© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Bearing Resistance and Failure Mode of Bolted-layered Cemboard Panels

A. F. Norhalim[1], Z. M. Jaini[2*]

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA

[2]Jamilus Research Center,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2020.12.09.018
Received 15 January 2020; Accepted 20 July 2020; Available online 26 December 2020

Abstract: The fabrication of precast slab can be made from wide range of material either neat concrete, foamed concrete or even composite. Until recently, a new interest has been discovered. Instead of wet concrete mixing process in plant, the precast slab can be substituted with fibre cement board or commonly referred as cemboard that meets the specific load requirements with minimum thickness. However, cemboard panel is preferable for lightweight floor system due to its physical strength limitation. Its thickness that relatively small around 15 mm to 25 mm contribute to the drawback and subsequently prohibited the application of cemboard panel as heavyweight floor system. Small specimens are prepared to determine the optimum orientation of bolts and type of bond by analysing the bearing resistance and bond-slip behaviour. It was found that the bearing capacity is governed by polyurethane glue. Meanwhile, the bond-slip behaviour is effectively controlled by the steel bolt. If the steel bolt is solely used as bond mechanism, the bearing capacity will rely on its quantity and capacity and increasing the quantity of steel bolt will eventually lead to the higher value of bearing resistance.

Keywords: Cemboard, bolted-layered, bearing capacity, bond-slip behaviour, push out test.

1. Introduction

Construction technique that adopting precast element has gained quite an entrance since the last decade. Besides the cost saving, speedy process and less time consumption, precast element serves aesthetic and versatile look since it can be manufactured in various shapes, sizes, colours and even finishes. Numerous approaches related to precast element were developed and applied to fulfil the exaggerated demands such as large panel system, frame system and slab-column system with shear wall. Technology has progressed to the degree that prefabricated precast element can be combined or assembled to form monolithically structures and behave globally [1]. It was found that precast element become preferred structural component for residential, commercial and industrial buildings [2]. This preference is attributed to its low cost [3][4], high quality assurance [5][6] and reduced construction time [7] that subsequently lead to economy when compared to conventional method [8]. However, precast element entails specific installation techniques. In urban areas, residential buildings that using precast elements are usually five to ten stories high or more. Many countries used various precast elements to provide low-income housing for the growing urban population.

There are numerous types of precast element that available for the construction of buildings. Highlighting the new interest by substituting conventional precast slab fabrication with fibre cement board or cemboard, the fabrication

*Corresponding author: rizuan@uthm.edu.my

process will only take place on site where cemboard panel will be fastened to the steel framing system using self-drilling screw or any other fastener that meets the required standard to ensure the workability of the floor system. Cemboard panel also can be manufactured in various thickness, depending on the desired purpose and design of structure. Besides the application as floor system, cemboard panel also has been used as cladding, building partition and sheathing board in cold-formed steel structure [9][10][11]. Beraldo & Carvalho [12] and Faria et al. [13] introduced single and multi-layered cemboard panel as compression member and composite slab that received good merit in green building index. The flexibility in the application of cemboard panel have broaden the usage limitation by day. Wan Badaruzzaman et al. [14] agreed that cemboard panel possess good resistance to compression and composite behaviour when it attached together to form multi-layer cemboard panel.

However, cemboard panel is preferable for lightweight floor system due to its physical strength limitation. Its thickness that relatively small around 15 mm to 25 mm contribute to the drawback and subsequently prohibited the application of cemboard panel as heavyweight floor system. Under imposed load and bending, multi-layer cemboard panel may experience failure in several ways such as wrinkling, delamination and detachment [15]. The exploitation of assembly and build-up principles using steel bolt seem appropriate for promoting far-flung utilization of cemboard panel. This creates an innovative approach known as bolted-layered cemboard panel that can be used for heavyweight floor system. Bearing resistance of structural element such bolted-layered cemboard panel fully depends on the size and spacing of steel bolt, ply thickness and number of layers [14][16]. This is to create an efficient design and subsequently to be contested as precast structure in industrialised building system. Until recently, the information about bolted-layered cemboard panel is still not readily available. In order to study and understand the bearing resistance and bond-slip behaviour of bolted-layered cemboard panels, this paper provides a comprehensive study regarding push-out test of bolted-layered cemboard panel.

