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Interlocking Hollow Blocks Masonry System; Structural Modification, Characterization, and Performance: Review

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ABSTRACT

The interlocking hollow block masonry system is widely used in buildings; its full structural potential has not yet been realized. This is mainly due to the lack of information regarding the exact behavior of interlocking hollow block system under different loading conditions (vertical and lateral loads). From the constructional engineering perspective, interlocking hollow concrete block is classified as conventional mortared and non-conventional morterless hollow block system. This research included a review of literature relating to the structural behavior of masonry block walls. Various types of masonry shear walls, namely un-reinforced and un-grouted, partially grouted un-reinforced partially reinforced, fully reinforced and wide spaced reinforced are discussed. Critical design parameters including reinforcement, vertical compression, aspect ratio (shape of the walls) and material properties that affect the behavior of the shear walls are reviewed. Mechanical properties of masonry such as compressive strength, tensile strength and shear strength, and tensile crack opening energy are also discussed.

1. Introduction:

Masonry is typically constructed with no reinforcement in most parts of the world where earthquake and wind hazards are rare. Such masonry is regarded as Un-Reinforced Masonry (URM). Masonry is, whether it is conventional or interlocking mortarlass, a complex material consisting of an assemblage of solid or hollow blocks with or without mortar joints, grout and reinforced bars each with different material properties. The behavior is more complex because of the discontinuity of the units in mortarless masonry or by mortar joints acting as a plane of weakness due to their low tensile and shear bond strength in conventional masonry [1]. Hence a system was developed recently whose configurations are deliberately shaped in such a way that they can be laid without conventional mortar bedding [2].
The grouted hollow URM walls may be used to increase their vertical loa carrying capacity or to account for local concentrated loading (to avoid bearing failure). The grouted cores may contain reinforcement in cases where seismic or wind hazards are accounted in the design. Embedding vertical reinforcement bars in masonry walls enhance their capability to resist horizontal earthquake forces. Adequate cross-sectional area of these vertical bars prevents the bar from yielding in tension. Further, the vertical bars also help protect the wall from sliding as well

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as from collapsing in the weak direction [3].

2. Previous Works:

The behavior un-reinforced masonry walls are usually brittle with little or no ductility and both structural and non-structural parts suffer various types of damages ranging from invisible cracking to crushing and eventually disintegration. This behavior is due to the rapid degradation of stiffness, strength and energy dissipation capacity, which results from the brittle sudden damage of the masonry wall [4]. This clause of research included the several designs of Interlocking Hollow Blocks as conventional mortared and non-conventional mortarless hollow block system.

2.1 Interlocking Hollow Blocks Development

[5] reviewed varies innovation masonry systems that had been suggested in latest years as well as highlights various arrangements. In addition, each system presents special solution to the usual masonry to improve the ease and stability construction. The main feature of the interlocking hollow block masonry is the replacement of mortar layers commonly used in bonded masonry with interlocking keys (protrusions and grooves) [6]. Many interlocking hollow concrete block systems have been developed over the world to enhance the building to resist the lateral load and earthquake. Using grout inside masonry can reinforce with steel rod at the critical locations (corner, ends, near opening, etc). When the wall is reinforced vertically and horizontally, it will be more resistance for shear and earthquake and the buildings will be stronger. [7] developed interlocking blocks as shown in Figure 1, to construct a single-storey house.

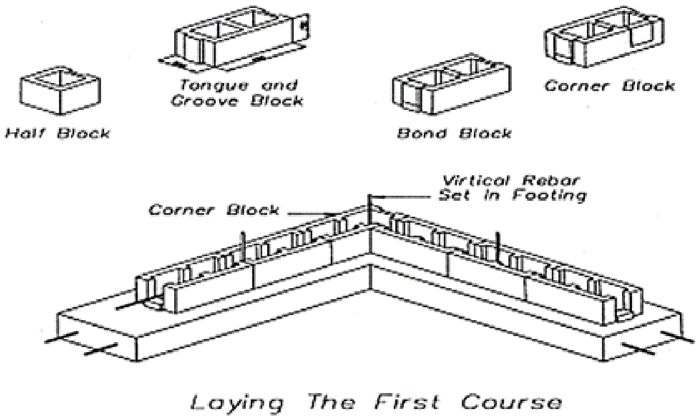

Figure 1 Interlocking Block Developed by Thallon

Interlockin hollow block system, for the construction of load bearing walls, three types of blocks are used and named Stretcher block, Corner block and Half Block [8] . The alignment in Haenar blocks is achieved by providing interlocking keys at the sides, while the interlocking between the blocks is ensured by providing a key (small projection) at the top of the blocks in addition to the inside inclined web at the bottom. The inside web acts as a support to the top key to interlock the blocks. In Peru, Mecano block system has been developed by [9] in which no interlocking is provided so that the blocks are simply stacked on each other. The blocks had accurate dimensions and smoothness. The shape of the blocks allows two-way hollow cores for introducing the reinforcement. For reinforced masonry construction, to be able to resist earthquake, two interlocking block systems were developed at Drexel University [10], which include a simple modified H-block and W-block interlocking system. Three different types are required to construct the walls; however, the vertical joints are made continuous along the height of the wall. [11] defined an analysis for mortarless block systems. His analysis illustrated in Figure 2 which includes the following:

1- The Azar Dry-Stack Block system was released in 1997. During stacking the blocks stability was provide in both vertical and horizontal joints. Two types of units (stretcher and corner) are formed by a core puller added to production line.

2- Three block units (a stretcher, a corner and a half) called Haener Block System.

