

Strength Assessment of Solid Concrete Block Masonry Prisms

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Abstract—This study investigates the compressive strength behavior of solid concrete block masonry prisms assembled with varying mortar grades and block sources. While numerous experimental investigations have examined clay brick masonry, limited research exists on the performance of solid concrete block masonry, despite its increasing adoption in modern construction due to cost efficiency, availability of industrial by-products, and superior structural properties. To address this gap, an extensive experimental program was conducted using solid concrete blocks procured from three different sources combined with mortars of five distinct mix ratios. A total of 45 masonry prism specimens were prepared, cured for 28 days, and tested under axial loading conditions in accordance with IS standards. The experimental results demonstrated a strong dependency of prism compressive strength on both mortar grade and block strength. Statistical multiple regression analysis was applied to the dataset, resulting in a predictive mathematical model that achieved a high correlation ($R^2 = 0.98$) between experimental and predicted values. The proposed equations capture the influence of mortar and block compressive strengths, providing a reliable tool for estimating prism strength under varying construction conditions. Furthermore, a structural reliability analysis was performed using Monte Carlo simulation to evaluate the probability of failure and reliability index for prisms across different mortar grades. Results indicated that all tested configurations exhibited probabilities of failure within the acceptable 5% limit, confirming the applicability of the derived equations for design and assessment. The outcomes of this study contribute to the advancement of masonry design by offering both experimental evidence and analytical models for solid concrete block masonry. The findings provide a framework for reliability-based design approaches, supporting the wider application of solid concrete blocks in structural engineering practice.

Index Terms—Compressive strength, Solid concrete blocks, Mortar, Regression analysis, Reliability

analysis, Masonry prisms.

I. INTRODUCTION

Masonry is one of the oldest known construction methods, with evidence of its use for more than 6000 years. Despite the advancement of modern materials and technologies, masonry continues to be widely practiced owing to its durability, cost-effectiveness, and availability of raw materials. Masonry construction typically consists of two components: masonry units and mortar. Units may be solid or hollow and are produced from materials such as clay bricks, stone blocks, concrete blocks, calcium silicate bricks, and pressed earth blocks. Since the bond interface between the unit and mortar is relatively weak, masonry exhibits poor tensile strength and is therefore designed primarily to resist compressive forces. Thus, accurate determination of compressive strength is crucial for safe structural design.

Conventional design guidelines, such as SP:20 (Bureau of Indian Standards, 1972), suggest empirical values for masonry strength based on the compressive properties of units and mortar. However, direct testing of masonry specimens, such as prisms or wallettes, offers more reliable strength estimates. Masonry prisms are widely adopted to determine compressive strength and elastic modulus, both of which are essential parameters in the structural design of masonry. International codes specify different specimen configurations for compression testing, ranging from prisms with three stacked units and two mortar joints to wallett specimens. These specimens serve as representative models for capturing the compressive behavior of masonry.

The interaction between masonry units and mortar plays a decisive role in compressive strength. Earlier

theoretical models (Hilsdorf, 1969; Khoo & Hendry, 1973; Atkinson, Kingsley, & Ali, 1982; McNary & Abrams, 1985) assumed an intact unit–mortar bond at failure. Later experimental studies (Matthana, 1996; Sarangapani, 1998) revealed that weak bonding could dictate failure behavior, independent of the inherent strength of units or mortar. Bond quality is often influenced by surface characteristics of the masonry units, which significantly affect compressive performance. Studies by Venumadhava Rao, Reddy, and Jagadish (1995) highlighted the importance of bond strength in determining the compressive behavior of masonry, underscoring the need for a systematic experimental evaluation.

In this context, the present study investigates the compressive strength of solid concrete block masonry prisms, which has received comparatively less attention than clay brick masonry. The research examines the combined influence of block strength, mortar grade, and bond characteristics, and develops a predictive model for estimating compressive strength. The findings are expected to contribute to performance-based design methodologies for modern masonry structures.