2. Fibre Cemboard

Instead of conventional concrete, the precast slab can be substituted with fibre cement board or commonly refer as fibre cemboard panel that meets the specific load requirements with minimum thickness. It means that the fabrication process will only take place on site where fibre cemboard panel will be fastened to the steel framing system using connector or fastener that meets the required standard to ensure the workability of the floor system. Fibre cemboard panel can be manufactured in various thicknesses, depending on the desired purpose. It is known as dry system that able the easiness and rapidity of laying as compared to the traditional cement-based screeds. Fibre cemboard panel is suitable for both non-load and load bearing structures, as well as compatible to combine with other materials that exceeded resistance to fire, acoustic, durability and lightness [17], [18]. In Malaysia, fibre cemboard panel is considered as lightweight material and based on autoclaved cellulose fibre cement board that manufactured in accordance with MS1296 (2010). The basic composition comprises of Portland cement, cellulose fibre, ground sand and water.

Fibre cemboard panel do not contain asbestos or glass fibre [19]. Fibre cemboard panel can be produced with various thicknesses ranging from 3.2 mm to 20 mm. Table 1 specifies the recommended thickness of fibre cemboard panel in relation of its application. On the other hand, fibre cemboard panel can be manufactured in various standard sizes and the approximate weight per piece as stipulated in Table 2. Jabatan Bomba dan Penyelamat Malaysia approved the application of fibre cemboard panel in building (Class O) that need to comply the Uniform Building By-Law Malaysia (1984). Compressive strength of fibre cemboard panel was found higher with 10% fibre content [20]. However, this claims can be contended by Shawia et al. [21] and Pan & Liu [22] who indicated that fibre content has relatively contribute to the insignificant compressive strength than plain cemboard. This happens because of intrinsic quality of natural fibre that can improve the tensile strength but not the compressive strength. Chakartnarodom et al. [23] asserted that the bond strength between fibre and matrix does affect the composite behaviour. It was proven as the Modulus of Rupture and Modulus of Elasticity have increased compared to plain cemboard. On the other hand, flexural strength of fibre cemboard panel is significantly higher than plain cemboard by 70% [21] [22][24] .

Table 1 - Thickness of fibre cemboard panel and the application [18]

Applications	Recommended thickness (mm)								
	3.2	4.5	6	7.5	9	12	16	18	20
Ceiling	•	•	•						
Eaves/soffit lining	•	•	•						
Cladding (wall/gable end)			•	•	•	•			
Internal partition			•	•	•	•			
Roof sarking			•	•	•	•			
Flooring						•	•	•	•
Permanent formwork						•	•	•	•

Table 2 - Standard size and weight of fibre cemboard panel [18]

Thickness (mm)	Mass per sheet (kg)		
	610×1220	1220×1220	1220×2440
3.2	3.31	6.62	-
4.5	4.65	9.31	18.62
6.0	6.21	12.41	24.83
7.5	-	-	31.03
9.0	-	-	37.24
12.0	-	-	49.65
16.0	-	-	66.20
18.0	-	-	74.48
20.0	-	-	82.76

Currently, fibre cemboard panel is used as flooring system in factory and laboratory which provided good noise insulation [25]. Since the demand on fibre cemboard panel increases significantly and promote to the industrialized building system (IBS), it is therefore vital to establish the design criteria as accordance to the code of practice. Although fibre cemboard panel has been widely used in several countries, yet there are studies that specify design limitations, especially for its strength and durability [26]. A non-destructive test using non-contact ultrasound scanner can be used as automated quality control of fibre cemboard panel [27]. In addition, fibre cemboard panel with composite profiled steel sheet and observed that the first defect occurs as local buckling whilst fibre cemboard panel remains in good condition [28]. On the other hand, it was identified that the compressive strength decreases due to the volume fraction and characteristics of material, while the tensile strength improves around 53% [29]. In term of material properties, for cemboard with density of 1430 kg/m^3 to 1630 kg/m^3, the flexural strength of fibre cemboard panel is 80% higher than any of typical building elements, except for rice-husk cement board panel [22].

In general, fibre cemboard panel has various advantages such as high post-crack load bearing capacity and impact toughness [30][31]. Furthermore, fibre cemboard panel complies the environmental and ecologic requirements [32]. Fibre cemboard is commonly associated with cold-form steel frame and has a significant resistant upon failure. In an observation, failure occurred at the connection due to screws pull-out and tearing from fibre content and cause the separation [11]. In placing more emphasis, shear walls made of steel frame and fibre cemboard panel reached maximum lateral load resistance and lost its persistence due to screw pull-out which followed by cracking [26]. Furthermore, steel frame with thicker fibre cemboard panel showed a higher lateral load carrying capacity which is around 4.5 times greater than steel frame with mortar [33]. This is caused by an additional bond strength from the presence of fibre compared to plain mortar [34]. On the other hand, fibre cemboard panel is relatively weak in resisting bending [14]. Despite that, when attached together with several pieces to form composite layer and subjected to compression, it possesses good resistant.