3- IMSI stretcher system produces an insulated, reinforced wall. IMSI has two rows of cavities, the outer row is for insulation and running electrical weirs where needed, the inner row is for grouting.

4- The Sparlock system avoids the height problem altogether by placing block in a stack bond where each block rest exactly on the block below instead of overlapping two units. So if the blocks below are of different height it does not affect the wall’s plumbs or stability.

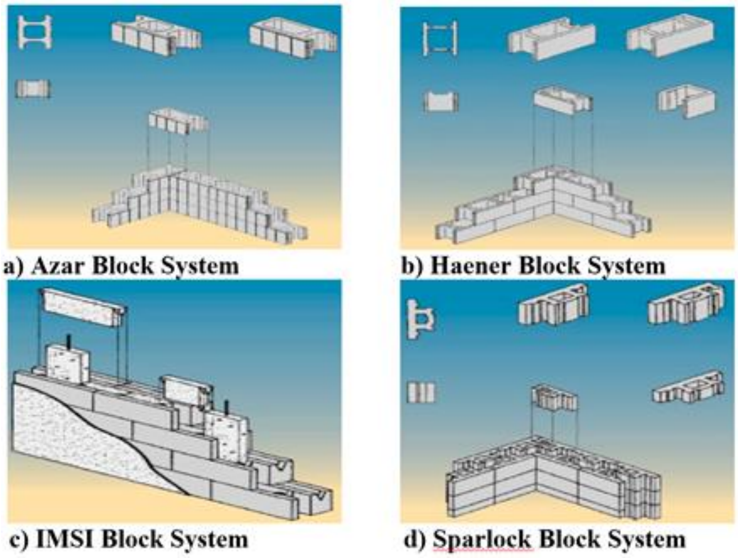

Figure 2 Different Interlocking Block System

The structural behavior of a new shape of interlocking block system developed at the Universiti Technologi Malaysia was investigated by [12]. The block chosen has two-core of voids. [13] outlined relative productivity assessment of conventional and interlocking block masonry with different construction methods. To measure the utilization of time by the members of the team, work sampling (adopting the 5 min rating technique) was used. The frequencies of occurrences of each work category, namely direct, indirect, and non-contributory, was established. Due to the variation in the non-contributory work component for different methods of construction, the net output was expressed as output per productive hour. Productivity enhancement of 80–120% was observed for dry-stacked masonry and 60–90% more for thin-jointed and mortar-bedded interlocking-block masonry than that of conventional masonry. The solid-interlocking-block and hollow interlocking block system was adopted and developed by the writers [14] as shown in Figure 3.

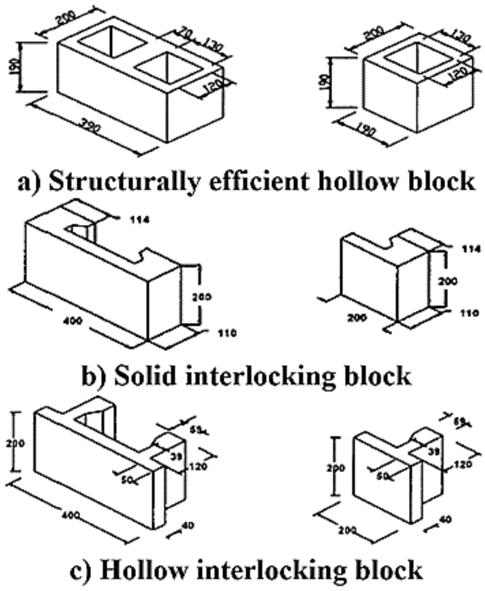

Figure 3 Dimensional Details of Masonry Units

Also, [15] mentioned that the current application of structural masonry in developed countries is marginal. For example, in Switzerland, the use of structural masonry increased significantly with the development of a new code of practice and full characterization of materials suitable for structural applications; in USA, reinforced and pre-stressed masonry are competitive solutions and in the Netherlands maxi-blocks with length of 1.0 m are produced aiming at building automation. The techniques and materials used to build masonry structures (load bearing masonry walls in the 20th century) show large variation from one country to another, even if some trend towards standardization has been observed in the last years. This heterogeneity is responsible for additional difficulties in the wide use of load bearing masonry walls. Ceramic brick is the mostly used material for the masonry units but concrete or calcium-silicate blocks are also common. Even for the same material, numerous shapes are available as shown in Figures 4 and 5.

