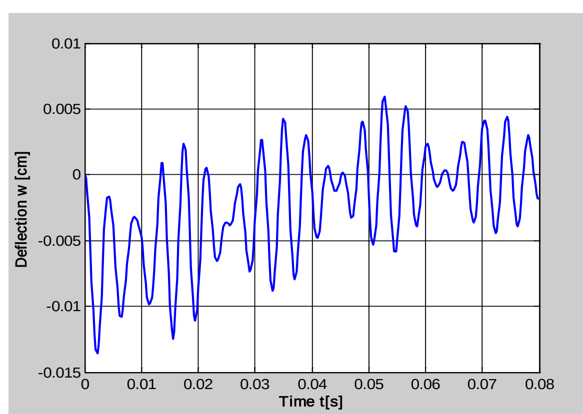

Figure 7: Displacement response wat the midpoint of the shell

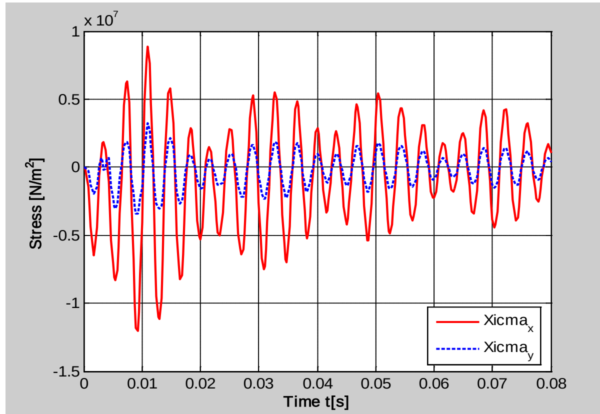

Figure 8: Stress response σ_x, σ_y at the midpoint of the shell

Table 1: Comparison of the values of displacements and stresses in two cases

	Deflection W_z^{max} [cm]	Stress σ_x^{max} [N/m²]	Stress σ_y^{max} [N/m²]
Case 1	0.01471	$21.964.10^6$	$1.111.10^6$
Case 2	0.01358	$12.009.10^6$	$3.423.10^6$

Comment: When there is a hole, both displacements and stresses in the structure are increased. Especially, the maximum stress in the structure increases rapidly. This explains the destruction vulnerability of the structure when it has defects.

b) The effects of the size of the hole

Examining the problem with the size of the hole changes: a_1 = 0.15 m, a_2 = 0.25 m, a_3 = 0.30 m. Displacement response and real-time stresses at point A corresponding to cases shown in Figures 9, 10.

Table 2: Extreme values of calculated quantities at point A when the size a changes

a [m]	W_z^{max} [cm]	Stress σ_x^{max} [N/m²]	Stress σ_y^{max} [N/m²]
0.15	0.01577	$20.389.10^6$	$1.212.10^6$
0.25	0.01521	$20.716.10^6$	$1.808.10^6$
0.30	0.01471	$21.964.10^6$	$1.111.10^6$

Comment: Generally, when increasing the size of the abatement hole, point A shifts closer to the stiffening rib, so the stiffness of the area surrounding point A increases, making the displacement of point A reduces, stress increases.

