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Techno Economic Feasibility Study of the Use of Hollow Blocks in Building Construction Practice in Bangladesh

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Abstract– ***Due to the tremendous population growth urban building construction got a significant boost in Bangladesh. Rising demand of fire bricks has been full filled by destruction of agricultural land and soil fertility. Bangladesh is lagging behind in taking the advantages of modern construction materials. To evaluate the technical feasibility and financial viability of the use of hollow blocks a comparative study is conducted using both fire brick and hollow blocks for structural design of a 10 storied building. Bangladesh National Building Code specifications are strictly followed though out the design. The structure is analyzed for both seismic and wind load. It is observed from the obtained results that almost 18% of the gross structural weight is reduced when the building adopted hollow blocks instead of fire brick. Which ultimately leads to the economic benefit of approximately 10% material cost reduction during the construction. This study finds that use of hollow blocks as partition material in construction industry of Bangladesh can be a smart alternative by offering both technical and financially benefits.***

Keywords: *Hollow Block, Structural Weight Reduction, Bangladesh, Fire Brick, Economic Feasibility.*

1. Introduction

Bangladesh is an over populated country with a high demand of urban accommodation. It has become a challenge for the construction industry to fulfill the growing demand because of the shortage of supply of the proper construction materials. Among the construction materials the demand of the bricks is significantly higher than the others. The bricks are supplied

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all over the country by a huge number of brick manufacturing companies using the traditional production process. Traditional manufacturing process of the fire brick offers a destructive environmental impact. The report of World Bank (2011) on the brick sector of Bangladesh indicates that 38 % of the fine particle air pollution in Dhaka is done by the brick kilns alone. This report also shows that fixed chimney kiln (FCK) is not an energy efficient option, rather highly polluting. However, still FCK dominates in the brick sector of Bangladesh. So a careful evaluation of the suitable alternatives to the traditional fire brick is just the demand of time. Here comes the use of hollow blocks which can be produced with almost negligible environmental impact.

In this study a 10 story building was designed using the hollow blocks for partition walls which was compared with the design using traditional fire brick. As the project is expected to be constructed in real life at Sylhet, Bangladesh National Building Code (BNBC) was followed strictly though out the design process. Sylhet is considered one of them most earthquake prone area in Bangladesh. Two building models considered one for hollow block partition walls and the other for fire brick partition walls were evaluated both for seismic and wind loads. In those particular situations, seismic load was found to be dominating over the wind load. Financial impact was also evaluated for the feasibility study of hollow blocks as an alternative to the traditional fire bricks.

2. Literature Review

The history of the use of concrete block can be tracked back to the reign of Roman emperor in 200 B. C. In the fifth century the development of the concrete technology was lost with the fall of the Roman Empire. Harmon S. Palmer was the first person to design hollow block at 1890 in the United States. The hollow blocks are being used since then. However, there are still a lot to develop in the hollow block technology. Many researchers tried to prove the supremacy of the hollow block over traditional materials. Ganesan and Ambalavanan (1988) studied the structural efficiency of the concrete bock in a load bearing masonry. In their study it is shown that using almost same amount of materials in a concrete block it can provide a better construction efficiency and increased bearing capacity. In research of Maroliya (2012) it is shown that use of hollow block can reduce the overall cost of a construction project. He also illustrated that the use of hollow block can speed up the work progress in real life application. Ahmed et al. (2014) also made a comparative study between brick masonry and hollow concrete block masonry. Thorat et al. (2015) showed hollow concrete bock as a new growing trend in India. Maintenance cost, factor of safety, cost of the fished wall of hollow concrete block was shown in that study. Barbosa and Hanai (2009) studied on the strength and deformation of the hollow concrete blocks. Raheem et al. (2012) illustrated in their study that hollow blocks can be an excellent choice of walling element providing better interlocking between blocks. Kumar and Raghunath (2015) used reinforced hollow concrete block in masonry wall in their study. Almost all the researchers has positive opinion regarding the use of hollow blocks as a replacement to the rational bricks.

3. Model Description

A ten story residential building was used as model structure, which was designed and estimated using both normal brick and hollow blocks. Later the outcomes of the analysis and estimation was compared to draw the conclusion of the study. The analyzed building model has a floor area of 2,530 square feet at each floor. Floor plan details are presented at Fig. 1. The ground floor has no partition walls considering the fact that the floor will be used for parking purpose. To ensure the modern life style facilities it was considered that top floor slab will be used as community hall. So an additional load of 20 psf was considered along with the standard residential load of 40 psf. BNBC code was strictly followed during the design process to ensure the acceptability of the design in context of Bangladesh. Ultimate strength design method was followed in this study as it ensures the financial viability of the construction by the utilization of the maximum usable material properties. Codes and material details are provided in Table 1.