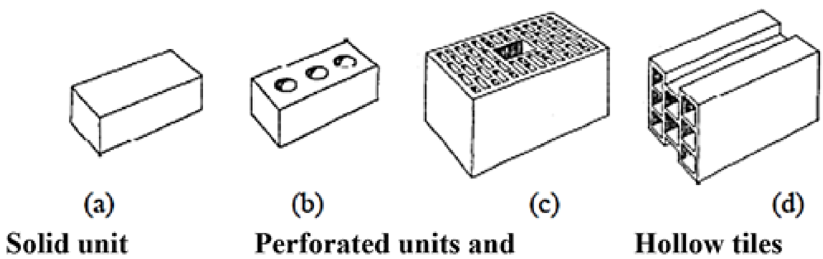

Figure 4 Schematic Representation of Ceramic Masonry Units

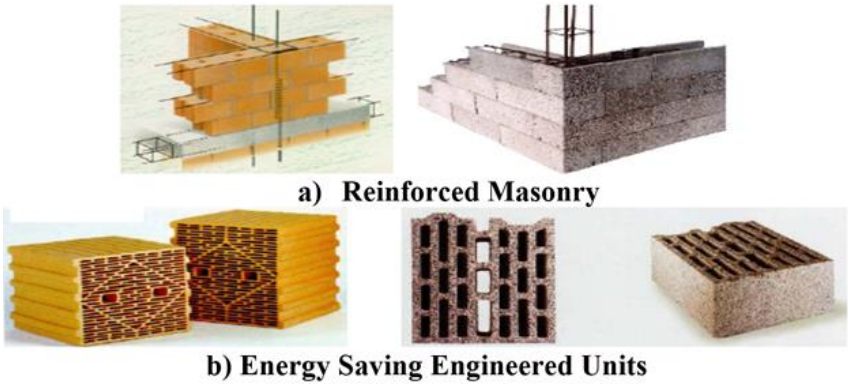

Figure 5 Some Aspects of Innovation

And, [16] developed blocks for earthquake resistance; two groups of Hollow Interlocking Compressed Stabilized Earth Blocks (HICSEB) group (245) and group (295), each one with different dimension can used with vertical and horizontal reinforcement. Figure 6 illustrated the blocks in detail.

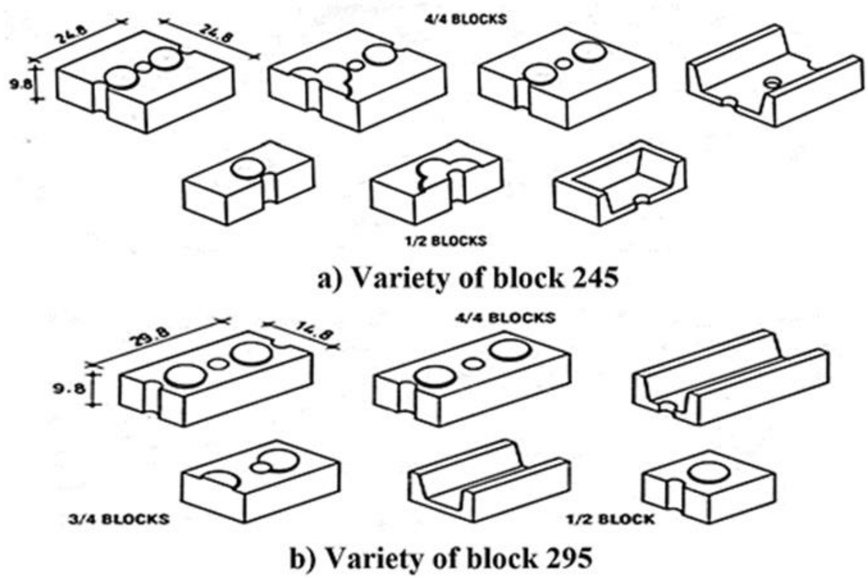

Figure 6 Auram Blocks for Earthquake Resistance

The hollow interlocking system (295) is only meant for single storey buildings and system (245) can be used safely up to two storey buildings only. The holes have been maximized (regarding the size of the block and the press design) at 5 cm diameter to allow a proper concrete cover for the steel. Also, a New type block in building engineering have been considered by [17] to study the mechanical properties which included the mortar strength, the concrete used in grouting holes, compression and shear strengths. Also failure mode were studied in concrete hollow blocks

2.2 Development of Interlocking Putra Hollow Block

Although, [18] developed another interlocking hollow block system (IHB) in Malaysia, as shown in Figure 7. Individual blocks and full-scale walls have been tested for different types of loading. The developed Interlocking Hollow Block (IHB) can be used for two-storey building with a good margin of safety.

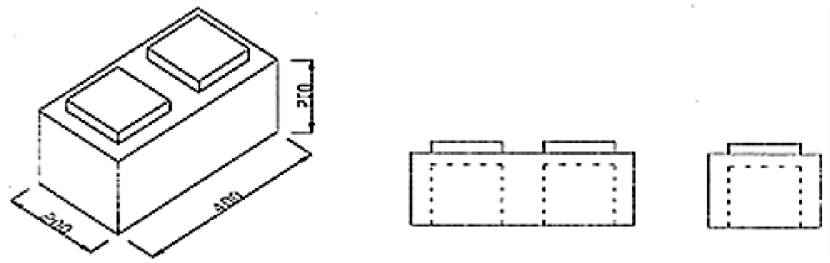

Figure 7 Interlocking Hollow Block System

Though, [19] studied the behavior of the interlocking block with different eccentricity of the applied load for un-reinforced dimension wall panel with 1200 mm width, 150 mm thickness and different height (1200, 1800, 2400 and 3000) mm. While, An interlocking block system according to the invention with different dimensions has been developed by [20] in Universiti Putra Malaysia called interlocking morterless load bearing building blocks. Three different configurations are provided namely; Stretcher, Corner and Half Block. The assembled blocks provide continuous hollow voids in the wall that allow the casting of reinforced concrete (grout) stiffeners in vertical and horizontal directions to enhance stability and integrity of the wall. Although, [21] studied different Interlocking Hollow Block models and described the development of new (IHB) masonry system appropriate for load bearing masonry wall construction. A number of block models have been configured along with their interlocking mechanism.

Behavior of interlocking hollow block panels with stiffener was investigated by [22]. The steel bars (10 mm in diameter) were used in the perimeter of the wall panel to increase the strength capacity of the panel. The comparison was done between the reinforced and un-reinforced wall panels to calculate the strength increase. Analytical models to simulate all aspects of behavior for interlocking Putra block system had been done by [2]. Interlocking action and grouted system had been conducted as well as nonlinear and failure mechanisms for interlocking Putra block were studied. Where, [23] tested full scale walls which were constructed by using Putra interlocking blocks. The tested specimens were divided in three groups as shown in Figure 8. Group “A” specimens are without any reinforced concrete (R.C.) stiffeners while, those in group B and C represent walls with different layouts of R.C. stiffeners. In group B the R.C. stiffeners are located at the perimeter of the wall, while the stiffeners in group C are located at the wall perimeter as well as at its mid height. These wall specimens were subjected to compression load at different eccentricities of 0, 20, 40, and 55 mm.

