Sustainable Housing Using an Innovative Interlocking Block Building System

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Abstract

With the increase in material costs in the construction industry, there is a need to find more cost saving alternatives so as to maintain the cost of constructing houses at prices affordable to clients. The use of the mortarless load bearing interlocking block building system has not yet become popular in Malaysia even though this system has been used in other countries. Universiti Teknologi Malaysia in collaboration with industry partner, CCA Systems Sdn Bhd, has developed a building system which incorporates the interlocking block as its main feature, which consists of three different block types for the frame and wall system. The formulated system integrates the production of construction elements with building construction at the site that results in cheaper building costs due to faster completion time, less skilled workers and less wastages. Sustainability can be achieved by using rice husk ash (RHA) as cement replacement and the use of Palm Oil Fly Ash (POFA) and recycled concrete and aggregate related construction waste as aggregates.

This paper describes the development of block production, the design of house using load bearing block and the construction of a pilot house using the load bearing interlocking block system.

Keywords: load bearing interlocking block, mortarless building system, cement replacement, recycled materials, cheaper building cost, faster completion time, pilot house, IBS.

1.0 Introduction

The demand of houses for low to medium income population of Malaysia has exceeded more than 37,000 units nationwide. The government has assigned the Syarikat Perumahan Nasional Berhad (SPNB) to develop these houses[1]. With the increase of construction materials costs such as cement, steel and timber, contractors are not enthusiastic to build these houses on a tight budget.

Alternatives through using the industrialised building systems (IBS) has to be sought and the government has been pressing the construction industry to use IBS for their projects. Projects using the IBS will be completed faster hence reducing construction completion time and cut the cost of manpower to more than half. Incentives for IBS usage is also given by the Malaysian government.
Based on structural aspects, IBS can be divided into five major types [2]:

- Type 1: Pre-cast Concrete Framing, Panel and Box Systems
- Type 2: Steel Formwork Systems
- Type 3: Steel Framing Systems
- Type 4: Prefabricated Timber Framing Systems
- Type 5: Block work Systems

The first four types of the IBS are for big-time players where the initial cost of entry is very high. Type 5 would be suitable for all contractors including the class F group.

The construction method of using conventional bricks has been revolutionised by the development and usage of interlocking concrete masonry units (CMU) and lightweight concrete blocks. The tedious and time-consuming traditional brick-laying tasks are greatly simplified by the usage of these effective alternative solutions [3][4].

Sustainability practices can enhance the cost reduction in construction. The following sustainability practices can be achieved such as by using rice husk ash (RHA) as cement replacement and the use of Palm Oil Fly Ash (POFA) and recycled construction waste as aggregates.

### 2.0 Interlocking block technique

The block's sizes are modular and rectangular (100 mm high, 125mm to 150 mm wide and 300 mm long) in shape. Its dimensions permit multi-dimensional walls making configuration such as buttresses, lintels or columns possible. Corner or junction block is required to maintain right angled corner or a proper T junction.

The interlocking blocks are different from conventional bricks since they do not require mortar to be laid during bricklaying work. Because of this characteristic, the process of building walls is faster and requires less skilled labour as the blocks are laid dry and lock into place.

Concrete blocks may be produced with hollow centres to reduce weight, avoid seepages or improve insulation. The holes inside the concrete block allow rebar and concreting (creating reinforced concrete) to run vertically through the block to compensate for the lack of tensile strength. Rebar used can be of mild steel instead of the usual higher grade steel. Once a section of wall is built, grout holes are filled with a lean cement mixture to seal the wall and making a permanent solid wall. The amount of grout used was calculated to be less than 7.5% of the mortar used in conventional masonry.
The concept of interlocking blocks is based on the following principles:

- The blocks were shaped with protuding parts, which fit exactly into recess parts in the blocks placed above, such that they are automatically aligned horizontally and vertically - thus bricklaying is possible without specialised bricklaying skills.
- Since the blocks can be laid dry, no mortar is required and a considerable amount of cement is saved.
- Each block has vertical holes, which serve four purposes:
  1. to reduce the weight of the block,
  2. to insert steel rods or treated kenaf bar for reinforcement,
  3. to act as conduit for electrical and water piping,
  4. to pour liquid mortar (grout) into the holes, which run through the full height of the wall, thus increasing its stability and providing barrier to seepages.
- The length of each block is exactly double its width, in order to achieve accurate alignment of blocks placed at right angles, else, a junction block is required.

