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# Hollow Concrete Blocks-A New Trend

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***ABSTRACT:*** *Hollow concrete block" have become a regular or frequent choice today in construction activities as these blocks offer various benefits, simplicities in their use as building elements, strength comparable with the conventional blocks like bricks, facilities to get reinforced thereby increasing the strength of constructed units, facility for better finish, adoptability for getting desired architectural shapes and beauty and above all rendering economy in construction. With these aspect under study the authors concentrated upon some case studies indicating the uses of HCBs in the construction of beam, walls etc. to study the outcomes of these studies and have, then based on the investigations of these case studies reviewed the various aspect related to the uses of HCBs. The paper briefly reviews all the above points referred.*

***Keywords:*** *Block masonry, compressive strength, economy, hollow concrete block and insulation, strength of masonry.*

## I. INTRODUCTION

One of the basic requirements of human being to sustain in the world is shelter. After evolution of human being, the need of shelter meant for safety, arises. In ancient time, man started taking shelter in caves, excavated below ground level and under hanging mountain cliffs and this type of shelter just provided safe place from environmental extremities. The concept of stability and safety as per structural features of shelter were completely out of mind. With the development and maturity of human mind, man began to modify the structural formation of shelter so as to address the increasing needs and facilities which an optimum shelter design possessed. After achieving a feat by the use of easily available material like mud in construction walls and then the technique of burnt clay brick masonry to form structural part of shelter, there was still a long journey is coming out for the best possible material for construction of stable and safe structural units of shelter. The desire for search of safe and stable structural materials keeping in view the economy of whole structure, paved way for usage of hollow concrete blocks.

Now a days, Hollow Concrete Blocks (HCB) and bricks are becoming very popular. These blocks are being widely used in construction of residential buildings, factories and multi-storied buildings. These hollow blocks are commonly used in compound walls due to their low cost. These hollow blocks are more useful due to their lightweight and ease of ventilation. The blocks and bricks are made out of mixture of cement, sand and stone chips. Hollow blocks construction provides facilities for concealing electrical conduit, water and soil pipes. It saves cement in masonry work, bringing down cost of construction considerably. Economy of the structure is one of the basic aspects upon which any design is based. The stability plays an important role but the best designer is one who comes out with design which gives the stable and economics structure. The development of the construction technology is closely related to development of adequate mechanization and handling technology. Hollow concrete is an important addition to the types of masonry units available to the builders and its use for masonry is constantly increasing.

## II. BACKGROUND

A Hollow concrete block is primarily used as a building material in the construction of walls. It is sometimes called a concrete masonry unit (CMU). A concrete block is one of several precast concrete products used in construction. The term precast refers to the fact that the blocks are formed and hardened before they are brought to the job site. Most concrete blocks have one or more hollow cavities, and their sides may be cast smooth or with a design. In use, concrete blocks are stacked one at a time and held together with fresh concrete mortar to form the desired length and height of the wall. Concrete mortar was used by the Romans as early as 200 B.C. to bind shaped stones together in the construction of buildings. During the reign of the Roman emperor Caligula, in 37-41 A.D., small blocks of precast concrete were used as a construction material in the region around present-day Naples, in Italy. Much of the concrete technology developed by the Romans was lost after the fall of the Roman Empire in the fifth century. It was not until 1824 that the English stonemason Joseph Aspdin developed Portland cement, which became one of the key components of modern concrete.