In addition, with a typical variable action of 2.5 kN/m^2, 16 mm thickness of fibre cemboard panel displays a convincing bending resistant and within deflection limit. Past researchers conducted displacement control test with one to three layers of fibre cemboard panel as a short column and suggested that load must be applied on smooth surface [13]. The explanation for the higher strength when the sample is loaded through the smooth surface rather than the rough surface is that it is due to the wood particles being predominantly perpendicular to the force direction. So, the wood particles resist stress caused by compression. For composite structure, fibre cemboard have been numerously associated with corrugated steel sheet and made a system called Profiled Steel Sheet (PSSDB) that possess a very significant behaviour as a precast element [14], [35]-[39]. Besides that, PSSDB system were also investigated by many researchers for the use of floors, walls, and roofs [37]. This shows that fibre cemboard are well established to be implemented in the structural and precast system.

3. Bearing Resistance and Slip-Displacement

Recently, bearing resistance of slab have been studied by numerous researches as vertical and lateral loads are both important to determine slab behaviour [40]-[43]. Bearing resistance take action when a load is applied on a laterally restrained slab and its edges tend to move outwards [40]. In order to simulate the real situation, both vertical and lateral loads need to be applied during experimental study. Slab will sustain the two directions of load and that is why in an experimental works, loading was supposed to simulate real-life loading [44]. This view is supported by Cajka et al. (2020)[45], who added that vertical and lateral loading is typical to be examined in the case of slab in building, especially in undermined areas. In flooring system, combined vertical and lateral loading has an important effect on the slab behaviour [46]. Slab behaviour under lateral loading also represents the global behaviour of a building experiencing sway and seismic movement has been studied recently by Alizadeh et al. [47], Eladawy et al. [48] and Isufi et al. [49]. In order to understand the effect of lateral loading and to study the bearing resistance, push-out test needs to be conducted.

According to EN 1994-1-1 (2004) [50], conventional three-layer push-out test is meant for tests on shear connectors and composite floor slabs. The approach was implemented by previous researches in determining the shear connector stiffness [16], [51]-[53]. Some modification based on the conventional push-out test has been made in few years back by Harsoyo [52] that published a new protocol of two-layer push out test. Apart from the main objective in determining stiffness of shear connector, modified push-out test protocol has been practiced to determine the value of bearing capacity or slippage load, slip behaviour, load-slip curve, and shear modulus [28], [51]-[53]. In this study, push-out test was conducted based on the modified push-out test to obtain the bearing capacity and to observe the failure mode.

4. Experimental Study

4.1 Materials and Specimens Preparation

Fig. 1 shows the materials used to produce the specimens which consist 16 mm thickness fibre cemboard, mild strength steel bolts and polyurethane glue. The diameter and length of steel bolts are 8 mm and 50 mm, respectively. In the fabrication of specimens, fibre cemboard was cut to form the small specimens with size 210 mm x 210 mm. Basically, the standard manufacturing size of fibre cemboard per piece is 1220 mm x 2440 mm. Two layers of fibre cemboard then attached together using the bond mechanism. In this study, there are three types of bond mechanism used specifically to investigate the bearing resistance and slip displacement under push-out test. The bond mechanism can be referred as (i) polyurethane glue, (ii) steel bolts and (iii) combination of steel bolts and polyurethane glue. Specimens that use bond mechanism based on steel bolts must be accommodated with holes. These holes are drilled before the installation of steel bolts and fastened with washer and nut. The installation of steel bolts is based on 70 mm spacing either in single-row (two steel bolts) or double-row (four steel bolts) as depicted in Fig. 2, while details quantity of specimens is breakdown in Table 3.

(a) (b) (c)

Fig. 1 - (a) Fibre cemboard, (b) Steel bolts, and (c) Polyurethane glue.