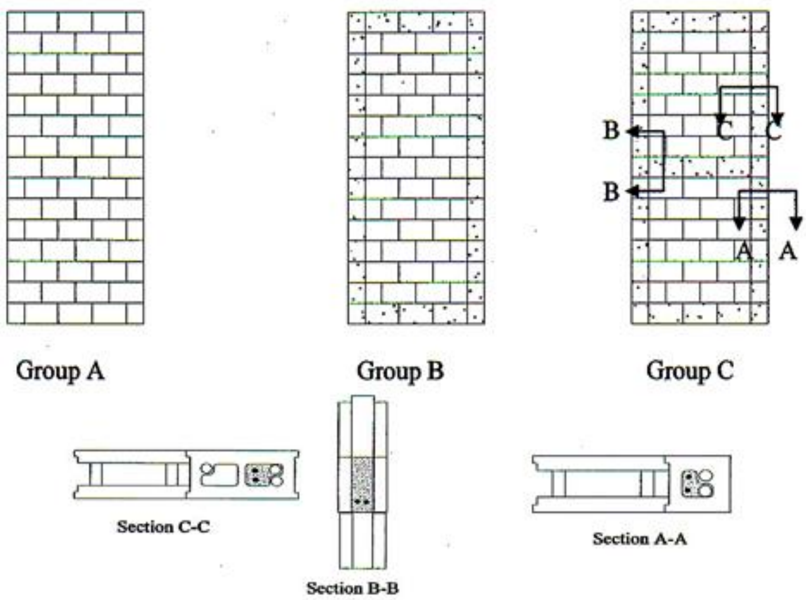

Figure 8 Details of Wall Panels with and without Stiffeners

The structural response of interlocking hollow block masonry wall with opening using Putra block under axial and eccentric vertical load were studied by [24]. The effects of stiffeners around the window opening on the structural behavior of the interlocking hollow block masonry system had been studied too. And, [25] reviewed the interlocking loadbearing hollow block (ILHB) system development. In Malaysia, PUTRA block system as interlocking loadbearing hollow block (ILHB) system has been identified and developed for construction industry. Numerous advantages for this system such as: environmentally friendly, strength, speed and cost in construction.

2.3 Reinforced Masonry System

Also, [26] investigated about the reinforced masonry system, which is a typical masonry wall structural system widely used throughout Latin America and South-east Asia for low and medium-rise houses and/or other kind of residential buildings. This system of construction is called "confined masonry walls" as shown in Figure 9. Cast-in-place, slender R/C columns are presented at most of the extreme edges and intersections of the masonry walls. In addition, cast-in-place R/C collar beams, wall girders or floor slabs usually are placed along the top of each masonry wall. In most cases, longitudinal re-bars and hoops are installed in the R/C columns before the masonry wall units are placed within the wall plane. After the brick or block masonry units are connected with mortar to a height of a half or one story, the concrete columns are cast, then the R/C collar beams, wall girders, or floor slabs are constructed using cast-in-place concrete after all the masonry walls and R/C cast-in-place columns have been completed. Four longitudinal re-bars are usually placed in each of the R/C column section.

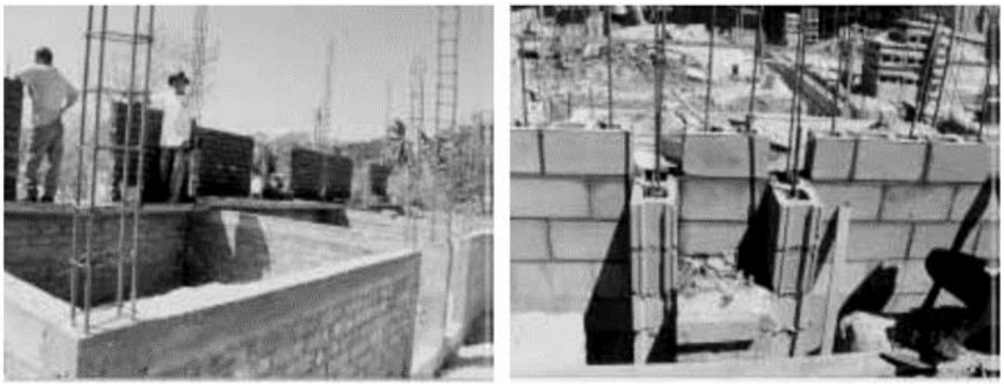

Figure 9 Reinforcing Details of a Masonry Wall in the Building

Study features of earthquake damage and technologies adopted for reconstruction of houses were done by [27]to develop appropriate seismic structures and construction practices, which will be expected to be accepted by communities, and to verify them by a series of joint experiments. Buildings should be reinforced by vertical bars embedded in masonry wall at the corners of all rooms and the side of the door openings. These vertical bars should be connected from foundation to roof band.

2.4 Applied Loads on Wall Panels

The contribution of masonry in-fills in resisting vertical and lateral forces has been studied by several researchers. Most have investigated the behavior of mortared and mortarless, reinforced or un-reinforced walls in-fills under in-plane vertical and lateral loading since this is the primary load resisting mechanism for horizontal forces [28].