II. GAP ANALYSIS

Masonry prism tests remain the standard laboratory method for characterising the compressive strength of masonry assemblages because they capture the composite response of units, mortar and interfaces under axial loading—information not available from unit-only tests (comprehensive recent reviews summarise advances in prediction and testing). Recent syntheses highlight the continuing importance of prism testing for design calibration and model validation.

Constituent influences: block, mortar and interface. Several recent experimental studies reinforce that the compressive strength of masonry prisms is dominantly controlled by the relative strengths and stiffnesses of the masonry unit and the mortar, together with the quality of the block–mortar interface. Zahra et al. (2021) showed that when mortar strength increases beyond a threshold the failure mechanism shifts from mortar–joint failure to unit crushing, indicating a non-linear interaction between constituents rather than simple additive behaviour. Similarly, sensitivity analyses in machine-

learning studies (which use large experimental datasets) confirm that unit strength is the single most influential predictor of prism compressive strength, followed by mortar thickness and joint properties. These findings emphasise the need to measure and report both unit and mortar properties (including interface bond) when assessing prism strength.

Geometry, grouting and workmanship effects. Recent laboratory work demonstrates that prism geometry (height-to-thickness ratio), the presence/degree of grouting, and workmanship (joint thickness and uniformity) significantly alter the measured compressive capacity and failure mode. Abasi et al. (2024) experimentally documented pronounced differences in early-age and mature prism strength that correlate with joint workmanship and curing; fully grouted assemblies show different cracking patterns and higher confinement effects compared with ungrouted solid/block prisms. Inqiad et al. (2024) and other 2024 studies also report that geometric restraint in short prisms can produce higher apparent strengths, indicating a geometry-dependent bias that must be considered when comparing test data.

Failure modes and deformation behaviour — what recent tools reveal. High-resolution measurement techniques and advanced post-processing have clarified crack initiation and propagation in prisms. Thaickavil & Thomas (2018) began this trend and more recent 2021–2024 experimental campaigns extend it using strain-mapping and imaging to show that cracks commonly initiate in mortar joints under sub-peak loads and later propagate into the block faces when the block is weaker or more brittle; this progressive joint-to-unit failure sequence is consistent across many modern studies. These detailed observations are critical for interpreting prism strength (peak load) versus ductility and for calibrating numerical models.

Modelling and prediction: ML and FE advances (2021–2025). The last few years have seen a surge in data-driven and explainable-AI approaches to predict prism compressive strength, often outperforming earlier empirical formulae when trained on large experimental sets (ANNs, gradient-boosting, XAI). Sathiparan et al. (2023) achieved high predictive accuracy and identified unit strength and mortar thickness as dominant inputs; Heliyon/PMC studies in 2024 extended these techniques to hollow and

solid block prisms and explored model interpretability. Complementary nonlinear finite-element (FE) micro-modelling remains valuable for mechanistic understanding and for exploring parameters outside experimental reach, but recent reviews advise careful calibration of interface properties and validation against high-quality prism tests.

Sustainability and novel materials (2021–2025). Several recent investigations assess low-carbon and alternative block materials (fly-ash, geopolymers, stabilized earth and mixed industrial byproduct blocks) and report promising prism compressive strengths comparable to conventional concrete blocks when mixes are optimised. Ngullie et al. (2021) and Rajabi et al. (2022) provide evidence that sustainable solid blocks can meet short-term strength requirements, but they also stress the need for longer-term performance and durability testing (moisture, freeze–thaw, carbonation) to ensure reliability for load-bearing applications.