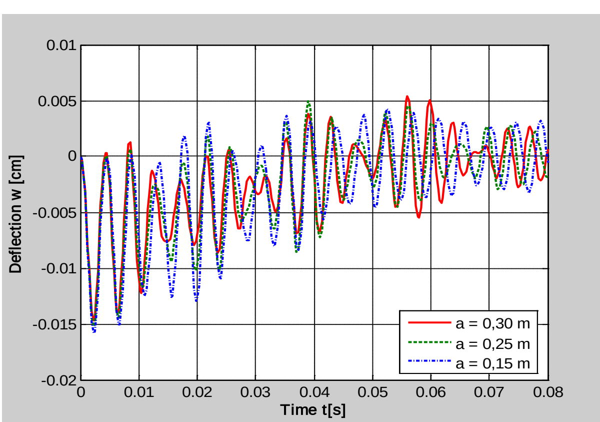

Figure 9: Deflection response w at point A based on a

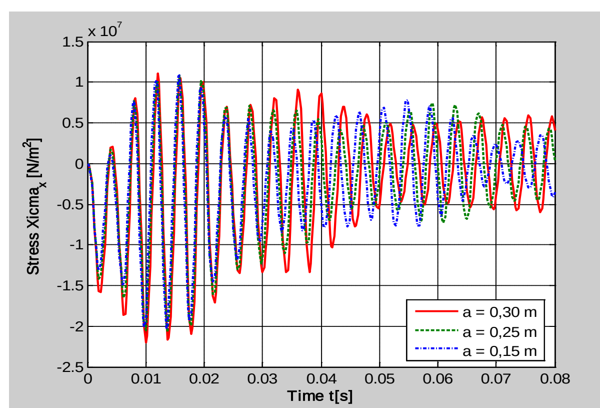

Figure 10: Stress response σ_x at point A based on a

c) The effects of radius r

Examining the problem with r changes: r_1 = 2.0 m, r_2 = 2.3 m, r_3 = 2.5 m, r_4 = 2.8 m, r_5 = 3.0 m. Extreme values of the deflection and stresses at the calculated point are expressed in table 3 and Figures 11 ÷ 14.

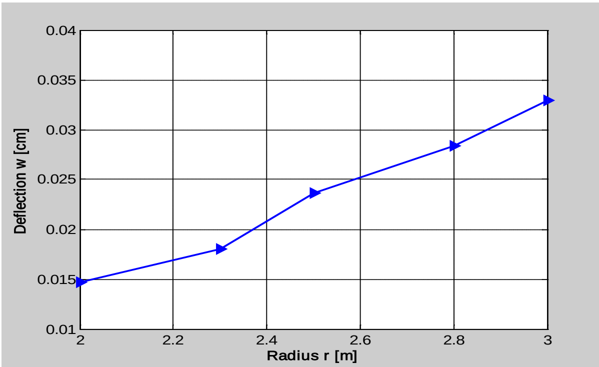

Figure 11: Deflection response w when changing r

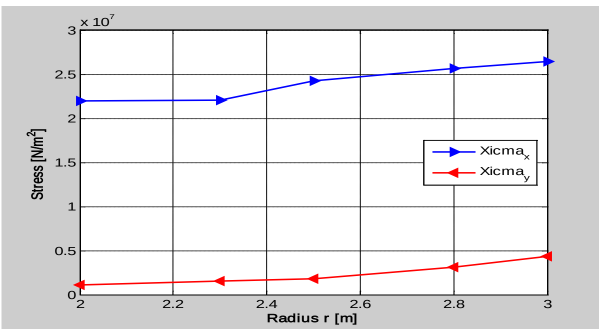

Figure 12: Stress response σ_x, σ_y when changing r

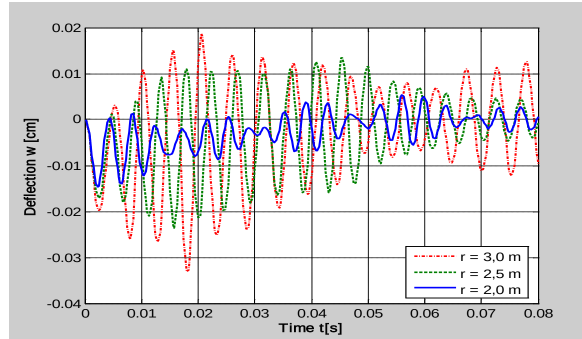

Figure 13: Deflection response w with various values of r

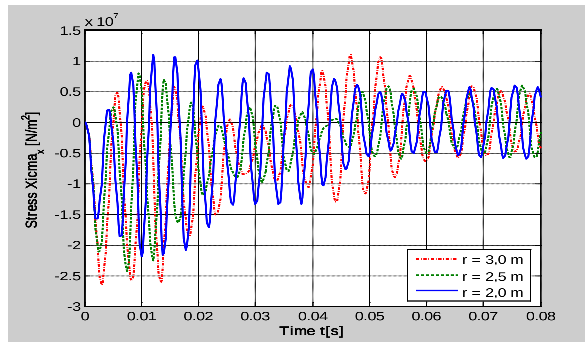

Figure 14: Stress response σ_x with various values of r

Comment: When preserving the opening angle of the shell and other parameters, increasing the radius r will increase the displacement and stress at the calculated point. At this time, the vibration of the structure increases rapidly (Figure 13).