The first hollow concrete block was designed in 1890 by Harmon S. Palmer in the United States. After 10 years of experimenting, Palmer patented the design in1900. Palmer's blocks were 8 in (20.3 cm) by 10 in (25.4 cm) by 30 in (76.2 cm), and they were so heavy they had to be lifted into place with a small crane. By 1905, an estimated 1,500 companies were manufacturing concrete blocks in the United States. These early blocks were usually cast by hand, and the average output was about 10 blocks per person per hour. Today, concrete block manufacturing is a highly automated process that can produce up to 2,000 blocks per hour. Concrete blocks were first used in the United States as a substitute for stone or wood in the building of homes. The earliest known example of a house built in this country entirely of concrete block was in 1837 on Staten Island, New York. The homes built of concrete blocks showed a creative use of common inexpensive materials made to look like the more expensive and traditional wood-framed stone masonry building. This new type of construction became a popular form of house building in the early 1900s through the 1920s. House styles, often referred to as "modern" at the time, ranged from Tudor to Foursquare, Colonial Revival to Bungalow. While many houses used the concrete blocks as the structure as well as the outer wall surface, other houses used stucco or other coatings over the block structure. Hundreds of thousands of these houses were built especially in the Midwestern states, probably because the raw materials needed to make concrete blocks were in abundant supply in sand banks and gravel pits throughout this region. The concrete blocks were made with face designs to simulate stone textures: rock-faced, granite-faced, or rusticated. At first, considering an experimental material, houses built of concrete blocks were advertised in man Portland cement manufacturers' catalogs as "fireproof, vermin proof, and weatherproof" and as an inexpensive replacement for the ever-scarcer supply of wood. Many other types of buildings such as garages, silos, and post offices were built and continued to be built today using this construction method because of these qualities.

## III. THE BENEFITS OF HOLLOW CONCRETE BLOCK:-

1. Economy in design of sub-structure due to reduction of loads
2. Saving in mortar for lying of blocks as compared to ordinary brick work. Saving in mortar for plasterwork. Uniform Plaster thickness of 12 mm can be maintained due to precision of the size of blocks as compared to brick work where plaster thickness of average 20 mm is required to produce uniform and even plastered surface due to variations in the sizes of bricks.
3. Insulation of walls is achieved due to cavity, which provides energy saving for all times. Similarly hollowness results in sound insulation.
4. Paint on finished walls can be applied due to cavity, which provides energy saving for all times. Similarly hollowness results in sound insulation.
5. No problem of the appearance of salts. Hence, great saving in the maintenance of final finishes to the walls.
6. Laying of Blocks is much quicker as compared to brickwork hence saving in time.
7. Thermal insulation property of hollow concrete block is more than ordinary brick wall.
8. Hollow concrete block is environmentally eco friendly.
9. Factor of safety of hollow concrete block is more than brick masonry.
10. Maintenance cost of the hollow concrete block is less than brick masonry.

## IV. REQUIREMENTS FROM CONCRETE BLOCKS:-

The basic requirement from any concrete is to provide strength and durability. Hollow concrete blocks, apart from providing the above listed benefits, possess adequate strength and structural stability, are highly durable, fire resistant, economical and provide fast and easier construction system. In addition to this they provide aesthetic beauty by providing better architectural features .In order to satisfy the basic constructional requirements these blocks have to satisfy the requirements of IS:2185

## V. HOLLOW CONCRETE BLOCKS USED IN CONSTRUCTION:-

As regards to the use of hollow concrete blocks there are certain remarkable and noteworthy points going in favor of these blocks.

1. The dead load of hollow concrete block is much lesser than a solid block; due to this, one can work with the structural engineer and reduce steel consumption in construction.
2. Hollow concrete blocks require minimal mortar.
3. If these blocks are engineered properly then dimensional accuracy and high finishing quality is obtained.
4. Usage of lintel blocks brings tremendous operational efficiencies resulting in lower cost.
5. Hollow concrete blocks have additives to improve their water resistance and seepage minimization.
6. Hollow concrete blocks can be engineered to achieve very high compressive strengths.

7. Hollow concrete blocks are much more sturdy.
8. The hollow concrete block adopt to modern design forms, richness of the texture etc.
9. Minimum maintenance cost and cost competitiveness with other materials make it a preferred material for today's building.
10. Hollow concrete blocks can effectively be used for cold storage and industrial go downs as they are thermally effective.

As indicated in the foregoing discussion, the HCBs are in substantial use in various construction units. In order to review their use, for specific purpose and the results, because of their use, obtained thereafter, details of certain case studies have been highlighted in subsequent discussion.