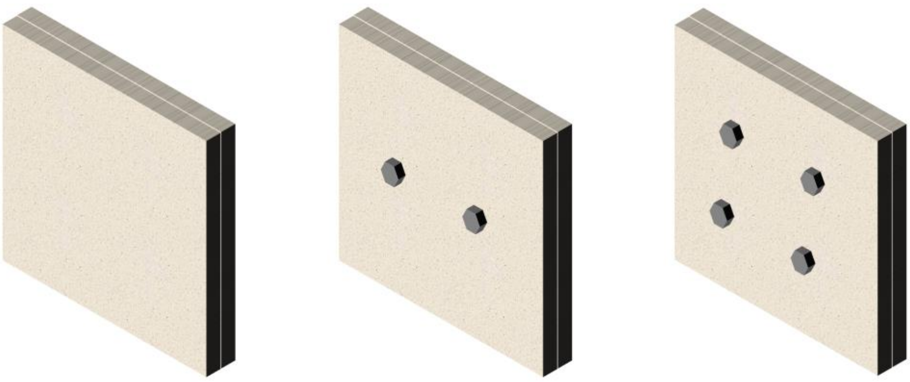


Figure 2 - Small samples and configurations of steel bolt (a) Glue; (b) 2 bolts; (c) 4 bolts

Table 3 - Quantity for small samples for push-out test

Bond mechanism	Number of bolts		Total
	2	4	
Polyurethane glue	-	-	3
Steel bolt	3	3	6
Steel bolt + polyurethane glue	3	3	6
	Total small samples =		15

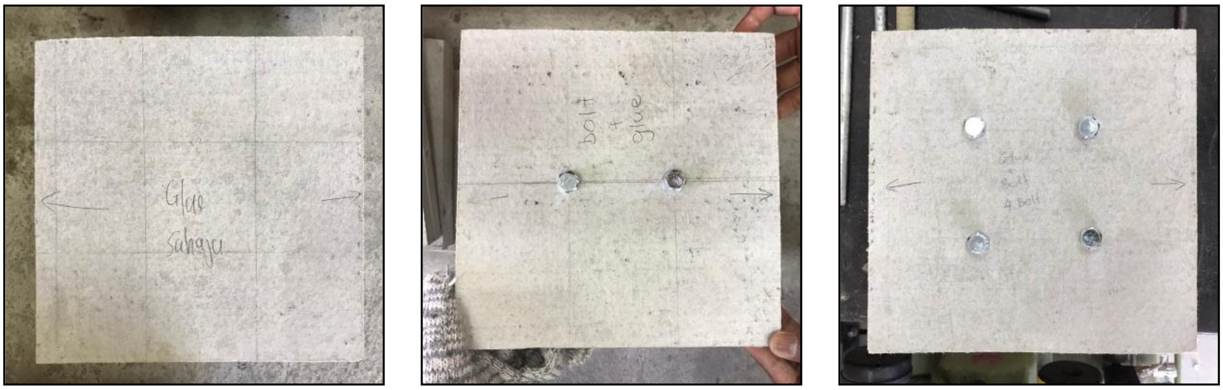


Figure 3 - Real specimens of push-out test (a) Glue; (b) 2 bolts; (c) 4 bolts

3.2 Push-Out Test

Push-out tests were carried out to determine the bearing resistance and bond-slip behaviour of bolted-layered cemboard sample [52][53]54]. Push out test as a method to obtain the stiffness of connections was also recommended by Nordin et al. [39]. The small samples were tested using the Universal Testing Machine. The details set-up of push-out test is displayed in Fig. 3 and Fig. 4. The push-out test for small samples used an automated loading machine Servo Control Universal Testing Machine with the capacity of 1000kN. The loading rate for the push-out test was 1 mm/minute as suggested by Jaffar et al [37].At the bottom part of one layer of fibre cemboard, steel plate has been placed as support condition. Meanwhile, at the top part of another layer of fibre cemboard, the in-plane force will be imposed until failure condition. Attention were paid directly to the contact surface between cemboard and the steel plate as a flat surface is required to ensure a smooth interaction. The maximum load and respective displacement were recorded directly into the load cell. Besides that, in order to ensure accuracy of displacement measured by the load cell, a calibration has been made by using high precision digital vernier calliper. It was found that the difference between displacement measured by the load cell and the vernier calliper was only 0.01mm, thus the displacement reading from the load cell is highly dependable.