2.4.1 Vertical Load

The behavior of face-shell bedded hollow concrete masonry subjected to in-plane concentrated loads was investigated by [29]. A total of 49 wallettes, some plain and others with one and two-course bond beams were constructed and subjected to either concentric or eccentric concentrated loads through various-sized loading plates. Standard hollow concrete units (400 mm x 200 mm x 200 mm) were constructed and a Type N mortar was used. Figure 10 shows the details of the bond beams and wallettes.

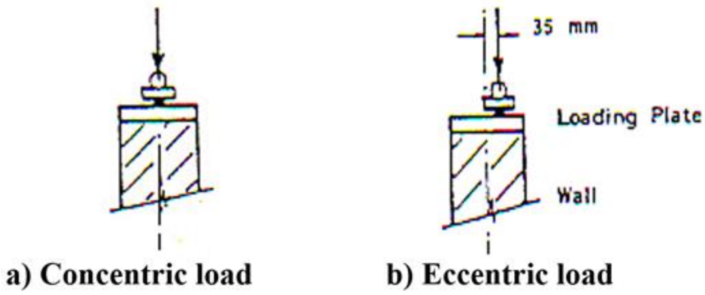

Figure 10 Loading Type

After tests have been done, all specimens with bond beams exhibited similar failure characteristics. The webs split first in the region directly beneath the concentrated load in the underside of the bond beam and in the first course immediately below. This web-splitting commenced at loads between 33% and

77% of the corresponding ultimate values, also a vertical crack formed normal to the plane of the wall in line with the load. With increasing load, web-splitting progressed along the top course of the hollow masonry and into the courses beneath until sufficient webs had split to cause collapse. For the bonded beam of a given size and type, the strength of the grout in the bond beam did not influence significantly the capacity of the masonry to resist a concentrated load, while the use of a bond beam increased the load resistance of the masonry because the load is partially dispersed by the beam before reaching the hollow masonry. While, [30] studied the behavior of hollow concrete masonry wallettes with bond beams and vertical columns of grout subjected to concentrated loads. Design rules were proposed for assessing the bearing strengths of hollow concrete masonry walls subjected to in-plane concentrated loads. All hollow concrete masonry was constructed using hollow concrete units (400 mm x 200 mm x 200 mm). All bond beams were reinforced with two numbers of 10 mm mild-steel deformed bars hooked at each end to ensure adequate anchorage. All vertical grout columns were reinforced with one of 10 mm rebar. The first wallette tests, was aimed at investigating the failure mechanisms and strengths of hollow concrete masonry walls with concentrated load applied on the bond beam above the hollow blocks as shown in Figure 11.

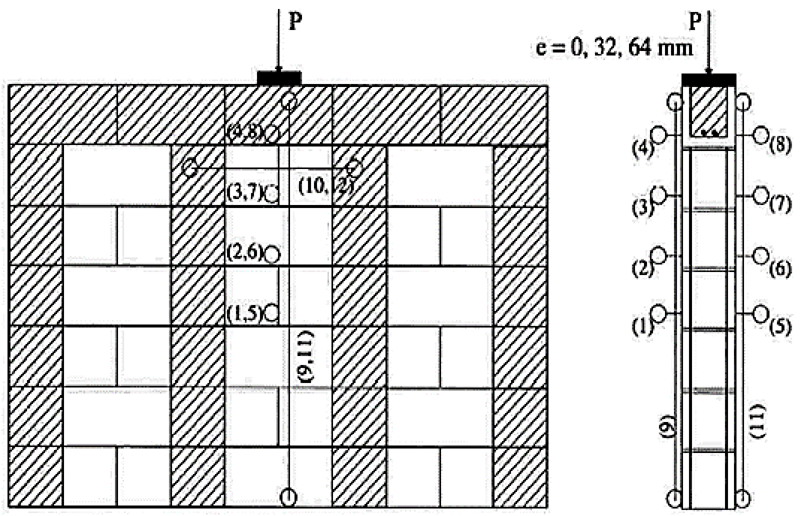

Figure 11 Linear Potentiometer Displacement

The second wallette was tested with the concentrated load being applied on the end columns of grout. The third wallette was tested with the concentrated load being applied in the middle columns of grout. For the first test under concentric loading, at about 55% of the ultimate strength, the webs splitted in the region directly beneath the concentrated load in the underside of the bond beam and in the hollow course immediately below. Furthermore a vertical crack formed normal to the plane of the wall in line with the load. In the final stages, the cracks in the webs became very large, producing buckling instability local to the loading plate. Also, The wall panels tested by [31] included three-unit wide, thirteen and fifteen courses high, which were considered large enough to be representative of the walls. The first 24th specimens were tested under concentrated axial load and 16 specimens under transverse load. In each type of the tests, the specimens were constructed in four groups having the cross-sections depending on the grouted and un-grouted cells with reinforced and without as shown in Figure 12.