Table 1: Material specification and design guideline

Method of Design	Ultimate Strength Design
Design Code	Bangladesh National Building Code
Concrete compressive strength , *fc'*	3,000 psi
Yield strength of Steel, *fy*	60,000 psi
Soil bearing capacity at 5' depth	2.00 ksf
Unit weight of reinforced concrete	150 pcf

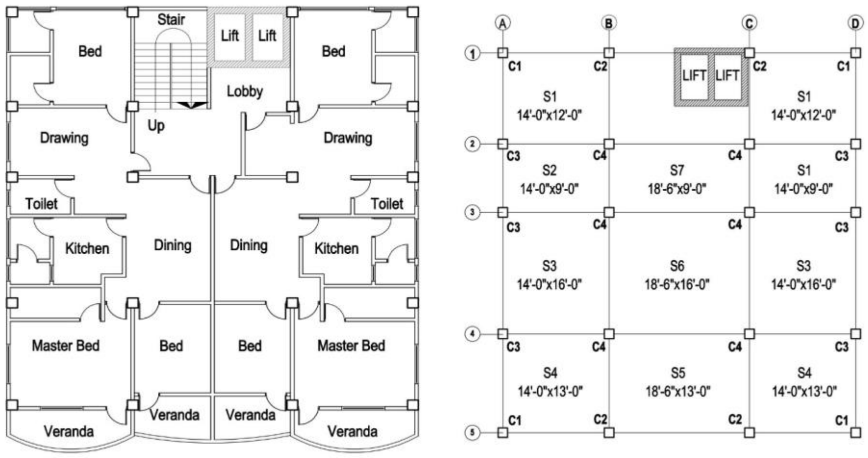


Figure 1(a): Architectural floor plan of the model

Figure 1(b): Structural floor plan of the model

Strong column and weak beam is the criteria that was always kept in mind during the design process to ensure ductile failure mode of the structure in case of natural hazardous situation. For this purpose the selected steel ratio was kept well below the balanced steel ratio. ACI code specifics that maximum steel ratio should be 75% of balanced steel ratio. Details of the general design consideration are listed in Table 2.

Table 2: General design assumptions

Maximum slab panel size	18 feet-6 inch x 16 feet
Calculated slab thickness	5 inch
Column size	20 inch x 20 inch
Beam size	12 inch x 20 inch and 12 inch x 16 inch
Foundation type	Pile
Size of the hollow block for 5 inch wall	390 mm x 190 mm x 100 mm
Size of the hollow block for 10 inch wall	390 mm x 190 mm x 140 mm

The size of the hollow block was selected as per the availability in the local market of nearby area of Sylhet. Unit weight of the hollow blocks for 5 inch and 10 inch wall is found 84 lb/ft^3 and 78 lb/ft^3 respectively. On the other hand, Unite weight of the fire brick is 120 lb/ft^3.

For seismic zone detection, it was considered that the project is located in Sylhet, Bangladesh. Wind load was also applied during analysis. But the earthquake load is found to be dominating in the given situation. Table 3 represents the details of the seismic and wind load parameters which were used in the analysis of the structural model.

Table 3: Earthquake and wind load parameters

Seismic Zone co-efficient, Z	3
Structural Importance co-efficient, I	1.25
Numerical Co-efficient, C	1.944
Site co-efficient for soil characteristics, S	1.5
Calculated Lateral Force	412.80 kip
Wind Speed	195 km/hr.
Velocity to pressure conversion co-efficient	47.2×10^{-6}

Using all the details mentioned above, the model building was designed using the actual measurements and material properties of the real building. In the modeling of building slabs, beams, columns, stairs, piles, water reservoir and shear wall were considered and they were designed following USD method. Electrical layout and other utility supply systems were not considered to simplify the model.

4. Results and Discussion

i. Technical Comparison

To make the design cost effective and safe column section sizes and number of bars of top five floors was kept uniform in height and less than those of bottom five floors for which it was adopted the same concept. In the columns a concrete cover of 2.5 inch was provided to comply with the national code and safe design standard. Beam dimensions were variable according to the position in the frame. Beams and columns identification is shown in fig. 1(b). Reinforcement detail of the columns is shown in fig. 2 for both the case of fire brick and hollow block. In the table the column detail of the top 5 floors is skipped as they provide no significant structural difference in case of the use of fire brick or hollow blocks.