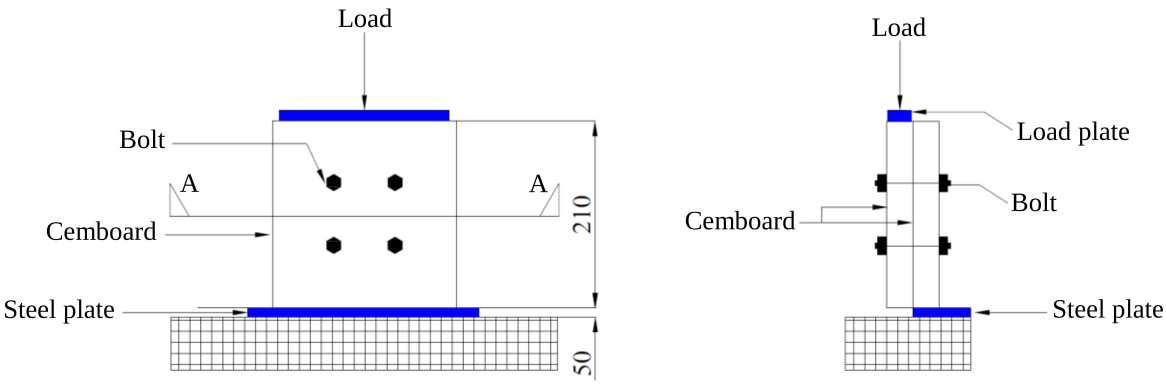


Fig. 4 - Schematic diagram of push-out test

Fig. 5 - Real experimental procedures

4. Results and Discussion

4.1 Polyurethane Glue Sample

Fig. 5 shows the force-displacement profile samples where the bond mechanism used is polyurethane glue. These small samples will be referred as GC. Based on the push-out test, the ultimate force at the peak point represents the bearing resistance. Meanwhile, the maximum displacement and displacement upon failure designate the bond-slip behaviour. It can be observed from GC that the bearing resistance is around 38.70 kN which corresponds to the maximum displacement at 3.43 mm. The displacement upon failure is 3.84 mm. Overall, GC produces high bearing resistance with less value of displacement. It also noticeable that there is the steep curve after the ultimate force which caused by the losing grip and strength of polyurethane glue.

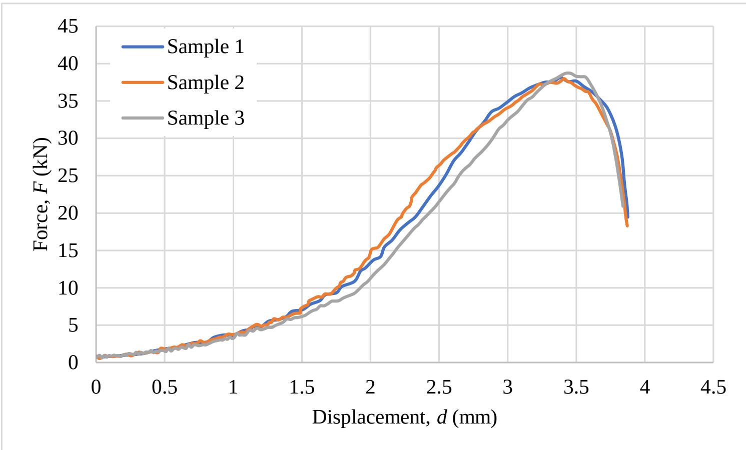
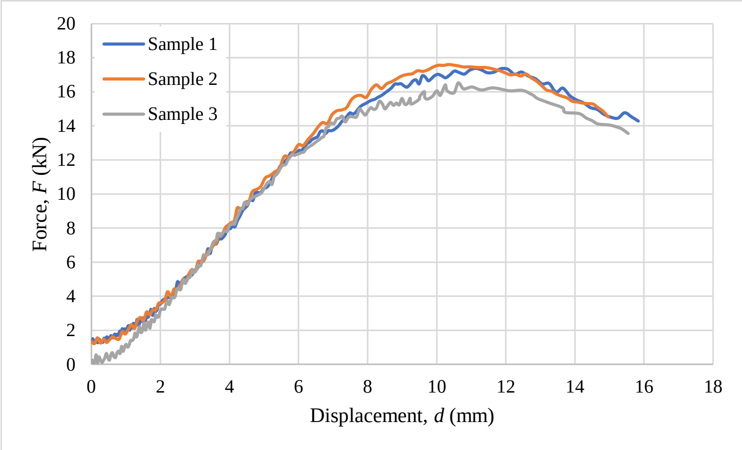