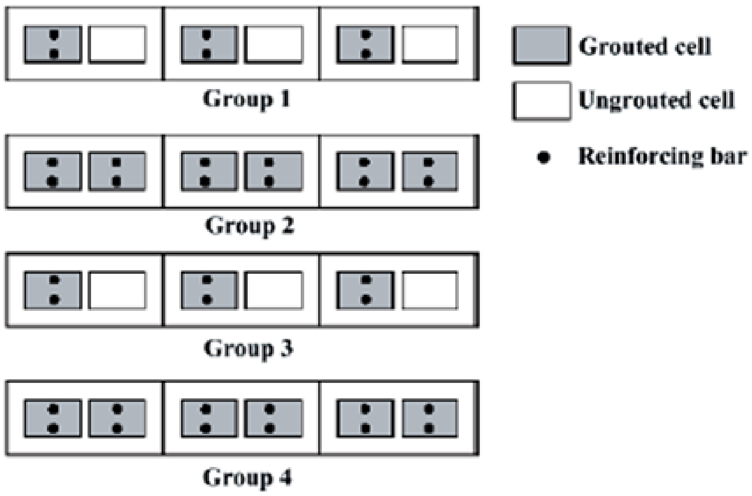

Figure 12 Cross-Section of the Wall Specimens

During the preloading, it was observed that cracks developed randomly in the test specimens due to the uneven surface of the masonry units. These cracks can be classified into two types. The first type is due to the load transfer caused by unequal friction that obstructs lateral deformation of the masonry units. The second type is due to flexural movements caused by the height tolerances of the masonry units in a course. Also, [31] found that the mortarless masonry wall specimens under concentric axial load showed large initial deformation soon after loading to about 35% of the compressive strength due to the uneven surfaces of the units. The relationship of concentric axial load and axial deformation was linear up to 65-80% of the ultimate axial load. Although, [32] did his research about ENDURA block system. There are five different block configurations in the ENDURA wall system: Stretcher, Right corner, Left corner, half stretcher, and Half Square. The variables between the walls included type of block, grout and reinforcement spacing, the use of a thin set mortar, and the vertical spacing of the bond beam. The significant conclusions from the testing performed were; firstly, the amount of grouted cells in the walls directly influences the overall strength of the wall. Secondly, the ultimate capacity of typical built ENDURA Walls was approximately the same as the ENDURA Walls built with the thin set mortar. Third, the walls reinforced with rebar placed in the center of the corner blocks appeared to have greater ultimate capacities than the walls with eccentrically placed rebar.

2.4.2 Lateral Load

To obtain biaxial stress-strain and failure data for masonry panels subjected to combine tension-compression loading, [33] tested seven masonry wall panels with 800 mm height by 1200 mm width. Masonry panels subjected to lateral tension and vertical compression were tested to determine the relationship between the compressive strength of reinforced masonry and the lateral strain. The results showed that for large lateral tensile strain, the compressive deterioration of masonry is nearly a linear relationship with respect to lateral tensile strain. Although, four concrete block masonry and two reinforced concrete walls were designed by [34] to simulate low-rise non-ductile walls built decades ago, before the application of one wall from each pair was retrofitted using a steel strip system consisting of diagonal and vertical strips that were attached using through-thickness bolts. Stiff steel angles and anchor bolts were used to connect the steel strips to the foundation and the top loading beam. All the walls were tested under combined constant gravity load and incrementally increasing in-plane lateral deformation reversals. The lightly reinforced concrete walls were also repaired using only vertical strips and retested. The four concrete block wall specimens were prepared using standard blocks of 200 mm nominal size. Each wall consisted of a total of nine courses, providing a nominal height of 1800 mm.

The experimental study conducted for the steel strip system, proposed to retrofit low-rise masonry and concrete walls, is effective in significantly increasing their in-plane strength, ductility, and energy dissipation capacity. For the particular specimens considered, addition of steel strips increased the lateral load resistance of each wall by approximately 300 kN. The details and connections used to ensure continuity between the steel strip system and the foundation and top beam also enhanced the sliding friction resistance.

And, [35] carried out large scale tests on masonry wall panels made of perforated bricks. The specimens were subjected to in-plane lateral loading combined with different levels of axial compression; concentrated compressive load applied to the wall top at different distance from the wall edge. Shear tests were performed on six wall panels that were produced of the masonry with the chain bond. Displacements were measured only at one level (at a height of 1450 mm from the wall bottom). Besides, the test showed that specimen collapsed after immediately a zigzag crack has appeared. Relationships between shear strength and deformability of masonry and compressive stresses perpendicular to the shear plane were also formulated. The relations between the height of the walls and lateral displacements, loads versus lateral displacements and strains were illustrated in Figure 13 (a and b).

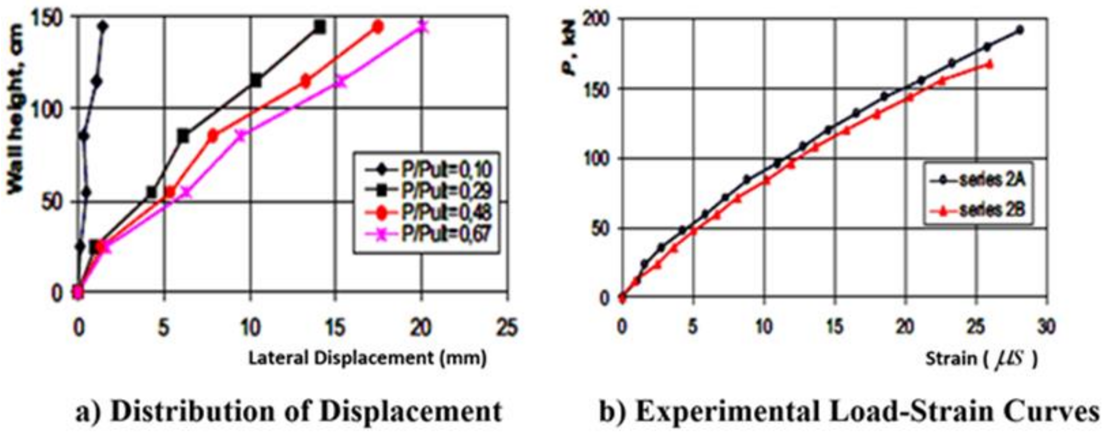

Figure 13 (a and b). Relations between Height vs Lateral Displacements and Loads vs Strains

