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A Compression Test Conducted on Normal-Weight Hollow Concrete Blocks

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Abstract

This work outlines the findings of a compression test conducted on normal-weight hollow concrete blocks (HCBs) to assess their structural performance and suitability for load-bearing applications. The test followed ASTM/IS standards, concentrating on essential factors such as compressive strength, failure mode, and dimensional stability. A total of 13 specimens (dimensions 140w x 190h x 390l mm) were prepared under air-cured tropical conditions until age 28 days. Using a universal testing machine, each specimen was tested under axial loading (compression testing) until failure. The average compressive strength was determined from multiple samples, and variations resulting from manufacturing inconsistencies were examined. The findings show that the HCBs meet the basic strength requirements for regular construction uses (surpassing ASTM C90). These results support the use of HCBs in affordable and structurally sound building techniques, while also pointing out chances to improve material consistency and manufacturing methods.

Discipline: Civil Engineering & Construction Technology.

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1 Introduction

There are two main types of concrete blocks, hollow and solid. Both types are commonly used in wall construction and other functions. The concrete blocks production has a five-step process including proportioning, mixing, compacting, curing, and drying (SCC, 2025). As concrete blocks are larger than bricks, thus less cement is needed in the mortar joints to hold them together. (BigRentz, 2021).

Hollow Concrete Block Masonry (HCBM) is a well-known building method that uses hollow concrete blocks (HCBs), also called concrete masonry units (CMUs). HCBs are used rather than traditional bricks or solid blocks. HCBM is appreciated for its efficiency, adaptability, and numerous performance advantages.

HCBs are rectangular blocks, utilizing precast concrete units, made of cement, water, and small/fine aggregates. They have one or more hollow cores (voids/openings) that take up more than a quarter (and often over half) of their cross-sectional area. These openings help to lighten their weight, improve insulation, and make it easier to install wiring or piping. Also, rebar can be run through these holes to boost stability (BigRentz, 2021). HCBs/CMUs are arranged in layers and adhered together with mortar. These HCBs/CMUs are extensively utilized for both load-bearing and non-load-bearing walls across residential, commercial, and industrial building projects.

2 Literature Review

HCBs are a commonly utilized construction material, especially in low-rise structures and infill walls. Understanding its mechanical properties, particularly under compressive loads, is essential for safe and effective design.

2.1 HCBs and Compression Behavior

HCBs are prefabricated units having one or more voids. HCBs can be assembled with mortar to create masonry walls. Contrary to solid concrete blocks, the internal structure of hollow blocks plays a crucial role as to determine their load-bearing capacity. Under compression, HCBM demonstrates a complex failure mechanism that involves both the block material and the mortar joints. Important parameters are compressive strength, modulus of elasticity, and ductility. Normally, the overall compressive strength of masonry is lower than that of the individual blocks due to mortar joints and stress concentrations.

2.2 Factors Influencing Compressive Strength of HCBs

A multitude of studies have explored the various elements that impact the compressive strength of HCBM:

2.2.1 Block Properties

HCB Block Compressive Strength: This is directly proportional to the strength of the masonry. Generally, blocks with higher strength result in greater masonry strength. (e.g., Kaushik et al., 2007; Sarangamath & Shetty, 2008)

HCB Block Geometry (Web and Face Shell Thickness): Increased thickness of webs and face shells offers a larger bearing area, thus enhancing strength. (e.g., Sarangamath & Shetty, 2008)

Aggregate Type: The kind of aggregate used in the blocks production can affect the strength of the HCB blocks and, as a result, the strength of the masonry.

2.2.2 Mortar Properties

Mortar Compressive Strength: Although an increase in the strength of mortar typically enhances the strength of masonry, this relationship is not always straightforward, particularly when the strength of the mortar surpasses that of the blocks. Excessively strong mortar may result in the premature failure of the blocks. (e.g., Kaushik et al., 2007)

Mortar Type (Cement-Sand Ratio, Additives): The proportions of the mix and the incorporation of additives can greatly affect the strength and workability of the mortar, thereby influencing the overall performance of the masonry.

Mortar Joint Thickness: Increased thickness of mortar joints may diminish the effective bearing area, which could potentially result in reduced masonry strength. (e.g., Sarangamath & Shetty, 2008)

2.2.3 Workmanship and Curing Conditions

Quality of Laying: Ensuring proper alignment, complete bedding of the mortar, and uniform joint thickness is essential for attaining the design strength.

Curing: Sufficient curing of both the blocks and the mortar is vital for ensuring proper hydration and the development of strength.

2.2.4 Aspect Ratio of Masonry Prisms

The ratio of height to thickness in the tested masonry specimen affects the observed compressive strength due to the effects of confinement. Generally, shorter and stockier prisms exhibit greater strengths. (e.g., IS 1905:1987, ASTM C1314)

2.2.5 Grouting and Reinforcement

Grouting: The process of filling the hollow cores with grout leads to a significant increase in both the compressive strength and stiffness of the masonry, particularly when it is paired with reinforcement. (e.g., Hedstrom et al., 1980; Kaushik et al., 2007)

Reinforcement: The inclusion of vertical and horizontal reinforcement within the grouted cores further improves strength and ductility, especially in applications subjected to seismic activity.