Fig. 6 - Force-displacement profile GC

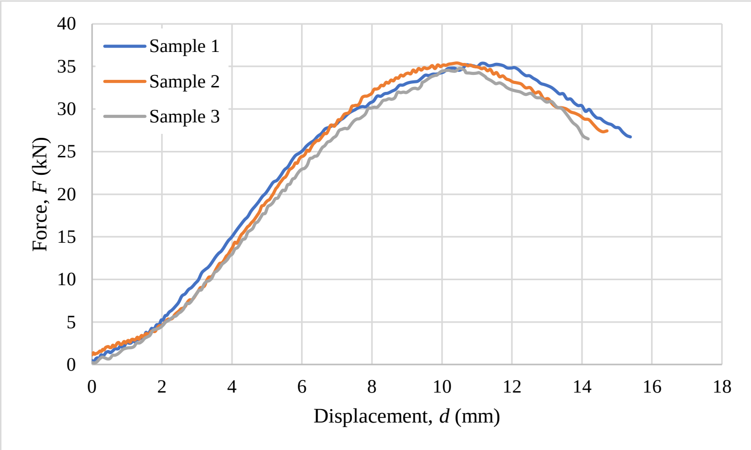
4.2 Steel Bolt Sample

Fig. 6(a) shows the force-displacement profile of small samples with two steel bolts (2BC). Meanwhile, the force-displacement profile for the small samples with four steel bolts (4BC) can be seen in Fig. 6(b). It can be observed that 2BC has bearing resistance approximately 17.17 kN that happen at the maximum displacement of 10.69 mm. For 4BC, the bearing resistance is 35.18 kN where the maximum displacement can be measured at 10.74 mm. A comparison between bearing resistance indicates that 4BC have higher values than 2BC around 68.80%. However, the difference in term of maximum displacement is relatively small or insignificant.

In these small samples, the steel bolt was found able to counter the stress distribution from the loading. Steel bolt tends to act as ductile behaviour and hence during the plastic deformation, it still able to stretch without undergoing fracture. The displacement upon failure can be observed happen at 15.45 mm and 14.76 mm for 2BC and 4BC, respectively. This value is around five time higher than that occur on GC. The displacement upon failure on 2BC and 4BC indicate that the steel bolt as bond mechanism can has better performance in term of bond-slip behaviour although the bearing resistance being lower than GC.



(a)



(b)

Fig. 7 - (a) Force-displacement profile 2BC; (b) Force-displacement profile 4BC

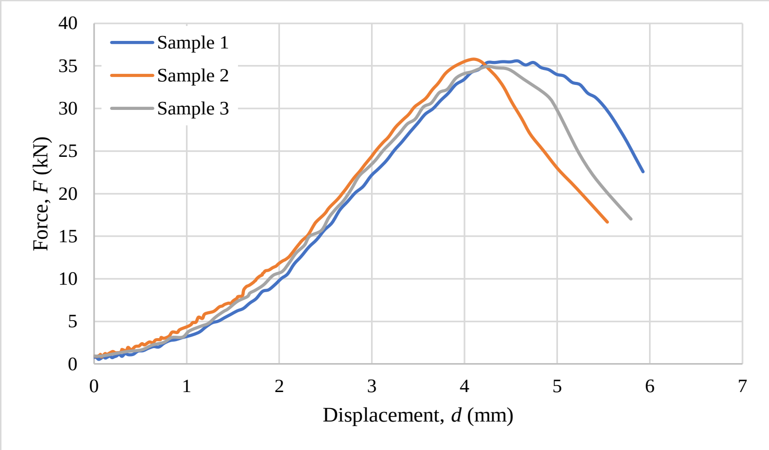
4.3 Combination Steel Bolt + Polyurethane Glue Sample

Fig. 7 shows the force-displacement profile for small samples with 2 steel bolts and polyurethane glue (2BGC). On the hand, Fig. 4.7 shows the force-displacement profile for small samples with 4 steel bolts and polyurethane glue (4BGC). It was found that the combination of steel bolt and polyurethane glue as bond mechanism create both brittle and ductile behaviours to the small samples. From the push-out test, the bearing resistance for 2BGC and 4BGC are 35.44 kN and 38.79 kN, respectively. Meanwhile, the maximum displacement at the ultimate force for 2BGC and 4BGC are 4.31 mm and 4.35 mm, respectively. The observation of bearing resistance and bond-slip behaviour indicated the absence of substantial changes. Increasing the number of steel bolt from two to four, the bearing resistance and maximum displacement displayed small differences at less than 4.5 % and 1.0 % respectively.