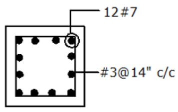
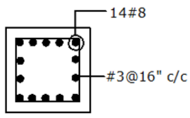
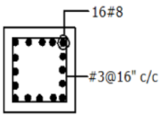
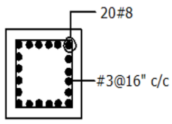
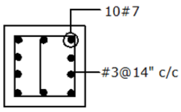
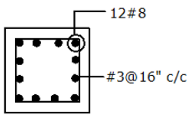
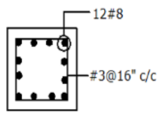
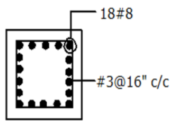
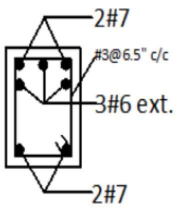
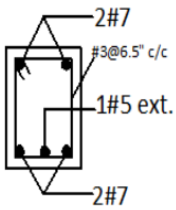
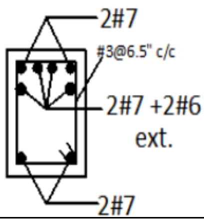
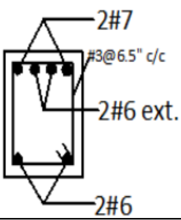
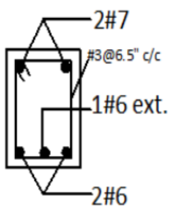
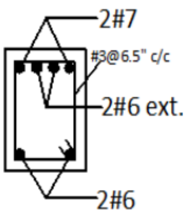
Column Type	C1	C2	C3	C4
Fire Brick Case				
Hollow Block case				

Figure 2: Steel bar arrangement comparison shown for column sections of bottom five floor levels

Two different shapes of beams were adopted in the building analysis model. Top five floors of the building utilized a beam dimension of 12x16 inch and bottom five floors used 12x20 inch beams. Multiple beam reinforcement arrangement patterns were considered in each floor. Due to the page limitation the details of only two typical beams are shown in fig. 3. It was observed from the obtained results that the reinforcement in the beams reduced significantly in case of the use of hollow concrete blocks for the same size of beams. However, it can be mentioned that size of the beams affects the amount the reinforcement required.

	Exterior section	Middle section	Interior section
Beam A1-A5 using fire brick			
Beam A1-A5 using Hollow Block			

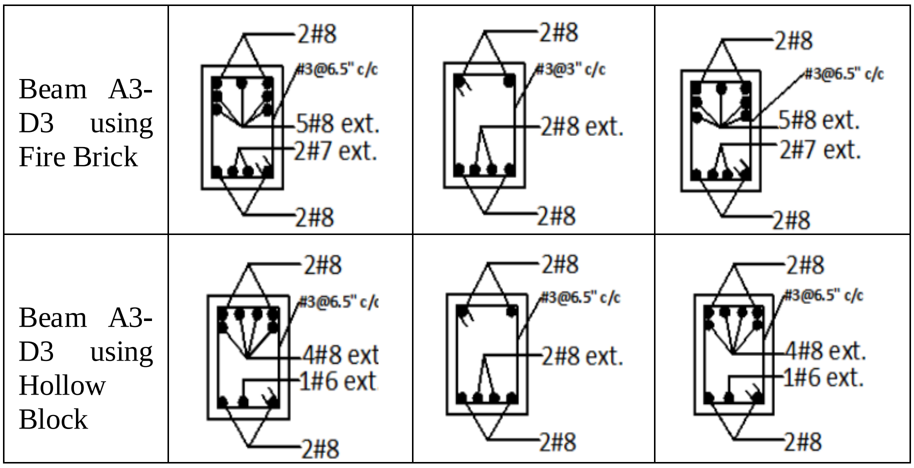


Figure 3: Steel bar arrangement comparison in Beam

From the design perspective it was also observed that almost 4.6% vertical load and 16.72% base shear of the building was reduced due to the use of hollow blocks instead of fire brick which resulted a significant reduction in the use of steel in various structural member.