Besides, [36] presented the results of experimental research on the structural behavior of dry joint masonry. The most relevant experimental results concern the strength response of stone dry joint masonry walls subjected to in-plane combined compressive and shear loading. Seven dry stone masonry shear walls were built and successfully tested. The tests subjected to combine vertical and horizontal loading as illustrated in Figure

14. The failure modes were observed in a diagonal direction.

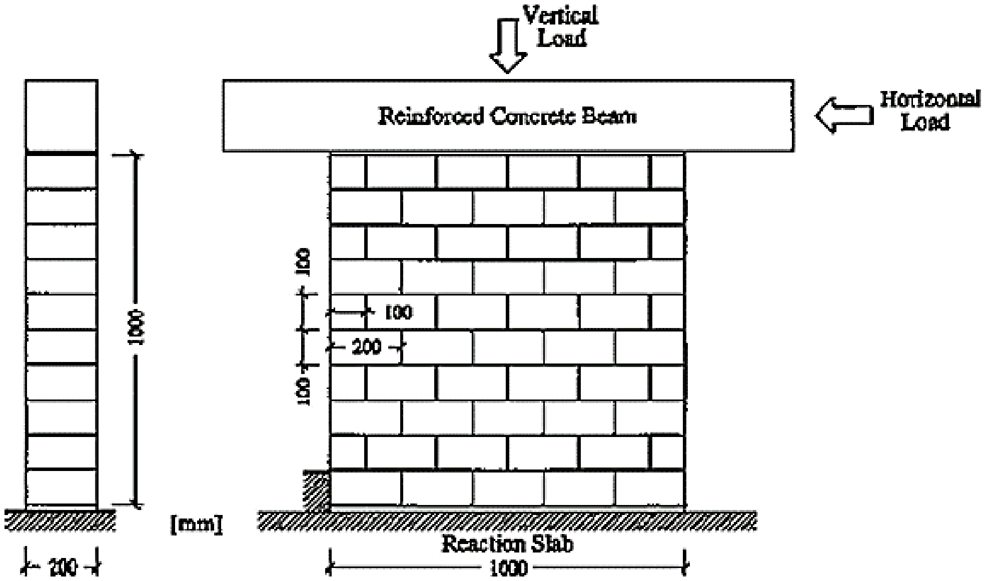

Figure 14. Wall Panel Set-up

In addition, [37], their investigations included U-shaped units where the blocks were laid after the vertical reinforcement was placed into hole. The hole is filled with concrete either as the construction proceeds or after the whole storey is completed. Since there is no channel formed to accommodate reinforcement on the upper side of the unit, horizontal steel is placed in the bed joints. The walls were tested as vertical cantilevers. The rapid resistance degradation and deterioration was also results of local brittle failure of units. The experimental investigations indicated that the robustness is an important property of hollow clay masonry units, which determines the behavior of masonry structures when subjected to seismic loads. The robustness of units is even more important in the case of hollow unit reinforced masonry, where sufficient anchorage and bond, as well as strength of the units should be provided to utilize the tension capacity of reinforcing steel. In addition, [38] simulated the shear wall tests; the specimens had a width/height ratio of 0.99. The deformation behavior of the tested walls was characterized by an initial horizontal tension crack that grew along the bottom and top of the wall. For all the tested walls, a diagonal stepped shear crack developed which under increasing deformation led to collapse of the wall. There were also some vertical cracks in the brick units and crushing at the compressed toe of the wall. Although, [39] compared different models to calculate the shear strength of un-reinforced masonry walls retrofitted using fiber reinforced polymers (FRP). The models were used to calculate the shear strengths of six URM-FRP walls. The specimens were subjected to either synthetic earthquake motions on an earthquake simulator or static cyclic loading. Each specimen was retrofitted on the entire surface of a single side using FRP with different axial rigidities. In the other hand, [40] studied the behavior of un-reinforced masonry walls retrofitted with composite laminates. One-third scale, structural steel frames in filled with un-retrofitted and retrofitted hollow block masonry walls were tested under displacement controlled diagonal loading to evaluate the behavior of the composite frame–wall system. From the test results, the laminates significantly increased the load-carrying capacity of the masonry assemblages exhibiting shear failures along the mortar joints (joint shear and diagonal tension).

An experimental research program was done by [41] to ascertain the compressive and shear strength enhancement of masonry wall panels using steel strips. The study includes eight wall panels, four each for compressive and shear strength evaluation. In each group of the four walls, one wall was un-strengthened, the second was single sided coarse steel mesh, the third was double sided coarse steel mesh and the fourth one was single sided fine steel mesh with closely spaced horizontal strips. During compression testing only vertical load was applied. For shear strength determination, lateral load with vertical pre-compression was applied. The results demonstrated that a significant increase in compressive and shear strength can be achieved by anchoring steel strips to the surface of masonry walls. The failure mode of cracks was in diagonal direction, in addition to the crushing due to applied load. The compressive strength was increased up to 12 to 26 percent due to strengthening of masonry wall panel with steel strips. Moreover the shear strength was increased up to 30% to 87% due to strengthening of masonry wall panel with steel strips, possessing more ductility. The easy external application and effectiveness against lateral/gravity loads is the added advantage of the technique. In addition, the technique was found effective for old buildings requiring strengthening and can be used in seismic zones after establishing the performance of strengthened masonry wall panel under dynamic and earthquake loading. Whereas, to improve the seismic performance of block masonry wall, a simple and economical structure named as the composite block masonry wall was proposed in China by [42]. Composite block masonry wall consisted of block masonry wall surrounded and confined by reinforced concrete beams and columns with shear keys. Horizontal reinforcements were provided in horizontal mortar joints in the alternate layer up to 800 mm from the inner side of both columns. The constant vertical load to simulate the dead load was applied to the specimen by the three vertical hydraulic jacks. The simulated earthquake load was applied by the horizontal hydraulic jack. From the experimental studies, the failure mechanism and the applicability of the composite masonry structures were examined. It can be said that this type of structures are good enough to be used in seismic zones.