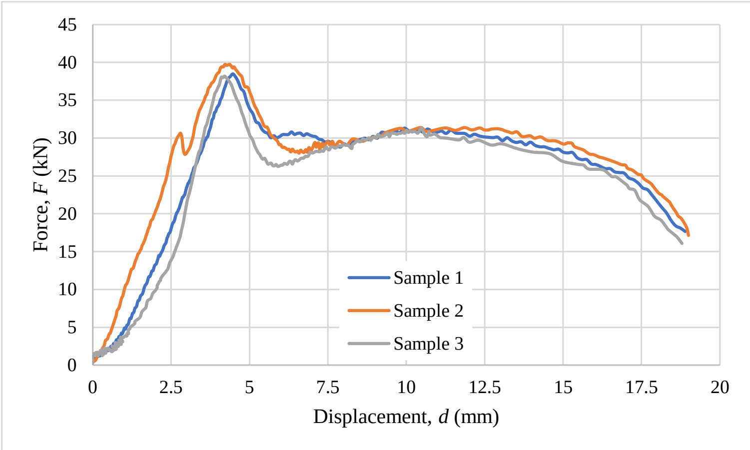
The displacement upon failure for 2BGC and 4BGC are 5.86 mm and 18.90 mm, respectively. It can be observed that the quantity of steel bolt plays a major role in governing the rapture behaviour. In these small samples, the bearing resistance is absolutely control by the polyurethane glue whilst the bond-slip behaviour depends on the steel bolt. By having a greater row number of bolts, the stress is mainly distributed on the first row of bolts, and each bolt only carry less stress distribution on the second row. Thus, only the first row of bolts plays the major role to cater the stress distribution until it reaches bearing capacity.

4.4 Effect of Bond Mechanism

It was found that the different types of bond mechanism have significant effect on the bearing resistance and bond-slip behaviour. A comparison of results attained by GC, 2BC, 4BC, 2BGC and 4BGC can be seen in Fig. 4.8. It can be observed that the small samples with polyurethane glue produce relatively high bearing resistance as compared to the small samples with steel bolt as bond mechanism. The highest recorded bearing resistance is 4BGC at 38.79 kN while the lowest value was measured on 2BG at 17.17 kN. The gap in term of bearing resistance between 2BC and 2BGC is 69.45 % which reflect an important effect of polyurethane glue on the small samples. The same condition was observed between 4BC and 4BGC where the difference of bearing resistance is 9.75 %. For the small samples with four steel bolts, the presence of polyurethane glue has little effect in resisting the loading.



(a)



(b)

Fig. 8 – (a) Force-displacement profile 2BGC; (b) Force-displacement profile 4BGC

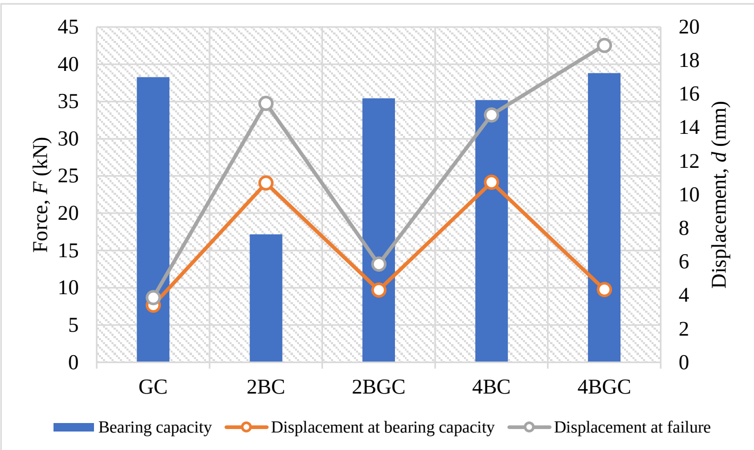


Fig. 9 - A comparison of bearing resistance, maximum displacement, and displacement upon failure for small specimens