Table 3: Extreme values of calculated quantities at point A when the size r changes

r [m]	W_z^{max} [cm]	Stress $\boldsymbol{\sigma}_x^{max}$ [N/m^2]	Stress $\boldsymbol{\sigma}_y^{max}$ [N/m^2]
2.0	0.01471	$21.964.10^6$	$1.111.10^6$
2.3	0.01799	$22.556.10^6$	$1.499.10^6$
2.5	0.02361	$24.284.10^6$	$1.841.10^6$
2.8	0.02837	$25.654.10^6$	$3.140.10^6$
3.0	0.03298	$26.448.10^6$	$4.340.10^6$

d) The effects of the height of rib

Assessing the effects of the height of the stiffening rib, the authors examined the problem with h_g changes: h_{g1} = 0.03 m, h_{g2} = 0.04 m, h_{g3} = 0.05 m, h_{g4} = 0.06 m, h_{g5} = 0.07 m. Displacement response and real-time stresses at point A corresponding to cases shown in Figures 15, 16, 17, 18.

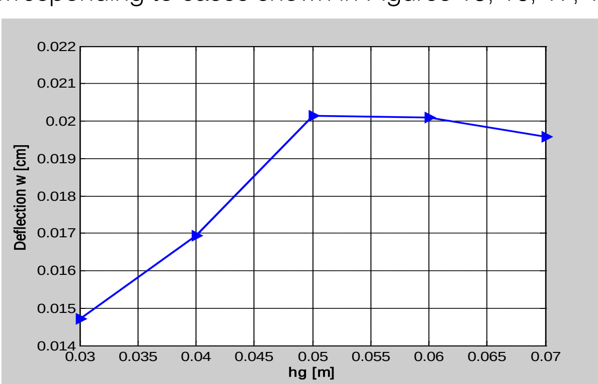

Figure 15: Deflection response w when changing h_g

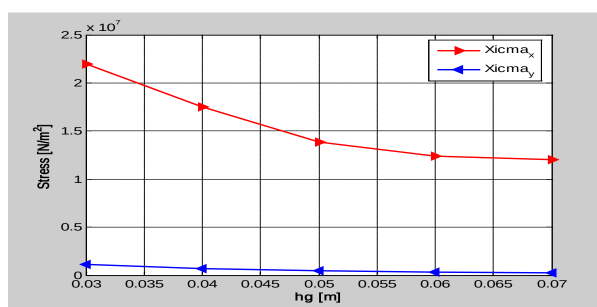

Figure 16: Stress response σ_x, σ_y when changing h_g

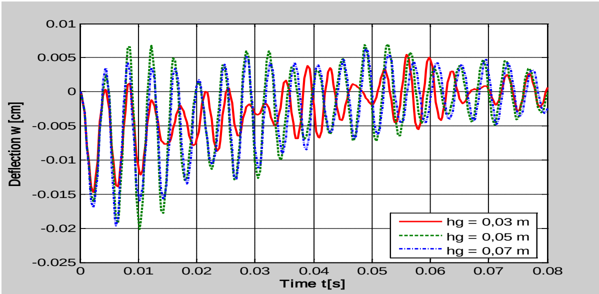

Figure 17: Deflection response w with various values of h_g

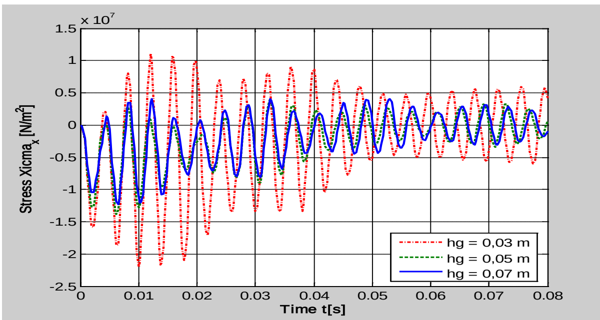

Figure 18: Stress response σ_x with various values of h_g

Comment: In the examined value range of h_g, while increasing h_g, stresses σ_x, σ_y at the calculated point reduce nonlinearly. The displacement at the initial calculated point increases (h_g = 0.03m ÷ 0.05 m), then decreases (h_g = 0.06m ÷ 0.07 m). This can be explained as follow: When increasing the height of rib, the stiffness of the shell increases making it less deformed. However, the shell uses the elastic seat connection, so when the stiffness of the shell increases making more load transfers to the elastic seating which leads to the increase of the total displacement of the calculated point. In phase h_g = 0.06m ÷ 0.07m, after the seating shifts down fully to become a hard seating, this time, the stabler stiffness structure will make the shell less deformed, so the displacement at the calculated point reduces compared to the previous case (h_g = 0.05m).