2.1 Shapes and sizes of interlocking blocks

A variety of interlocking blocks have been developed during the past years, differing in shape and size, depending on the required
strengths and uses. The system developed has the following shapes and forms:
- Full blocks (300x 125 - 150x 100 mm) for all standard walls (single or double block thick)
- Half blocks (150 x 125 - 150 x 100 mm), which can be moulded to size, or made by cutting freshly moulded full blocks in half.
- Channel blocks, same sizes as full and half blocks, but with a channel along the long axis, into which reinforcing steel and concrete can be placed to form lintels or ring beams.
- The vertical sides of the blocks can be flat or have recesses, and the vertical grout holes can be square or round.
- Inserts for electrical switch housing and conduit as well as water piping outlet can be incorporated.
- Special blocks for window sills.

2.2 Production of interlocking blocks

Interlocking blocks were produced in special moulds, in which compaction is done mechanically, depending on the type of block, material used, required quality and available resources. The blocks can be made directly at the building site, or on a larger scale in a production yard.

Concrete blocks are the common manufactured interlocking load bearing blocks that require high compression strength. After opening the lid and ejecting the block, it was removed and flipped before stacking in a shaded place for curing and hardening. Moist conditions is to ensure uniform curing and hardening.

Soil-cement or soil-lime blocks [5] are also manufactured using machines of lower compacting force. Soil-cement blocks have strengths lower than 4N/mm² and hence are used as normal bricks.

Rice husk ash and concrete blocks need proper compaction. Higher compaction and greater strengths are achieved by feeding in a vibrating feeder which vibrates the mould. After demoulding, the blocks are carried away on pallets for curing.

A typical compressive strength of concrete blocks are 7N/mm²

Figure 3 Hydraulic powered block press for making interlocking (a) soil-cement blocks and (b) concrete blocks
3.0 Building Design and Construction

3.1 Construction Concepts using Load bearing blocks

The cavity holes of the interlocking blocks permit the introduction of vertical reinforcement embedded in concrete without the need for any form work thus eliminating the use of wood in form work. Reinforcement can be introduced to make the building withstand earthquakes and heavy wind loads. A single brick wall can be used for double storey construction load bearing walls. There are 33.3 bricks per square meter of walls. Because of the size and resistance of the bricks, load bearing walls can be constructed.

Before placing the first course in a mortar bed, the blocks must be laid dry on the foundation around the entire building, in order to ensure that they fit exactly next to each other (leaving no gaps), and that an exact number of full blocks are used, otherwise the system will not function. When laying the first course in the mortar bed, care must be taken that the blocks are perfectly horizontal, and in a straight line, or at right angles at corners.

Once the base course is properly hardened, the blocks are stacked dry, with the help of a wooden or rubber hammer to knock the blocks gently into place. Up to 10 layers can be placed at a time, before the grout holes are filled with a liquid mortar - 1 part cement to 3 parts sand (or soil or rice husk ash) to 1 part water.

Interlocking blocks are ideally suited for load-bearing wall constructions, even for two or more storey buildings, provided that the height of the wall does not exceed 20 times its thickness, and wall sections without buttresses or cross walls do not exceed 4.5 m length (to prevent buckling).

Though less economic, non-load bearing constructions are more common. The walls are constructed in the same way as load-bearing walls, but merely serve as infills between the reinforced concrete frame (post and beam) structure, which supports the roof. Care must be taken to achieve a good bond between the walls and frame-work.

![Image of the bungalow at Tanjung Putus, almost completed using construction with load bearing interlocking concrete block walls](image)

Figure 4: The bungalow at Tanjung Putus, almost completed using construction with load bearing interlocking concrete block walls

3.2 Building design using load bearing blocks

Almost any type of building can be constructed with interlocking blocks, the main design constraints being that the plan should be rectangular and all wall dimensions and openings must be multiples of the width of the block type used. All other principles of design and construction, such
as dimensioning of foundations, protection against rain and ground moisture, construction of ceilings and roofs, and the like, are the same as for other standard building types.