## VI. CASE STUDY I: USE OF REINFORCED HOLLOW CONRETE BLOCKS

Since the demand for the continued use of masonry has led to evaluation of reinforced masonry, the recent research investigations and the development of improved design and construction techniques have established the reinforced concrete masonry as a proven structural system. Hence, the reinforced concrete masonry has become one of the new developments of the engineered construction.

Reinforced hollow unit concrete masonry is a method in which steel reinforcement is embedded in grout within the concrete blocks such that the masonry, grout and steel act together to resist applied forces. In a study carried out by Mr. M.K.Maroliya, the flexural behavior of the beam made of HCB was checked. The basic objective of the study was to find the moment carrying capacity of reinforced concrete masonry beams. Besides this, crack patterns in beams and columns were also studied.

Four singly reinforced beams were cast using hollow concrete blocks. The grout used for filing the cells of blocks was of proportion 1:2.5:3. Beams were tested in pure bending. Tests on beam revealed that moment carrying capacity of beams increased with increased in percentage tensile reinforcement.

Cracks in beams initiated at middle third portion of the beam where bending moment happens to be maximum in pure bending case. Cracks appeared at tensile zone and progressed upward with the increase of load. Almost all cracks appeared at mortar joints which happen to be the weakest portions of masonry beams.

During the study the constituents used had following specifications:

Cement used in mortar confirmed to IS: 269-1958.

The sand used confirmed to the requirements of IS: 382-1963

The type of steel used to reinforced masonry is same as that used in reinforced concrete, Confirming to IS: 456-2000.

All other details related with the work carried out by Mr. Maroliya have been shown hereunder.

**6.1 Table showing description of beams:**

Each beam consists of two courses of grouted of grouted hollow block masonry. All beams were singly reinforced. The reinforcement descriptions in various beams have also been shown.

| Sr. No. | Designation | Dimension of beam (b x d) (mm x mm) | Longitudinal reinforcement | Shear stirrups |
|---|---|---|---|---|
| 1. | B1 | 140 x 320 | 2- Ø8 | 2 lgd-Ø6 @200 c/c |
| 2. | B2 | 140 x 320 | 2- Ø10 | 2 lgd-Ø6 @200 c/c |
| 3. | B3 | 140 x 320 | 2- Ø12 | 2 lgd-Ø6 @200 c/c |
| 4. | B4 | 140 x 305 | 2- Ø10 | 2 lgd-Ø6 @200 c/c |

- Overall dimension of each beam = 140 x 390 mm
- Holding bars in each beam = 2 nos. 8 mm Ø

**Construction of Beams**

Constructions of beams were done polythene sheets spread on the floor. Lower course of beam was constructed with block type "B" (channel shaped) which enables easy placing of reinforcement. Mortar mix used for assembling block was having proportion 1:3. Reinforcement cage was prepared by testing the longitudinal reinforcement with shear stirrups. This cage was then placed in the lower course of beam. After placing reinforcement, upper course of beam was constructed using block type "C". After bars were placed in position at top of upper course of blocks by inserting them in shear stirrups.

Grout of proportion 1:2.5:3 was then filled in cavities of two courses of blocks and compacted

**Testing Of Beams**

For testing beams, special setup was prepared between plates compression testing machine.

Since the test span of beam was more than the length of trolley of machine, beams were tested upside down i.e. compression face of beam was placed at bottom and rollers of lower trolley were used as means of applying concentrated load .

Load was gradually applied to the beam. On appearance of initial crack, reading of load indicating dial was taken. Then, loading was continued till ultimate failure of beam occurred.

| Designation | Dimension of beam (b x d) (mm x mm) | Percentage tensile reinforcement | Initial load (in tonne) | Failure load (in tonne) (W)* | Ultimate moment (M) (in KN-m) |
|---|---|---|---|---|---|
| B1 | 140 x 320 | 0.22 | 3.00 | 3.3 | 17.82 |
| B2 | 140 x 320 | 0.35 | 3.40 | 3.6 | 19.44 |
| B3 | 140 x 320 | 0.50 | 3.85 | 4.0 | 21.60 |
| B4 | 140 x 305 | 0.74 | 4.15 | 4.5 | 24.30 |

- W is the concentrated load at each third point of beam.