Table 4: Extreme values of calculated quantities at point A when changing the size of h_g

h_g [m]	W_z^{max} [cm]	Stress σ_x^{max} [N/m²]	Stress σ_y^{max} [N/m²]
0.03	0.01471	21.964.10⁶	1.111.10⁶
0.04	0.01694	17.487.10⁶	0.706.10⁶
0.05	0.02014	13.857.10⁶	0.477.10⁶
0.06	0.02010	12.361.10⁶	0.340.10⁶
0.07	0.01958	12.052.10⁶	0.272.10⁶

V. Conclusions

The paper had:

– Set up the governing equations of system, finite element algorithm and computer program to analyze the dynamics of the rib-stiffened shallow shells with a holes on elastic supports under the effect of the blast loading.

– Examined some structural factors such as: hole size, curve radius, height of rib, thereby making the assessment of the influence level of these factors to the dynamic response of the mentioned shell.

The results of the paper can be used as a reference for the calculation and design of similar structures, with any hole.

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Pile Load Testing & Determining Bearing Capacity of Cast in Situ Pile: A Case Study

By Fatema Sultana, Nusrat Khanum Zinia, Farjana Akter & Md. Motiur Rahman Khan

Ahsanullah University of Science & Technology

Abstract- Piles are designed to transfer the load of superstructure to the deeper harder soil strata crossing the upper weaker strata of soil. Cast in situ piles are usually designed by many analyses and using many empirical formulas. But due to a great degree of prevailing uncertainties of subsoil behavior, variation of strata in the same site, diversity in the procedure of construction applied at site, piles are needed to be tested to double or so of design load to verify the conformity with that design load obtained by static design calculation. A case study of load test on a pile of 600mm diameter & length of 35.250m was conducted through ASTM D 1143-81 method. The test load data were collected and converted into graphical forms. The results were interpreted through load-settlement curves applying various methods for determining the allowable load bearing capacity of the pile.

Keywords: cast in situ piles, design load, load bearing capacity, static design calculation, load settlement curve.

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PILELOADTESTINGDETERMININGBEARINGCAPACITYOFCASTINSITUPILEACASESTUDY

Strictly as per the compliance and regulations of :

Pile Load Testing & Determining Bearing Capacity of Cast in Situ Pile: A Case Study

Fatema Sultana [α], Nusrat Khanum Zinia [σ], Farjana Akter [ρ] & Md. Motiur Rahman Khan [Ѡ]

Abstract- **Piles are designed to transfer the load of superstructure to the deeper harder soil strata crossing the upper weaker strata of soil. Cast in situ piles are usually designed by many analyses and using many empirical formulas. But due to a great degree of prevailing uncertainties of subsoil behavior, variation of strata in the same site, diversity in the procedure of construction applied at site, piles are needed to be tested to double or so of design load to verify the conformity with that design load obtained by static design calculation. A case study of load test on a pile of 600mm diameter & length of 35.250m was conducted through ASTM D 1143-81 method. The test load data were collected and converted into graphical forms. The results were interpreted through load-settlement curves applying various methods for determining the allowable load bearing capacity of the pile.**

Keywords: cast in situ piles, design load, load bearing capacity, static design calculation, load settlement curve.

I. Introduction

A variety of measures involves to determine the load bearing capacity of piles that might be either analytical or empirical in nature. The former requires an evaluation of soil and pile interaction along with several underlying assumptions. On the other hand, the latter is founded on the use of outcomes of in-situ tests and procedures (Medubi et al. 2012). when the soil condition is unpredictable, Pile load test is generally conducted. The test piles are constructed and load will be applied Before constructing the actual load bearing piles of the main structure so that various information's can be gathered. In geotechnical engineering, the bearing capacity determination for piles is a fascinating topic. Due to the complicated nature of the embedment ground of piles and lack of suitable analytical models for foreseeing the pile bearing capacity are the main reasons for the engineer's tendency to peruse further research on this issue. Among different common methods, pile load testing can represent reasonable results, but such tests are expensive, time-consuming, and the costs are often difficult to justify for ordinary or small projects (Thounaojam& Sultana, 2016).