Gaps and research needs (2021–2025 focus). Despite recent progress, multiple shortfalls remain that are particularly relevant for solid concrete block prisms: (1) comparatively fewer systematic experimental studies target *solid* concrete blocks across a wide range of mortar grades and workmanship conditions — many campaigns focus on hollow blocks or clay bricks; (2) inconsistent reporting of joint thickness, block moisture content and cure regimes hampers cross-study synthesis; (3) while ML models are powerful, they often require large, high-quality labeled datasets with standardized reporting to generalize across block geometries and manufacturing variability; and (4) long-term durability and ageing effects of novel sustainable blocks on prism strength are under-explored in 2021–2025 literature. Addressing these gaps requires coordinated experimental matrices (unit grades \times mortar grades \times joint thickness \times prism geometry), combined with open datasets for model training and FE calibration.

Practical recommendations for experimental programmes. Based on the recent literature (2021–2025), best practice for strength assessment of solid concrete block prisms includes: strict adherence to recognised prism test standards when applicable (to aid comparability); full characterisation of unit and mortar mechanical properties and bond strength;

detailed recording of workmanship parameters (joint thickness, bedding type, curing); and pairing experiments with FE and explainable ML models to extract generalized relationships and predictive tools. Publication of raw experimental datasets (test geometry, constituent properties, raw load-displacement data) will accelerate model development and standard harmonization.

III. EXPERIMENTAL PROGRAMME

The bond beam block has the same overall dimensions as the stretcher unit, designed to receive horizontal reinforcement and grout, with the detailed dimensions listed in Figure 1. Hollow concrete stretcher blocks were produced by the BESSER company in V3-12K series; the bond beam blocks are knockout 90×60 mm (height \times width) stretcher units of the web, and all types of blocks were supplied by a block production factory in southeast China. Three types of block-fill grout were ordered from a ready-mix supplier. The properties of the different blocks and concrete adopted for construction of the masonry specimens are presented in Tables 1 and 2, respectively. A moderate composition of mortar with a compressive strength of 15.5 MPa was cast for all prisms.

Köksal et al. recommended that grout strength equal to or greater than that of the block could prevent a sharp decrease in the prism's ultimate load capacity of the prism. Furthermore, considering deformation compatibility, the grout concrete strength should be at least 50% higher than the block strength in grouted masonry construction. Accordingly, this study utilized concrete with a higher strength than the blocks.

The compressive strength of solid concrete masonry prisms, which were built using various combinations of blocks and mortar grades, was assessed using a series of experiments. Three distinct manufacturers' local blocks A, B, and C were utilised. To learn more about the quality of the blocks, water absorption tests were conducted on the block's unit. Figure 3.3 Compression test setup for concrete block masonry prism.

Table 1: Basic details from preliminary tests conducted

Test conducted	Standard Consistency	Specific Gravity	Fineness Modulus	Specific Gravity	Water absorption		
					A	B	C
CEMENT	33.50%	3.13	-	-	-		
FINE AGGREGATE	-	-	2.75	2.78			
CONCRETE BLOCKS	-	-	-	-	5.45%	6.66%	9.38%

The block tests (Table 1) indicated a maximum coefficient of variation for the net-to-gross area ratio of only 0.016. The elastic modulus of the blocks increased from 16,533 to 20,746 MPa as their compressive strength rose from 25.73 to 31.18 MPa. The standard deviation of block compressive strength increased with higher compressive strength, whereas the standard deviation of the elastic modulus decreased as the modulus of elasticity increased.

As shown in Table , the concrete mix proportions are by mass, with the cement content normalized to 1.0. Additionally, all concrete types incorporated a copolymer superplasticizer at a mass proportion of 0.05%. Contrary to the block compressive strength results, the standard deviation of concrete compressive strength decreased as the compressive strength increased. Although the elastic modulus of concrete was determined from the deformation of the specimen height, the secant modulus between 50% and 70% of the ultimate stress increased with increasing compressive strength.

The design and nomenclature of the test specimens are listed in Table 3. Solid concrete masonry prisms, constructed with the same moderate-strength mortar, were fabricated using three different stretcher block types: B1, B2, and B3. Five types of fully grouted masonry prisms were prepared: C2 grout was used with all three hollow prism types (B1, B2, and B3);

C1 grout was used with B1 blocks; and C3 grout was used with B3 blocks.