**Discussion On Beam Results**

The moment carrying capacity of beams increases with increases of percentage tensile reinforcement. The ratio of experimental load to theoretical load obtained from working stress method varies between4.2 to 4.6. These values are quite high. Also, looking to the analysis carried by working stress method, it appears that beams might be over reinforced but experiments showed that cracks initiated at tensile face i.e. beams were under reinforced. These contradictions are due to lesser value of permissible stress taken for masonry.

On the other hand, ratio of experimental load to theoretical load obtained from ultimate load theory varies between 1.1 to1.7. It proves that experimental results are in good agreement with theoretical values from ultimate theory.

**Failure Pattern and Causes Of Failure**

In beams, cracks initiated at middle third portion of beam where bending moment was maximum. Cracks appeared at tensile face of beam and started propagating towards compressive face with the gradual increase of load.

Almost all cracks appeared at mortar a joint which happens to be weakest portion of masonry beams.

At ultimate load, reinforcement started to yield which caused mortar joint to open and hence cracks appeared at mortar joint.

In the experiment 4 beams were tested namely B1, B2, B3& B4 as shown in the table above. In beams B1 to B3, only flexural cracks appeared at middle third portion of beam while on beam B4, shear cracks also developed along with flexural crack. Shear cracks initiated from support and propagate diagonally. It indicates that shear reinforcement was insufficient in beam B4.

From the results of the experimental study conclusions that can be drawn are:

- The order to use HCBs in making a beam, percentage tensile reinforcement in blocks should be adequate so as to increase moment carrying capacity of beam.
- The beams so created using HCBs should be never be left under reinforced so as to stop the initiation of the cracks from bottom face of the beams.
- Utmost care should be taken to see that the mortar joints in the masonry made of HCBs does not happen to be the weakest portion for the initiation of the cracks.
- All possible care should be exercised to see that the beam safe in shear and diagonal cracks do not take place at supports.

## VII. CASE STUDY II:-HOLLOW CONCRETE BLOCK MASONRY WALL

Hollow concrete block is important additions to the types of masonry units available to the builders and its use for masonry a constant increase, some of the advantages of hollow concrete block construction are reduce mortar consumption, light weight and greater speed masonry work.

This project is a study of construction of Hollow Concrete Block (HCB) masonry. The emphasis in the present study is carried out by M K Moraliya to study the crack patterns developed in the structural elements such as walls, columns constructed with HCB, to the load carrying capacity of the HCB individually and when use in masonry work.

### 7.1. Discussion on wall

Three sets of wall of size 0.2m width, 0.8m length and 1.8m height constructed with different mortar 1:3, 1:4, 1:5 proportion were tested in the compression testing machine (CTM). Each set consist of three wall

made up of same proportion of mortar. Because of the concrete of being homogenous, the structure gives different results when tested under the same conditions. The walls were kept hollow inside. The load carrying capacity of the walls and the crack patterns developed due to the load were studied.
The HCBs tested in CTM. The bearing surfaces of the CTM are wiped clean and any dry loose or other materials are removed. The HCBs taken out from the curing and are allowed to dry for 24 hours in open air. The dimensions of the HCBs are measured to the nearest 0.2 mm and their weights are noted before testing. The load is applied in these bed faces. The axis of the bed face is carefully aligned with the center of spherical seated plate. No packing is used the faces of the test specimen and steel plate of the testing machine.
Compressive strength of the HCB tested in CTM is as shown in the table below

| Sr. no. | Size of hollow concrete block | Average compressive load of 10 reading | Stress in N/mm² on net area |
|---|---|---|---|
| 1 | 400X200X200 | 9.0 | 2.2 |
| 2 | 200X200X200 | 10.0 | 8.8 |

During the experiment for wall of size 0.2m x0.8m x1.8m, the concrete plate was cast of size 0.4mx1.0mx0.1 m also hooks were made for putting the edge of bars of the steel provided in mesh of the concrete plate. For column size 0.4mx0.4mx1.8 m, the concrete plate was cast of dimension 0.6m x0.6m x0.1 m. This plates were cast simultaneously and allowed curing for 28 days to got the enough strength of plates. After that the walls were constructed on it.