Sometimes it is found that the capacity of the pile is too high comparing the design load, in such cases the actual piles to be constructed can be redesigned. By doing so foundation cost might be reduced. In Bangladesh generally the land owner or the contractors are not that much interested to conduct this test due to its high cost and time consumption. But it will be very helpful for the structure if this test is done. Once the substructure is complete after that any kind of change in sub structure very much costly and difficult. So instead of doing so if pile load test is done then any kind of mistake can be resolved in the initial level of structure.

Pile load test have been carried out to achieve following objectives-

- To determine the settlement under working load
- To confirm the adequacy of design bearing capacity
- As proof of acceptability
- Determine allowable bearing capacity

II. Methodology

This report presents the test results of monotonic static axial pile load tests on cast in situ pile for the site of "A" in Dhaka city. This test was carried out with a view to confirm the carrying capacity of single pile under monotonic static load and to know the settlement behavior of this pile under test. The main purpose of the static pile load test is to demonstrate construction method and to confirm the design assumptions and the bored pile loading capacity. This test also shows the actual safety factor applied for the piles. Static analysis methods estimate shaft and base resistances separately and differently (Thounaojam& Sultana, 2016).However, the use of dynamic formula is highly criticized in some pile-design literatures. Dynamic methods do not take into account the physical characteristics of the soil. This can lead to dangerous miss-interpretation of the results of dynamic formula calculation since they represent conditions at the time of driving. They do not take in to account the soil conditions which affect the long- term carrying capacity, reconsolidation, negative skin friction and group effects.

To observe the design capacity, a test pile is constructed and estimated load is given upon the designed pile. There are three kinds of static pile load testing.

1. Compression pile load test.
2. Tension pile load test.
3. Lateral pile load test.

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In this research project, The Compression pile load testing was conducted and also the test included Anchor method.

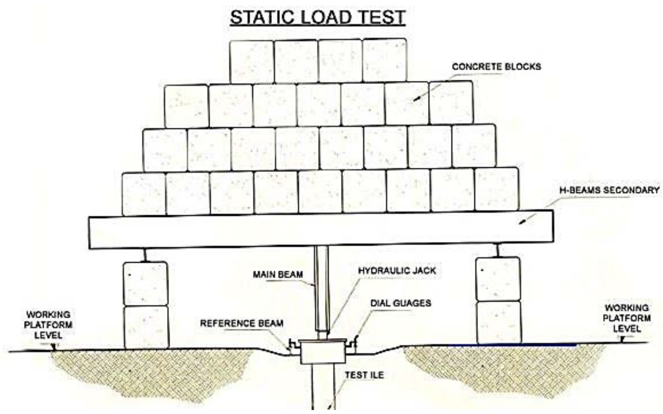

Figure 1: Static load test

The readings are recorded in all the dial gages, the load cell, and the pressure gage for the jack at 1 minute intervals, on the Time-Settlement Data Sheet. The load is given to the pile up to 50%, 100%, 125%, 150%, 175% and 200% and the Gross settlement is checked. Again, with the same procedure stated above, Net settlement is observed. Settlement is checked to a precision of 1/5" (0.5 mm) on the reference points, at a minimum as follows:

1. Immediately before the test,
2. Immediately before rebounding from 100 percent of the design load (all cycles),
3. Immediately before rebounding from 200 percent of the design load (both cycles), and
4. At the end of test, after the final rebound reading

A case study of load test on a pile of 600mm diameter & length of 35.250m was conducted through ASTM D 1143-81 method. The test load data were collected and converted into graphical forms. The results were interpreted through load-settlement curves applying various methods for determining the allowable load bearing capacity of the pile.

Figure 2: Sand Bag used for loading the pile

Figure 3: Hydraulic jack

III. Observation

Physical description of test pile and equipment used are provided in table 1 & table 2 bellow

Table-1: Physical description of test pile

Test pile no	Date of pile casting	Date of testing	Length of pile	Dia. of pile	Applied load
TP-16	17-06-2014	11-07-2014	35.250 m	600 mm	2,87,814 kg

Table-2: Description of equipment used

Test pile no	Plunger dia.	Pressure gauge			Dial gauge	
		range	Calibration date	Regression equation	sensitivity	range
TP 01	265 mm	0-500 kg/cm^2	16-06-2014	Y=0.516x-0.146	0.01 mm	0-50 mm

IV. Data Analysis

When pile is subjected to gradually increasing compressive load in maintained load stages, initially the pile-soil system behaves in a linear-elastic manner up to point A on the settlement-load diagram and if the load is realized at any stage up to this point the pile head rebound to its original level (Abebe& Smith, 2016).