3 General Information Regarding Hollow Concrete Blocks (HCBs)

3.1 Characteristics of Hollow Concrete Blocks

Composition: Generally composed of cement, aggregates (such as stone chips and sand), and water. For non-load-bearing applications, lightweight aggregates may be utilized.

Dimensions: Offered in various nominal sizes, including 400 mm in length, 200 mm in width, and 200 mm in height (actual dimensions are slightly reduced to allow for mortar joints). HCBM is also available in other dimensions, such as 100 mm x 200 mm x 400 mm, 150 mm x 200 mm x 400 mm, and 200 mm x 200 mm x 400 mm. Half-size blocks and specialized shapes (for instance, lintel blocks, corner blocks, partition blocks) are also available.

Void Area: Typically, hollow blocks possess a void area that ranges from 35% to 60% of their total cross-sectional area.

3.2 Types of HCBs based on Use

There are many types of HCBs available, including

- Load-bearing blocks
- Non-load-bearing blocks
- Partition blocks
- Lintel blocks
- Corner/column blocks

3.3 Grade of HCBs

HCB is classified into three grades, i.e., Grade A, Grade B, and Grade C. Grade A and B are for load-bearing walls, while Grade C is for non-load-bearing structures, see Table 1.

Table 1: Grades of HCBs

HCB	Application	Dry Density kg/m^3	Minimum average compressive strength at 28 days
Grade A	Load-bearing walls and structures.	>1500	3.5-7.0 N/mm^2 (MPa)
Grade B	Load-bearing walls and structures.	1100-1500	3.5-5.0 N/mm^2 (MPa)
Grade C	Non-load-bearing applications	1000-1500	1.5 N/mm^2 (MPa)

4 Details of the Test

4.1 HCB Specimens

In this study, normal weight hollow concrete blocks (HCBs) are manufactured with dimensions of 140x190x390 mm and possess a design strength (cylinder strength at age 28 days) of 180 ksc. A total of 13 specimens, each 28 days old, were prepared for this study under air-cured tropical conditions (humidity 55% or higher). Each specimen has a nominal cross-sectional area of 322.5 cm^2 (excluding the hollow areas). The dimensions and weights of each specimen were observed. The specimen average dry density is 2264.5 kg/m^3. Table 1 shows details of the test specimens.

4.2 Testing Apparatus

In this study, the test uses a calibrated Universal Testing Machine (UTM) to apply load to HCB specimens. A UTM, or a universal tester or materials testing machine, is a multifunctional device utilized for assessing the mechanical characteristics of materials, components, and structures. It exerts controlled forces on specimens and evaluates their reactions to mechanical stresses, including tension, compression, bending, and shearing. This study focuses on the compression test only.

4.3 Testing Standards: American Society for Testing and Materials (ASTM)

ASTM C90 pertains to load-bearing units, whereas ASTM C129 deals with non-load-bearing units, encompassing material specifications, dimensions, and testing protocols.

5 Test Results

5.1 HCB Compressive Strength Test Results

Testing using the UTM, Table 1 gives the compressive strength test results of the studied HCB specimens at 28 days. ASTM C90 – 16a specified a minimum compressive strength for individual units at 12.4 MPa (1800 lb/in^2 (psi) or 126.6 kg/cm^2 (ksc)). All the test results obtained from this test are higher than the value recommended in the ASTM C90, with the average compressive strength of 15.5 MPa (2245.5 psi or 157.9 ksc).

Table 2: Details and results of test specimen at age 28 days

Test Specimen					Dry density	Max Failure Load	Compressive strength		
ID	Dimensions (mm)			Weight (kg)	(kg/m^3)	(tons)			
	Width	Height	Length				ksc	psi	MPa
Z01	139	190	389	13.81	2253.8	45.55	141.2	2008.3	13.8
Z02	138	189	390	13.85	2272.3	43.64	135.3	1924.4	13.3
Z03	139	189	390	13.75	2255.9	46.34	143.7	2043.9	14.1
Z04	139	190	389	13.88	2265.2	50.58	156.8	2230.2	15.4
Z05	138	190	389	13.91	2270.1	48.62	150.8	2144.9	14.8
Z06	139	190	390	13.98	2281.5	55.27	171.4	2437.9	16.8
Z07	139	189	390	13.77	2259.1	52.57	163.0	2318.4	16.0
Z08	139	189	390	13.73	2252.6	60.11	186.4	2651.2	18.3
Z09	139	190	389	13.85	2260.3	47.65	147.8	2102.2	14.5
Z10	138	190	389	13.84	2258.7	51.36	159.3	2265.8	15.6
Z11	139	190	389	13.87	2263.6	59.89	185.7	2641.3	18.2
Z12	139	190	390	13.99	2283.1	54.24	168.2	2392.4	16.5
Z13	139	189	390	13.79	2262.4	49.55	153.6	2184.7	15.1
Average	138.8	189.6	389.5	13.85	2264.5	50.93	157.9	2245.9	15.5

5.2 HCB Test Failure Modes

5.2.1 HCB Splitting/Vertical Cracking

Splitting/vertical cracking is caused by tensile stresses that are perpendicular to the loading direction. This splitting appears as vertical fissures along the surface of the block. This HCB failure in cracking could be attributed to blocks that are either weak or insufficiently compacted, or to those that have a high-water content during the production process.