### 7.2. Wall Test

Compressive test of the nine walls with different mortar proportion was carried out and the results are shown in following tables:

**Wall constructed with mortar 1: 5**

| Sr. no. | Load at initial cracks in tone | Load at final cracks in tone | Stress at initial cracks in N/mm² | Stress at final cracks in N/mm² |
|---|---|---|---|---|
| 1 | 12 | 12.5 | 1.46 | 1.52 |
| 2 | 11.6 | 12.8 | 1.41 | 1.56 |
| 3 | 11.7 | 12.3 | 1.43 | 1.50 |

**Wall constructed with mortar 1: 4**

| Sr. no. | Load at initial cracks in tone | Load at final cracks in tone | Stress at initial cracks in N/mm² | Stress at final cracks in N/mm² |
|---|---|---|---|---|
| 1 | 11 | 12 | 1.34 | 1.46 |
| 2 | 10 | 12 | 1.22 | 1.46 |
| 3 | 10 | 13 | 1.22 | 1.49 |

**Wall constructed with mortar 1: 3**

| Sr. no. | Load at initial cracks in tone | Load at final cracks in tone | Stress at initial cracks in N/mm² | Stress at final cracks in N/mm² |
|---|---|---|---|---|
| 1 | 6.5 | 7.0 | 0.79 | 0.85 |
| 2 | 11.5 | 12.4 | 1.4 | 1.51 |
| 3 | 12.5 | 13.5 | 1.52 | 1.65 |

- The only conclusion that can be drawn, form these case study is, that the wall constructed using HCBs is more economical than the brick wall and renders speedy construction.

## VIII. CASE STUDY III: BRICK MASONRY AND HOLLOW CONCRETE BLOCK-A COMPARISION

In two case studies indicated above the structures created using HCBs were tested for specific purpose namely for flexural strength, in case of beam, and load carrying capacity in case of wall, Unlike these two case studies one study was carried out by Rafiq Ahmad et.al to compare brick masonry and HCB masonry. The study was carried out concentrating upon cost aspect.
The various constituents of the entire study are discussed below:

### 8.1. Materials used

1. Cement:
   Khyber ordinary Portland cement of 43 grade confining to IS 8112:1989 was used throughout the work
2. Sand:

Sand used throughout the work comprised of plane river sand with maximum size 4.75mm confining to zone II as per IS 383-1970 with specific gravity of 2.6.

3. Hollow Concrete Blocks:
   Hollow concrete blocks of size (16x8x8) inch and (8x8x8) inch were used for making walls.
4. Bricks:
   Bricks were used of modular size (22.5x10x7.5) cm.
5. Mortar:
   1:4 cement sand mortar as used for wall masonry were made in the standard manner as prescribed by IS: 3535-1986

**8.2. Procedure for construction of walls**

Two girders were placed side by side such that their flanges would act as the base for the walls. These girders were place on the bottom member of the loading frame. A layer of mortar was placed on the girders to provide a uniform and leveled base for the wall. The walls were built on this leveled surface as per IS code recommendations with 1 cm thick mortar. A layer of mortar was also provided at the top so that load would be transmitted uniformly. A total of eight walls were constructed comprising of four hollow concrete block masonry walls and four brick masonry walls.