3.1.1 Design and name of test specimen.

Specimen Details

Testing was conducted on three types of hollow block masonry specimens built with stretcher blocks (HB1, HB2, and HB3) and five types of fully grouted block masonry specimens with bond beam blocks (G1B1, G2B1, G2B2, G2B3, and G3B3 series).

Bond beam block prisms are analogous to face-shell bedded prisms constructed with stretcher blocks, owing to the void in the mortar layer between the central block webs; related research conclusions can be cited in this context. In North America and Australia, face-shell mortar bedding is common practice due to its benefits of faster construction and reduced mortar consumption. Furthermore, Jia found that the strength improvement in prisms built with full bedding, compared to those with face-shell bedding, is statistically insignificant. However, Ganesan and Ramamurthy discouraged the use of face-shell bedding in hollow prisms based on finite element analysis, which revealed high lateral tensile stress concentrations in the webs . Furthermore, neither face-shell bedding nor bond beam blocks are specifically addressed in Chinese masonry design codes, test standards, or construction handbooks. Therefore, as bond beam hollow prisms are uncommon in practice and exhibit drawback mechanisms under compression, hollow prisms built with stretcher blocks were constructed for simplification in this study. However, their compressive strength values should be considered indicative when compared to grouted prisms, given the different failure conditions induced by grouting.

The typical dimensions of the test specimens are shown in Figure 2a; a height-to-thickness ratio of 5.0 was adopted to minimize its influence. Prisms constructed in a running bond pattern better represent wall behavior than stack-bonded prisms due to the presence of perpendicular joints in each course. A schematic diagram illustrating the constitution of fully grouted bond beam masonry walls, including potential horizontal and vertical reinforcement.

Three specimens were cast for each hollow block masonry prism combination. A total of 36 fully grouted prisms, encompassing five types,

were constructed. An average mortar joint thickness of 10 mm was maintained for all specimens. Grout was consolidated by a single pass of a 25 mm immersion vibrator in each cell and was not revibrated after initial settlement. All specimens were level-capped with gypsum plaster and cured for 28 days in the laboratory.

3.1.2 Testing Methodology

Uniaxial compressive strength tests on hollow and fully grouted prisms were conducted using a 10,000 kN capacity electro-hydraulic testing machine, capable of applying displacement with a measurement precision of 0.001 mm. Load was monitored by the machine with a measurement precision of 0.1 kN. The specimens were capped with two 25 mm thick steel plates at the top and bottom to ensure uniform distribution of axial stress during compression. To ensure full contact between the specimen and the bearing, a spherical bearing was bolted to the bottom platen of the machine. Test specimens were subjected to a constant displacement rate of 0.3 mm/min; displacement and corresponding load were recorded using an electronic data acquisition system.

In the first phase of testing, all three types of hollow prisms and 20 of the fully grouted prisms (across five types) were tested to failure at a uniform displacement rate, with each test lasting approximately 15 to 40 min. In the second phase, the remaining 16 fully grouted specimens (representing three types) were subjected to cyclic loading, with tests lasting from 50 to 120 min. Loading and unloading cycles were performed multiple times to analyze how the strength of the grouted prisms changed with different loading patterns. The general loading and unloading schemes, represented by load-displacement curves for monotonic and cyclic tests (with machine adjustments removed).

IV. TEST RESULTS

The concrete brick prisms exhibited a ductile failure mode characterized by brick crushing. Each specimen exhibited similar crack patterns regardless of the test variables. For the concrete brick masonry prisms, cracking initiated after the elastic deformation region, resulting in a vertical crack approximately $L/8$ away

from the brick edge.(a). Following the initial crack, a secondary.



