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# Structural performance of reinforced interlocking blocks column

Yeong Huei Lee [a], Poi Ngian Shek [b], Shahrin Mohammad [a,*]

[a] Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia
[b] Construction Research Centre (CRC-UTM), Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia

## HIGHLIGHTS

- Interlocking block columns are tested under axial load.
- The fresh and harden properties of infills have been recorded.
- Analysis showed infills have significant correlation with column strength.
- A reduction factor is proposed while adopting current code design specifications.

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## ABSTRACT

Interlocking blocks have been actively applied into current wall systems in the construction industry and limited references can be found on the axial loaded compressed column. Therefore, in this research, interlocking blocks have been innovatively assembled as columns for developing a new system that can replace the conventional concrete construction to block construction, without concrete beams and columns. These interlocking block columns are tested in the laboratory in order to investigate their structural performance under axial load. The fresh and harden properties of infills have been recorded. As the compressive strength of infill materials increased, the initial stiffness and strength showed a significant growth. An incrementing trend was also noted when increasing the reinforcement bar size. Pearson and partial correlation analysis showed infills have significant correlation with column compressive capacity. Comparison has been conducted between experimental results, Eurocode reinforced concrete and Masonry Standards Joint Committee (MSJC) design specifications. The differences were ranged from 0.65 to 1.85. Parametric study with variables of infills and reinforcement bar was carried out by adopting the Eurocode design to interlocking block columns and introducing a 0.8 reduction factor. Design recommendations have been made where the strength of infills should limit to 50 MPa and reinforcement bar size should not greater than 30 mm. As the dimension in assembling the column, further reduction on slenderness can be ignored.



## 1. Introduction

The demand for residential houses has increased drastically to accommodate the rising population in developing countries. Since the 1980s, the method of interlocking blocks was introduced as an alternative to conventional masonry bricks in wall panels for low-rise buildings. This new invention does not require any formwork to maintain the structure during the concreting process. By using interlocking blocks, block-laying work is made possible without the use of any mortar layers to hold the blocks together, since these blocks are designed with an interlocking mechanism that enable the blocks to be laid firmly on top of each other. In contrast to masonry structures, there is no mortar joint at the bedding area between the units for this system [1]. The mortarless block system requires less skill and reduces construction time during installation [2]. There are a few systems using this approach such as the Azar dry-stack block system, Haener block system, IMSI block system, Sparlock system, Durisol block system and Faswell block system [2,3]. Interlocking blocks is one of the innovative products resulting from the mortarless block system. Table 1 shows the benefits gained from the interlocking block construction as compared to reinforced concrete system [4].

Beam flexural behaviour has been studied with the interlocking block system [5]. The flexural strength for interlocking beams that were assembled using grout as filler was higher than the one using the mortar. Patel, et al. [6] has conducted a compression strength

* Corresponding author.
*E-mail addresses:* yhlee@civil.my (Y.H. Lee), shekpoingian@utm.my (P.N. Shek), shahrin@utm.my (S. Mohammad).

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**Table 1**
Benefits from interlocking construction as compared to reinforced concrete system.

| Attribute | Reinforced concrete (RC) | Interlocking block system |
|---|---|---|
| Speed | Curing time required and highly depend on the local weather | 30–40% faster than RC |
| Formwork | Timber or steel formwork is required | Minimum formwork required where eliminate 50–75% beam and column formworks |
| Worker | Skilled workers for plastering works, carpenters and bar-benders | Reduce skilled workers |
| Cost | Cost highly depend on skilled workers | Cost can be reduced from formwork, skilled workers and construction time |
| Waste | Timber waste from formwork | Less waste than RC construction |
| Quality | Quality highly depends on workmanship | Blocks are quality controlled by factory manufacturing |

test to determine the compression strength of a masonry wall with interlocking blocks and a conventional masonry wall. Two dial gauges were clamped at the frame to measure deformation of both specimens at an interval of 5 units of compression load. It was proven that the masonry wall with interlocking blocks demonstrated higher compressive strength than a conventional masonry wall. A mortar-free column made of coconut-fibre reinforced interlocking blocks was tested under harmonic and earthquake loadings to understand the structural seismic behaviour [7]. The investigated parameters included top relative displacement, base shear, overturning moment and block uplift. It is believed that mortar-free construction can reduce the dynamic load by earthquake due to the relative movement of the interlocking blocks [7].

For compressive structures, interlocking blocks as a wall system has drawn the attention of current research trends. The wall slenderness and bonding of interlocking blocks determine the strength of the designed wall. Previous studies on interlocking block systems [8,9] provided suggestions which were applied to this masonry construction for low rise buildings. Jaafar et al. [10,11] tested interlocking mortarless hollow-block panels under compressive loads. They found that it can be considered as a load-bearing wall since it can withstand loads, same as the conventional mortared system. Depicting similar behaviour to the wall system, the column should be given an attracting point assembled by the interlocking block system.