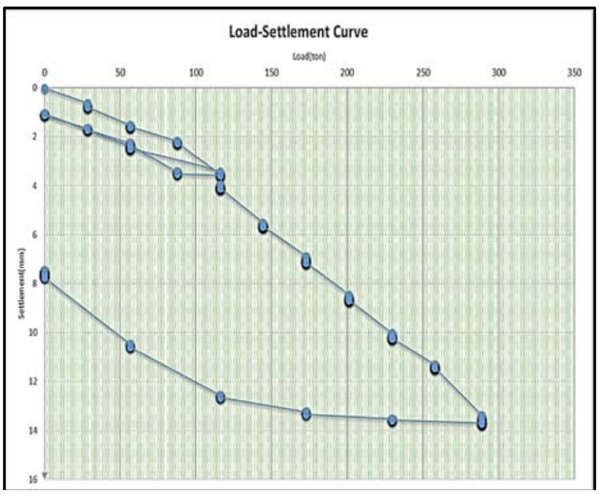

Figure 4: Load Settlement Curve

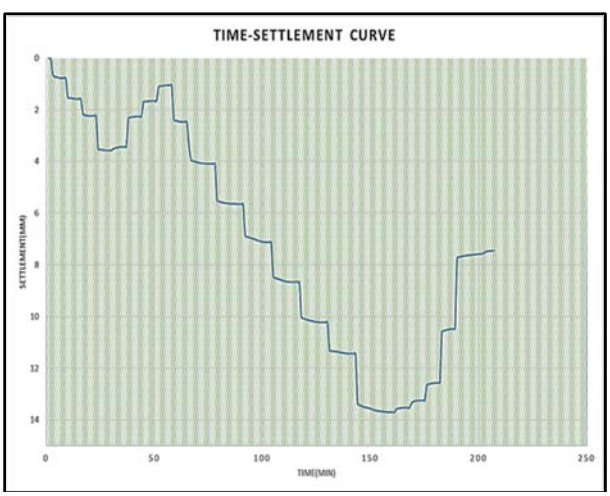

Figure 5: Time Settlement Curve

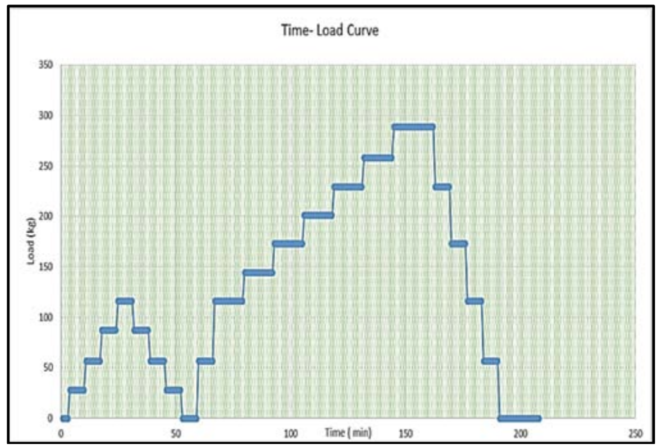

Figure 6: Time Load Curve

There are different methods used for determining Bearing Capacity, such as

- Tangent-Tangent Method
- Hansen Method
- Chin's Method
- Decourt's Extrapolation

The Tangent-Tangent Method has been used to determine the bearing capacity of the pile. According to Tangent-Tangent Method the test result is 118 tons.