FIG: 01



FIG: 02

Table 2: Compressive strength of Mortar

Specimen No		Compressive load (kN)	Compressive Strength (MPa)
Mortar ratio	Source A		
1:3	1	176	35.44
	2	182	36.51
	3	182	36.51

1:4.5	1	133	26.68
	2	129	25.87
	3	126	25.28
1:5	1	130	26.08
	2	125	25.07
	3	105	21.06
1:6	1	70	14.04
	2	80	16.05
	3	75	15.04
1:7	1	45	9.02
	2	45	8.64
	3	45	9.36

The average compressive strength of the mortar cubes of 1:3, 1:4.5, 1:5, 1:6 and 1:7 ratios was found to be 36.15 MPa, 25.94 Mpa, 24.07 MPa, 15.04 MPa and 9.02 MPa respectively.

Table 3: Compressive strength of concrete block masonry prisms

Specimen No		Compressive load (kN)	Compressive Strength (MPa)
Mortar ratio	Source A		
1:3	1	840	10.500
	2	875	10.938
	3	850	10.625
1:4.5	1	790	9.875
	2	735	9.187
	3	755	9.437
1:5	1	550	6.875
	2	545	6.812
	3	555	6.437
1:6	1	490	6.125
	2	480	6.000
	3	480	6.000
1:7	1	310	3.875
	2	290	3.625
	3	315	3.930

4.1 RELATIONSHIP BETWEEN MORTAR STRENGTH, BLOCK STRENGTH AND MASONRY STRENGTH

A relationship can be modelled through regression analysis or by developing empirical formulae for mortar strength, block strength, and masonry strength. In general, it is accepted that masonry compressive strength—often referred to as f_p is

dependent on both mortar and block strengths. Empirical studies indicated that the masonry strength, f_p , can be estimated using expressions that consider properties related to mortar, f_m , blocks, f_b and the interaction of them as follows:

$$f_p = a * f_b + b * f_m \quad (4.2)$$

Here a and b are the coefficient of block compressive strength and mortar compressive strength which is depends on factors such as block size, mortar joint thickness and construction techniques. Regression analysis involves several key terms that are essential to understand its application and interpretation In the context of regression analysis, goodness of fit or coefficient of determination or coefficient of multiple determination (R^2) refers to how well the regression model fits observed data points. It evaluates the degree to which the variation in the dependent variable is explained by the independent variables or predictors used. The value of R^2 ranges from 0 to 1. Here, 0 indicates that the model does not explain any of the variability in the dependant variable. 1 indicates that the model does explain all the variability in the dependant variable. A higher R^2 value indicates that the model is better fit to the data. In regression analysis, ANOVA (Analysis of Variance) is a statistical technique used to check the significance of the overall regression model and how much each independent variable contributes to the dependent variable as a predictor. The regression residual is just a difference between the observed values of a dependent variable and the values predicted based on a regression model. Residuals alone could indicate much about how well the regression model describes the data. Ideally, the magnitude of the residuals must be small, and the patterns must be random. Large residuals may be indicative of either some important relationship being omitted from the model or influential outliers existing in this data set.

V. CONCLUSIONS

An experimental investigation was conducted to evaluate the compressive strength characteristics of solid concrete block masonry prisms assembled using different mortar grades and block sources. A total of

45 prisms were tested under uniaxial compression after standard curing, generating a consistent and reliable experimental dataset.

The results demonstrate that masonry compressive strength is controlled by the combined mechanical properties of the blocks and mortar. While an increase in mortar strength contributes to higher prism strength, the extent of this contribution reduces once the mortar strength exceeds that of the masonry units. Failure modes observed in the tests confirm a shift from mortar-controlled behavior to block crushing with increasing mortar grade.

A regression-based predictive relationship was developed to estimate prism compressive strength as a function of block and mortar strengths. The strong correlation between predicted and experimental values confirms the adequacy of the proposed model for strength estimation. The model provides a rational framework that may be useful for analytical studies and numerical model calibration.

The findings address the limited experimental data available for solid concrete block masonry and offer insight into the role of constituent materials in governing compressive behavior. Further research is recommended to investigate time-dependent effects, durability, and cyclic loading conditions relevant to structural masonry applications.

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