**8.3. Testing:-**

1. Testing of individual hollow concrete block and brick units:
   Individual hollow concrete blocks confining to IS: 2185-1984 (Part 3) and brick units confining to IS : 1077-1986, IS : 2180-1985 and IS : 2222-1979
2. Testing of mortar blocks of size (15x15)cm were made and tested after 28 days confirming with IS: 4031 (part 1)
3. Testing of wall: After the walls were built curing was done for 7 days and testing was done after 28 days. A rail section which completely covered the top section of the wall was placed. The rail section was placed so that load from the jack would be uniformly distributed over the wall. The jack was placed centrally over the rail fixed to the upper member of the frame. The proving ring was placed under the jack for measurement of the load. The testing was started by pumping the jack at a higher rate initially then lowering the rate as cracks appeared, in order to observe the modes of failure.

**Light weight character**: The average dry weight of hollow concrete block units were compared with dry weight of brick units confining in same volume and difference in weights was measured.

**Economy:**

Cost per cubic meter of brick masonry comes out to be Rs.3875 and Cost per cubic meter of brick masonry comes out to be Rs.3290. The cost of block walls per metre$^3$ of hollow concrete masonry came out to be 17.78%less than that of brick walls. So, block masonry was economical than brick masonry.

**Compressive strength of mortar specimens**

| Sample no. | Compressive or crushing strength kg/cm² |
|---|---|
| 1 | 159.55 |
| 2 | 168.88 |
| 3 | 153.33 |

**Compressive strength of the individual block and brick unit**

| Sample no. | Compressive or crushing strength of individual HCB of size (16''x8''x8'') kg/cm² | Compressive or crushing strength of individual HCB of size (8''x8''x8'') kg/cm² | Compressive or crushing strength of individual brick of size (22.5x10x7.5) kg/cm² |
|---|---|---|---|
| 1 | 36.37 | 29.00 | 96.49 |
| 2 | 35.87 | 27.75 | 86.40 |
| 3 | 37.62 | 31.00 | 144.73 |
| 4 | 35.00 | 28.25 | 112.28 |
| 5 | 30.12 | 24.25 | 126.75 |

**Compressive strength of various wall types**

| Wall No. | Wall type | Length | Height | Aspect ratio (H/L) | Aspect ratio (H/T) | Observed load (KN) | Permissible Load (KN) | Compressive strength (N/mm²) |
|---|---|---|---|---|---|---|---|---|
| 1 | Hollow block | 1.23 | 1.04 | 0.846 | 0.52 | 320.1 | 103.3 | 1.30 |
| 2 | Hollow block | 1.23 | 0.83 | 0.675 | 4.15 | 308.6 | 103.3 | 1.25 |
| 3 | Hollow block | 1.03 | 1.04 | 1.00 | 5.2 | 291.5 | 87.4 | 1.18 |
| 4 | Hollow block | 1.03 | 0.83 | 0.806 | 4.15 | 275.3 | 87.4 | 1.12 |
| 5 | brick | 0.96 | 1.03 | 1.08 | 5.15 | 440.3 | 182.0 | 2.29 |
| 6 | brick | 0.96 | 0.84 | 0.875 | 4.2 | 407.3 | 182.0 | 2.12 |
| 7 | brick | 0.96 | 1.03 | 1.08 | 5.15 | 386.7 | 182.0 | 2.01 |
| 8 | brick | 0.96 | 0.84 | 0.875 | 4.2 | 345.6 | 182.0 | 1.80 |

On the basis of the results obtained in the above study, the following conclusions were drawn:

- Compressive strength of the brick units and brick masonry wall came out to be more than compressive strength of HCB units and hollow concrete wall masonry.
- Sound insulation property of hollow concrete masonry was more than that of brick masonry.
- Thermal insulation property of hollow concrete masonry was more than that of brick masonry due to presence of air in hollow concrete units.
- As the cost of block walls per meter cube of masonry comes out to be lesser than that of brick walls. Block masonry is economical than brick masonry.
- Maintenance cost of HCB masonry is less than brick masonry because of no effloresces found as it is found in brick masonry wall.