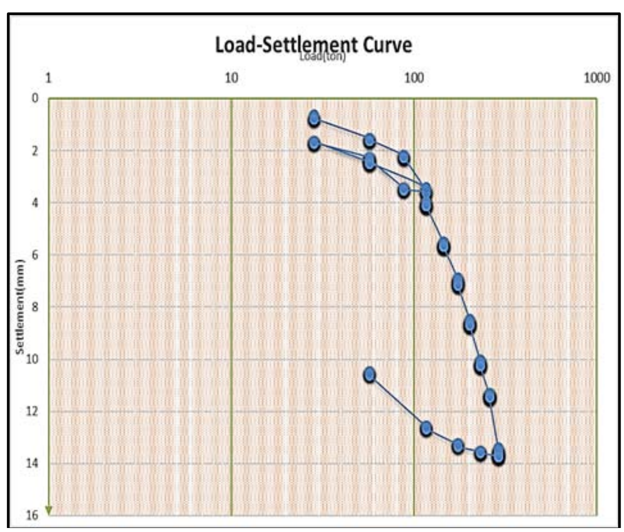

Figure 7: Load -settlement curve 1

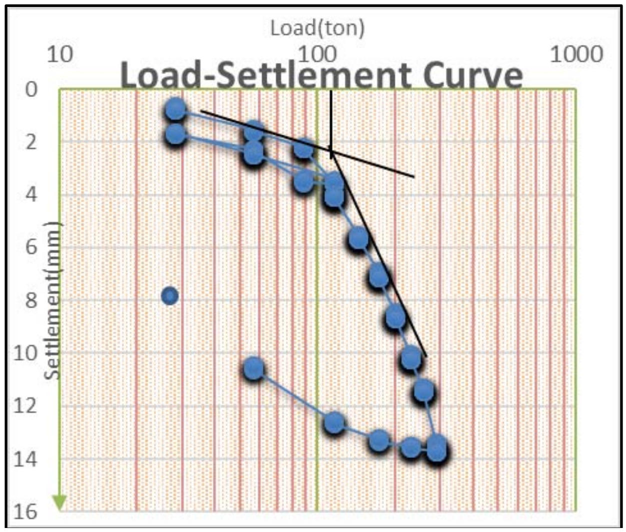

Figure 8: Load -settlement curve 2

V. Result

Ultimate and Allowable load capacities by different methods are presented in table 4 & 5. Initially, the Ultimate load and then the Allowable load have been estimated.

The summary of the test result is as follows in table-3:

Table-3: Test result of the test pile

Test pile no	Length of pile	Test result		
		Max^{m} applied load	Gross settlement	Net settlement
TP 16	35.250 m	2,87,814 kg	13.700 mm	7.455 mm

Table-4: Ultimate load capacity of the test pile

S.L No	Test pile no	Ultimate load capacity in kg			
		BNBC (1993)	Davisson 1973	IS: 2911 (Part-VI)-1979	BSI(1986)
1.0	TP-16	>2,87,814	>2,87,814	2,66,857	>2,87,814

Table-5: Allowable load capacity of the test pile

S.L No	Test pile no	Allowable load capacity in kg			
		BNBC (1993)	Davisson 1973	IS: 2911 (Part-VI)-1979	BSI(1986)
1.0	TP-16	1,43,907	1,91,876	1,77,904	1,43,907

VI. Conclusion

All results of static load test indicate very conservative pile design as the (settlement/pile diameter) ratios are less than 1% for all piles. Therefore, it is strongly recommended to optimize the pile design for projects by determining the actual ultimate pile capacity, which may need to conduct pile test to failure or near to failure. There were two test piles which was observed for both the tests but only the second test result calculation is discussed here. For the 1st test the net settlement was 3.055 mm & the design load was 110,000 kg. For the second test the net settlement was 7.455 mm & the design load was 115,954 kg. From the Load Vs Settlement graph, we found the value was nearabout 118 tons. So the allowable load capacity to be considered is 118 tons.

Acknowledgement

The test was conducted in a site situated at Banasree, Dhaka for the construction of YAMAGAT - DHAKA Friendship Hospital.

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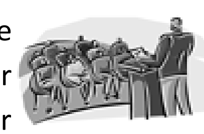

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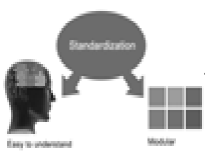

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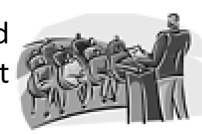

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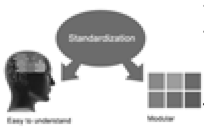

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"

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3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

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11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.

- Do not give permission to anyone else to "PROOFREAD" your manuscript.

- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

Criterion for Grading a Research Paper (Compilation)
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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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