It is advisable to place channel blocks around the building, at window sill height, to install a ring beam. They should also be placed directly above doors and windows to install lintels, and directly below the roof to finish the walls with a ring beam. To increase structural stability, especially in earthquake regions, steel rods or treated kenaf should be inserted in the vertical grout holes, especially at corners, wall junctions and on either sides of openings.

3.3 Pilot house construction using load bearing interlocking block system

The first completed bungalow house was constructed in FELDA Laka, Kedah in 2008 in 40 days for a built up area of 1571 sq ft.

Initially the foundation, ground beam and ground slab is laid with the appropriate vertical steel implanted as shown in Figure 6a. It takes normally a week for the foundation to set then the first layer of interlocking load bearing blocks is arranged to ensure that the wall is straight and right angle at corner as shown in Figure 6b.

After that the crew of six workers can independently stack up the blocks to the required height.

Horizontal bars are placed for the construction of ring beam around the house for added stiffness as shown in Figure 7a.

![Figure 5 Principles of interlocking load bearing block construction](image-url)
Figure 6  Typical construction site of an interlocking load bearing concrete block house

(a) Foundation slab    (b) First layer of blocks

Figure 7 Typical construction of ring beams

(a) Below window level    (b) roof ring beams

Figure 8 Final touches and the complete house
Similar process of arranging the block was done up to the roof beam where another two layers of channel blocks was used to simulate the roof ring beam as shown in Figure 7b.

This process takes two weeks to complete, then the roofing, plumbing, electrical, sanitary and finishing will take another two to three weeks as shown in Figure 8.

The construction time taken to complete the first bungalow was 40 days. As the workers gained more experience building more houses, the construction time can be reduced further with permitting weather.

4.0 Sustainability practices for blocks production

Different materials can be used in the production of blocks to reduce the cost of construction and the recycling or reuse of construction wastes. Alternative in using various soil types are tested to replace aggregate in block production for the non load bearing section of the construction of the house.

- Concrete blocks: A typical mix of cement-sand-gravel with ratio that usually lies between 1:2:6 and 1:3:5, by weight is used. Quarry dusts [6] can be used to replace gravel. The compressive strength of 7 N/mm² can be achieved depending on the compaction pressure used during blocks production and technique of block curing.

- Soil-cement blocks: Depending on the soil types [7] and cement qualities, the cement-to-soil ratio usually lies between 1: 6 and 1: 10, by weight. (Laboratory tests are essential).

- Rice husk ash (RHA) cement blocks
  The cement-to-RHA ratio is generally 1: 4, by volume. Two types of blocks can be produced: white blocks, with a compressive strength of 4 N/mm², using ash containing amorphous silica, taken from field kilns, operating below 900°C; black blocks, with a compressive strength of 1.4 N/mm², using ash containing crystalline silica, from boilers operating up to 1200°C;

5.0 Conclusion

The following conclusions can be derived from the project:-

- The materials required for block production and building construction are usually locally available in most regions; therefore, in areas in which timber is expensive, construction with interlocking blocks has environmental advantages (no deforestation, low energy requirement for block production and transportation).

- Compared with conventional masonry, the dry assembly of interlocking blocks saves construction time and a large amount of mortar, which would otherwise be required for the horizontal and vertical joints.

- Without the need of high-waged skilled masons (except for the base course), by saving cement (less mortar) and with the speed of construction, the building costs are lower than for standard masonry construction.

- Additional cost reduction is achieved by building load bearing walls since there is no timber formwork required.

- The structural stability and durability of interlocking block constructions can be far
greater than for comparable timber constructions. Grout holes and channel blocks provide means to insert steel reinforcements in vulnerable parts of buildings for increased wind and earthquake resistance.

- Interlocking blocks can be produced on a small scale on the building site (for self-sustained construction), or on a large scale in centralised production units.

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