## IX. CONCLUSION

The main aim of the paper being the review of the experiences obtained by different researchers in their studies to use the HCBs for constructing various structural elements, three case studies have been indicated above. Based on the observations discussed in these case studies the authors would like to draw the following conclusions:

1. Being light in weight HCBs provide economy in design of sub-structure due to reduction of the loads.
2. Laying of blocks saves mortar as compared with ordinary brick work. There is saving in mortar plaster work too.
3. Cavity of blocks helps achieving insulation of walls and provides energy saving for all times. Hollowness results in sound insulation.
4. There is no problem of appearance of salts thereby saving in maintenance of final finishes to the walls.
5. Laying of blocks is much quicker as compared to brick work hence, saving in time.
6. HCBs are environmentally eco-friendly.
7. Factor of safety HCB masonry is more than brick masonry.

In view of all the above discussions and the conclusions drawn thereafter, it can be finally concluded that if the HCBs are engineered properly then they help obtaining dimensional accuracy and high finishing quality and having cost competitiveness with other materials they have become the preferred materials for today's buildings.

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## REFERENCES

[1]. ACI Committee 531, "Building code Requirements for Concrete Masonry Structures", ACI Jounral, Proceedings V.75, No.8, p. 384-403, Aug. 1978.
[2]. ACI Committee 531, "Commentary on Building Code Requirements for Concrete Masonry Structures", ACI Jounral, Proceedings V.75, No.8, p. 460-498, Sept. 1978.
[3]. Boult, B. F., "Concrete Masonry prism testing", ACI Jounral, Vol.76, p. 1145, Oct. 1979.
[4]. Curtin, W. G., Shaw, G. and Beck, J. K. "Design of reinforced and prestressed masonry", Granada publishing limited, London, 1988.

[5]. Curtin, W. G., Shaw, G., Beck, J. K. and Parkinson, G. I., "Structural Masonry Detailing", Granada Publishing Limited, London, 1989.

[6]. Curtin, W. G., Shaw, G., Beck, J. K. and Bray, W. A., "Structural Masonry Designers Manual", Granada Publishing Limited, London, 1982.

[7]. CP: 111-1964, "Structural recommendations for load bearing walls", British Standard Institution.

[8]. Journal on use of soil cement hollow concrete and others precast cement concrete component and others precast cement concrete components by Indian institute of Engineers (India).

[9]. Neville A.M., Properties of concrete, pitman publishing, 1973.

[10]. Orchard D.F., Concrete Technology volume-I, applied science publishers limited, Third Edition, 1973.

[11]. Shetty M.S., Concrete Technology, S. Chand & Company Ltd., Ramnagar, New delhi, Second Edition, 1986.

[12]. Rixom M.R., Concrete Admixtures use and applications, cement admixtures association, 1977.

[13]. Mr. M K Maroliya, Load Carrying Capacity Of Hollow Concrete Block Masonry Wall, (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 6, November- December 2012, pp.382-385.

[14]. IS 8112:1989 43 Grade Ordinary Portland Cement – Specification. IS 8112:1989, Bureau of Indian Standards, New Delhi.

[15]. IS 383-1970, Specification for Coarse and fine aggregates from Natural sources for concrete, BIS, New Delhi.

[16]. IS 3535-1986, Methods of Sampling Hydraulic Cements, Bureau of Indian Standards, New Delhi.

[17]. IS : 2185-1984 (Part 3), Concrete Masonry Units, Autoclaved Cellular Aerated Concrete Blocks, BIS, INDIA.

[18]. IS : 1077-1986, Common burnt clay building brick Specification, BIS, New Delhi.

[19]. IS : 2180-1985, Heavy Duty Burnt Clay Building Bricks, BIS, New Delhi.

[20]. IS : 2222-1979, Specification for burnt clay perforated building bricks, BIS, New Delhi.

[21]. IS: 4031 (part 1), Method of Physical Tests For Hydraulic Cement, BIS, New Delhi.

[22]. IS 4031 (Part I), Method of Physical Tests For Hydraulic Cement, BIS, New Delhi.