And, [43] investigated the lateral load resistant capacity and deformation capacity of masonry walls. Vertical load through the jacks was first applied up to the designed value at the beginning of the test, and then was kept as constant load during the test. The specimen was subjected to static cyclic loading; load-time curve of sine function was used. The loading test was continued until severe cracks occurred in the masonry wall and was terminated when the specimen was about to collapse. Likewise, [44] presented in his research a study of the lateral capacity of the reinforced concrete houses constructed in Puerto Rico. Six full scale specimens were constructed and experimentally investigated in order to establish the lateral behavior and find the different failure modes of the house's components. In these specimens the behavior of various parameters were investigated, among them were wall-slab frame behavior, in-filled frame behavior, un-reinforced and reinforced solid masonry panels, and un-reinforced and reinforced perforated panel. Figure 15 (a and b); illustrate the construction's details for the wall panels.

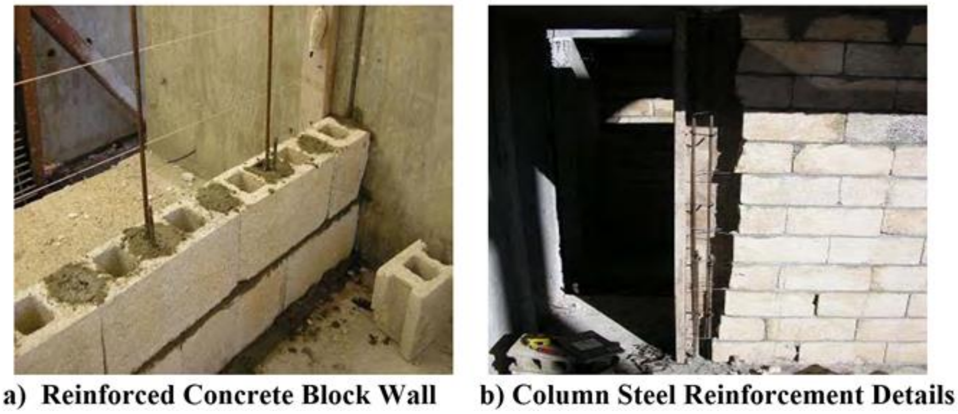

Figure 15 (a and b). Different Construction Categories and Failure Modes

The results demonstrated that the lateral resistances of the specimens were governed by different failure modes; among them are: masonry corner crushing, toe crushing and shear failure of the piers. The lateral capacity and the energy dissipation of the specimens increased significantly when partition wall was included inside the frame. In addition, the behavior of wide spaced reinforced masonry (WSRM) walls subjected to in-plane horizontal forces in the presence of low to high vertical stress has been investigated by [45]. From the experiments, it has been found that the average experimental values of the normalized horizontal load for the WSRM walls at the peak and the ultimate load stages was 34% higher than that for the non-WSRM walls. Regardless of the spacing of the vertical reinforcement, all walls cracked along the loaded diagonal. With the increase in the horizontal displacement, crack width increased for almost the whole length of the diagonal crack. Where, [46] investigated the response of Lateral load for un-reinforced masonry walls. The aim was to better understanding for the behavior of masonry walls using low quality local bricks. A comprehensive experimental program was undertaken with masonry wall elements of 600 mm x 600 mm x 110 mm constructed from local bricks from Cikarang in West Java – Indonesia [47]. Wall specimens were constructed and tested under a combination of constant vertical compression load and increasing horizontal or lateral in-plane loads. Using the results from the experimental program, a simplified model for the equivalent diagonal spring stiffness of local clay brick walls was developed. This stiffness model derived from experimental results in then used to simplify the structural analysis of clay brick wall panels in Indonesia. Although, [48] compared the experimental with analytical limitations from different observed models to assess their efficiency. Based on these results, applications were considered for general analytical model of Confined Masonry (CM) walls that can be used for lateral load analysis and design.

Finally, most of the previous research works have been done according to B.S code [49] and/or ASTM code [50] based on the tests requirements and its classifications.

3. Summary and Conclusions

This research has presented and summarized the experimental research's work to review the behavior of masonry wall panels with and without stiffeners, and conducted in the area of in-filled frames. The effect of masonry in-filled walls in changing the stiffness, ultimate capacity, ductility as well as the failure mode of framed structures, so that, it has been one of the most interesting research topics in the last five decades. Theory of shear walls and analysis of stresses in critical areas of the shear, failure mechanisms of the shear walls under lateral in-plane loading in the presence of axial compression and failure modes of the un-reinforced masonry have been reviewed. In addition, development of interlocking hollow blocks and use of stiffeners to increase the strength capacity of the wall panels to resist wind and seismic forces were also discussed. Material properties of masonry such as the compressive strength, shear and tensile strengths have been reviewed to help with understanding the behavior of the stiffened walls. Brittle modes of failure in the masonry such as diagonal tension failure, bed joint slip, premature crushing at the toe of the wall, or loss of anchorage of reinforcement must be prevented. Under the combined effects of vertical and lateral loads, the strength and deformation characteristics primarily depend on the wall geometry, level of axial load, and the amount and distribution of vertical and horizontal steel.

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