Columns with homogenous and elastic material that comply with Hooke's law are categorised as short, intermediate and long, distinctions from the failure-mode consideration. Short column fail at the yielding of materials; intermediate columns initiate the yielding of material in some portion of the cross section, followed by buckling; and long column fails with pure buckling. The end conditions of the columns provided evidence for effective height on structural prediction. In column design, referring BS EN1996-1-1 [12] and BS EN1992-1-1 [13], summation of all material properties with partial safety factor is required for design axial load as shown in Eq. (1).

$$N_{Rd} = \sum \frac{k_i}{\gamma_i} \times f_i A_i \tag{1}$$

where $k_i$ is the design constant, $\gamma_i$ is the partial safety factor, $f_i$ is the material characteristic strength and $A_i$ is the material area that corresponding to the loading. The characteristic strength and area are the main parameters in the design. Therefore, this research aims to investigate the structural performance of interlocking block columns with different infill materials, concrete grade and bar size by axial compression laboratory testing. In this study, short columns are studied with pinned ends pure axial compression test.

## 2. Design Specification of column

With reference to BS EN1996-1-1 [12], masonry structural design, the design of a reinforced wall and beam are described. There is no clear design guide on reinforced interlocking block columns. Therefore, the design specifications from BS EN1992-1-1 [13] have been adopted to calculate the ultimate loads. However, these design codes cannot be used for interlocking block columns as they are only applicable for designing reinforced concrete columns [14]. Thus, the design codes need to be modified by replacing the characteristic strength of concrete, $f_{cu}$ with the strength of grout, $f_{gu}$ and interlocking block, $f_{bu}$. The area made of concrete, $A_c$ was substituted with grout, $A_g$ and an additional area of interlocking blocks, $A_{ib}$. Eq. (2) shows the original formula of BS EN 1992-1-1 for compressive stress. This formula was modified to Eqs. (3) and (4) to consider various materials for interlocking block columns.

$$f_{cd} = \alpha_{cc} f_{ck} / \gamma_c \tag{2}$$

$$N_{Rd} = \frac{0.85 f_{ck} A_C}{\gamma_c} + \frac{0.85 f_{mk} A_m}{\gamma_m} + \frac{0.85 f_{gk} A_g}{\gamma_g} + \frac{f_{bk} A_b}{\gamma_b} + \frac{f_{yk} A_s}{\gamma_s} \tag{3}$$

$$N_{Rd} = 0.567 f_{ck} A_c + 0.567 f_{mk} A_m + 0.567 f_{gk} A_g + 0.1 f_{bk} A_b + 0.87 f_{yk} A_s \tag{4}$$

$N_{Rd}$ – Design axial load, kN; $f_{bk}$ – Characteristic strength of interlocking block, N/mm$^2$; $f_{mk}$ – Characteristic strength of mortar, N/mm$^2$; $f_{yk}$ – Characteristic strength of steel reinforcement bar, N/mm$^2$; $f_{gk}$ – Characteristic strength of grout, N/mm$^2$; $A_b$ – Gross cross-sectional area of interlocking block, mm$^2$; $A_m$ – Gross cross-sectional area of mortar, mm$^2$; $A_s$ – Area of the longitudinal reinforcement, mm$^2$; $A_g$ – Gross cross-sectional area of infill, mm$^2$.

According to MSJC code [15], a reduction factor of 0.8 should be introduced to the overall formulation where there is a minimum eccentricity from axial load that reduces the column compressive strength. Hence, Eq. (4) can be written as Eq. (5). Both equations of (4) and (5) will be used for the comparison with experimental data.

$$N_{Rd} = 0.454 f_{ck} A_c + 0.454 f_{mk} A_m + 0.454 f_{gk} A_g + 0.08 f_{bk} A_b + 0.696 f_{yk} A_s \tag{5}$$

## 3. Experimental program

For the experimental program, there were two parts of investigation, namely material properties and column axial load test. According to [16], specifying the weakest mortar that will perform adequately is a good practice, where stronger is not necessarily better for masonry construction. The MSJC code [15] does not distinguish between two masonry structures constructed from Type M and Type S mortars. However, a mortar as an infill material has not been investigated. The comparison will be made with grout and concrete as infill materials. Grout has been used as an infill material in hollow masonry construction. The fluidity of grout allows it to completely fill the opening in the units.

The involved materials are infills (grout, mortar and concrete), interlocking block and reinforcement bar. There are two types of infills, pores and centre void in the assembling of interlocking column as shown in shaded area of Fig. 1. For the concrete as an infill, only centre void is filled with concrete and mortar is used for the pores as concrete may not fit in due to bigger aggregate size.