5.2.2 HCB Shear Failure

HCB shear failure is shown as diagonal cracking resulting from a combination of compressive and shear stresses. This appears as diagonal fractures originating from corners or edges towards the center. This may result from HCBs exhibiting asymmetrical shapes or experiencing improper loading.

5.2.3 HCB Web Crushing

HCB web crushing is due to the excessive load applied to the slender web of the hollow block. It appears as localized crushing of the internal web, frequently with minimal external cracking. This could be due to HCBs that have thin webs or a poor-quality concrete mix.

5.2.4 HCB End Crushing (Bearing Failure)

HCB end crushing occurs due to inadequate support or poor load distribution. The failure manifests as crumbling or spalling at the upper or lower edges. This failure happens when HCBs are subjected to uneven loading or are placed on irregular surfaces.

Figure 2: A specimen after testing failed from end crushing and shear failure.

5.2.5 HCB Block Spalling

HCB block spalling occurs due to surface tension and inadequate bonding of the surface. It manifests as chipping or flaking of the outer layer of concrete. The underlying cause is that HCBs that have experienced insufficient curing or have substandard surface finishes.

Figure 3: Mixed failure mode of block spalling and end crushing.

6 Advantages and Drawbacks of Hollow Concrete Block

6.1 Benefits of Hollow Concrete Block Masonry

Cost-Effectiveness: Generally, more affordable than solid bricks due to less material usage and quicker construction times. The larger block sizes decrease the number of joints, which saves on mortar.

Reduced Dead Load: The hollow design of the blocks significantly lowers the overall weight of the structure, potentially leading to reduced foundation costs.

Thermal Insulation: The air trapped within the hollow cavities offers excellent thermal insulation, helping maintain warmth in winter and coolness in summer, thereby lowering energy consumption for heating and cooling.

Sound Insulation: The hollow areas also enhance sound insulation, minimizing noise transfer.

Faster Construction: The larger size of the units compared to bricks allows for faster building processes.

Durability and Low Maintenance: Concrete blocks are extremely durable and require little maintenance, providing a long service life.

Fire Resistance: Concrete blocks offer effective fire protection.

Versatility: Suitable for a variety of uses, including load-bearing and non-load-bearing walls, foundations, partition walls, and retaining walls.

Eco-Friendly: They can utilize fewer raw materials and have a reduced environmental impact compared to traditional bricks, particularly when produced with recycled materials.

6.2 Drawbacks of Hollow Concrete Block Masonry

Lower Compressive Strength (Unfilled): Unfilled hollow blocks exhibit lower compressive strength than solid blocks. However, this can be greatly enhanced by filling the cores with concrete and reinforcement.

Water Absorption: Concrete is porous, and hollow blocks may be more susceptible to water absorption if not properly waterproofed or sealed, which can lead to damp issues.

Seismic Performance (Unreinforced): Unreinforced hollow block masonry may demonstrate inferior seismic performance. Nevertheless, this can be mitigated through appropriate design and the application of reinforced masonry techniques.

Requirement for Reinforcement in Heavy Load Scenarios: In applications that involve bearing heavy loads or suspending extremely heavy items, the use of grouting and reinforcement is frequently essential.

Visual Appeal: Certain individuals might consider the look of exposed concrete blocks to be less attractive compared to other masonry finishes. However, there are numerous textures and colors to choose from, and these blocks can also be rendered or plastered.

Table 3: Summarized Advantages and Drawbacks of HCBs.

Advantages	Drawbacks
• Lightweight – Simplifies handling and transportation. • Accelerated Construction – Increased dimensions decrease installation duration. • Thermal and Acoustic Insulation – Air cavities diminish heat and sound transmission. • Economical – Reduced need for mortar and plaster. • Environmentally Sustainable – Frequently utilizes industrial by-products (such as fly ash).	▪ Structural Constraints – Inadequate for extremely high loads unless additional reinforcement is applied. ▪ Moisture Absorption – Requires effective waterproofing measures. ▪ Reduced Aesthetic Appeal – Necessitates plastering or finishing to enhance visual attractiveness.

7 Conclusion

This report shares the results of tests conducted on 13 hollow concrete block (HCB) samples. These samples are 140 mm wide, 190 mm tall, and 390 mm long. These samples are 28 days old. The main goal is to find their structural performance and suitability for load-bearing purposes. The results show that all HCB samples exceed the ASTM C90 standards. Thus, this fulfills the minimum strength criteria for typical construction applications. These findings endorse the use of HCBs in cost-effective and structurally reliable building methods.

8 Availability of Data and Materials

Data can be made available by contacting the corresponding authors.

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