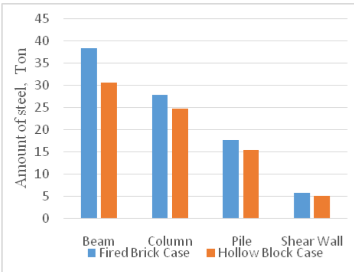


Figure 4(a): Amount of steel used in structural members

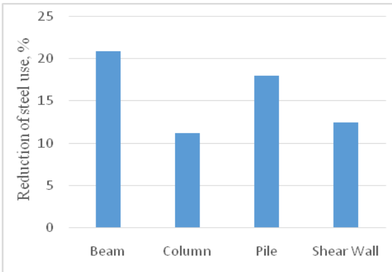


Figure 4(b): Reduction of the steel use.

The structural analysis showed that weight of the superstructure was 5,436 kip when it was calculated using fire brick. In case of the application of the hollow block the weight was found to be reduced to 4,458 kip, which was 17.99 % reduction of the total structural mass. Shear wall and piles were also designed for the reduced overall weight of the structure. The amount of the steel used in the beams, columns, piles and shear wall is shown in fig. 4(a). Figure 4(b) illustrates the reduction in steel use.

ii. Economic Comparison

For economic comparison the price of construction materials was determined form a market survey. Price of the steel, cement, sand and stone was considered 57,000 tk/ton, 500 tk/bag, 20 tk/cft and 170 tk/cft respectively during the cost evaluation. Price of the normal fire brick was 6 tk each where the hollow blocks for 5 inch and 10 inch wall was 25 tk and 28 tk respectively. Total number of fire bricks required was 1,59,032 where 35,724 and 361 pieces were required for 5 inch and 10 inch walls respectively in case of the use of hollow concrete blocks. Which directly ensured a 5.45% save of the brick cost alone. Overall saving from the other structural members is demonstrated in fig. 5.

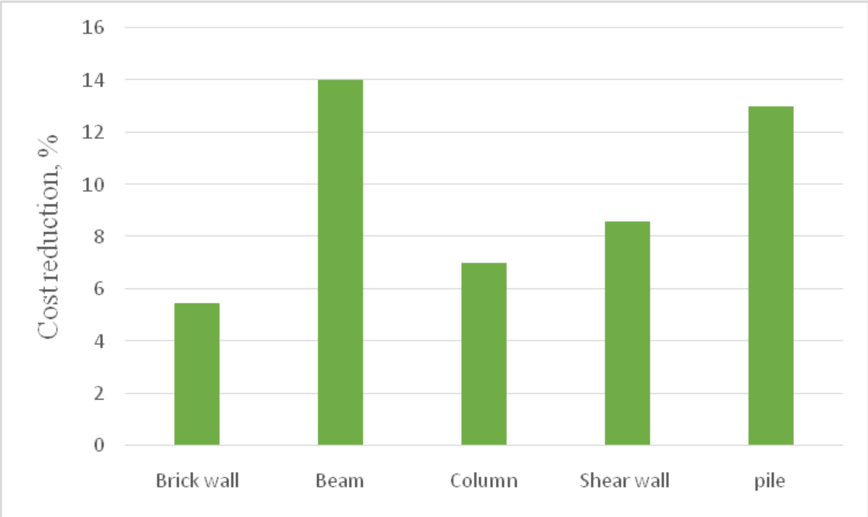


Figure 5: Overall cost reduction in structural members

Total saving from the overall material cost is 10.20% considering steel, cement, sand and stone. From the obtained result it is ensured that use of hollow blocks in the walls can be a sustainable alternative to the traditional fire brick.

Use of hollow block also provide some other economic benefits over the traditional fire brick. As the hollow block has a relatively smooth surface, the finishing cost of the walls can be minimized. Not only that, as each block is relatively larger, it also reduce the construction time. In addition to that, hollow block can provide a better aesthetic view with less maintenance. However, it must be mentioned that all of these additional benefits has a direct economic relationship with the overall project cost.

5. Conclusion

On the basis of the obtained result from two different analysis assuming the variable is the use hollow concrete block and traditional fire brick, following conclusions can be drawn:

- Use of hollow concrete block can reduce significant structural load. Which is approximately 18% for the case studied.
- Steel use can be reduced if a construction project utilizes hollow concrete blocks. Which is directly connected to the overall finance of a project.
- Almost 10.20% of the gross material cost is reduced for the case studied when hollow blocks replaced the tradition bricks.
- Significant amount of time can also be saved from the exterior and interior finishing works as the concrete blocks offer less hassle when compared to the fire bricks.

Considering all the technical advantages and economic benefits, it is evident that use of hollow blocks in Bangladesh can be a feasible alternative to tradition fire brick. In addition to that hollow blocks offer a cleaner manufacturing process, which helps to reduce the adverse environmental impacts.

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