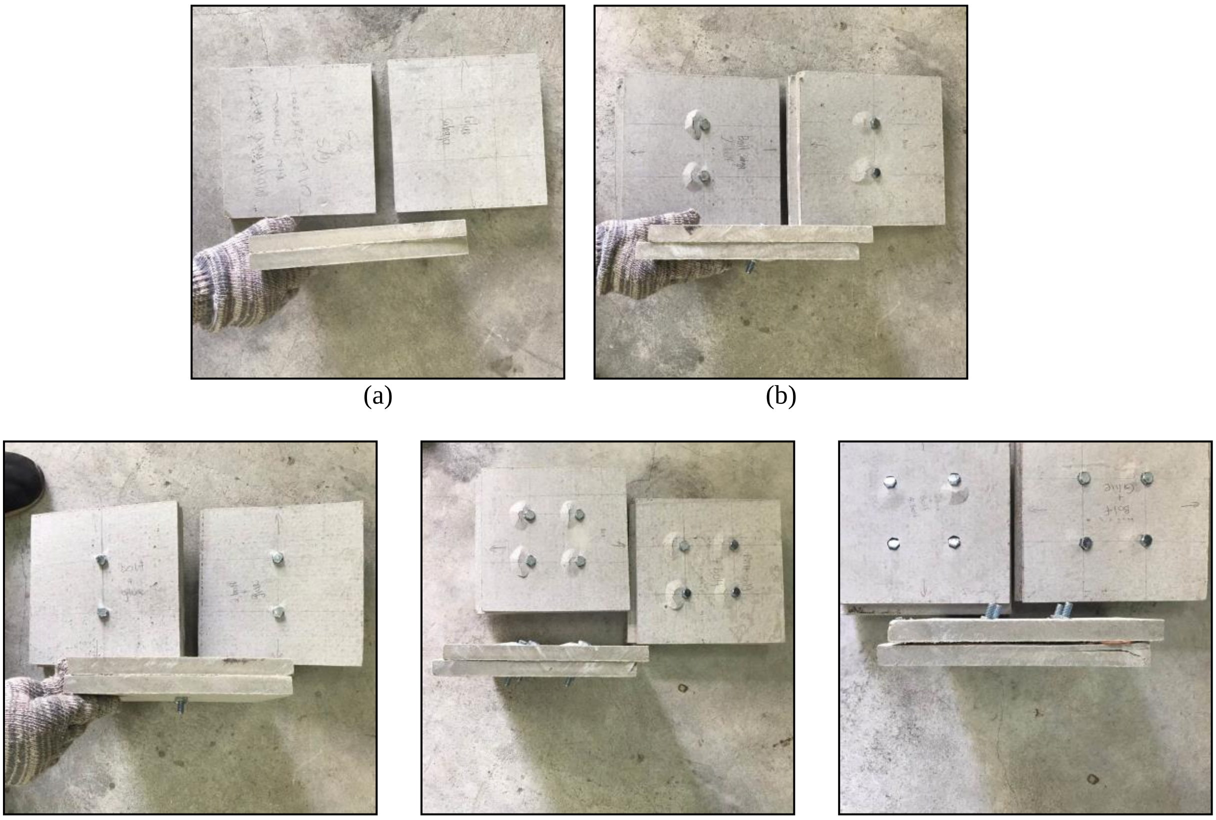
Under the push-out test, the bearing capacity of small samples is governed by polyurethane glue. Meanwhile, the bond-slip behaviour is effectively controlled by the steel bolt. Although GC has highest bearing resistance among the small samples, it also has the lowest bond-slip behaviour. In contrast, 4BC and 4BGC display the optimum performance in term of bearing resistance and bond-slip behaviour. It was identified that for small specimens with steel bolt and polyurethane glue, the bearing resistance is firstly controlled by the polyurethane glue. The rigidity created by polyurethane glue helps the fibre cemboard to gain strength. When the strength reaches the ultimate state, polyurethane glue experiences degradation in strength and cause detachment. At this stage, displacement occurs at the small rate. As polyurethane glue completely futile, steel bolt take place to resist the loading and delay the displacement.

Considering the capacity of steel bolt, 2BC has 8.59 kN per steel bolt while 4BC has 8.80 kN. On the other hand, 2BGC has 17.72 kN per steel bolt while 4BGC has 9.70 kN. Without the presence of polyurethane glue, the steel bolt works equally in resisting the loading. When associating the polyurethane glue, the small samples with more quantity of steel bolt depicted lower performance in term of bearing resistance but portray optimum condition in bond-slip behaviour. The presence of polyurethane glue was found able to create rigid bond mechanism and hold fibre cemboard in place. Therefore, it can be observed that 2BGC has higher bearing resistance than 2BC and similarly to 4BGC and 4BC. In term of bond-slip behaviour, polyurethane glue shows meaningless contribution, and the small samples did not perform well. Displacement upon failure shows a unique pattern where 2BG and 4BG are higher than GC, 2BGC and 4 BGC.

4.5 Failure Mode

Polyurethane glue possesses brittle behaviour and when it failed, the delamination occurs instantly and hence contribute to the sudden rapture. This condition can be observed in the polyurethane glue samples. The failure occurs when the two layers of fibre cemboard are completely detached. On the other hand, in the case of steel bolt samples, steel bold can hold the fibre cemboard efficiently from the splitting. However, it was found that the crack propagates from the area of steel bolt when the stress distribution accumulated and become higher than yield stress. Subsequently, fibre cemboard experiences fracture while steel bolt remains intact. This phenomenon can be explained by the steady decreasing curve of hardening. It should be emphasized here that the sudden rupture did not take place before the complete slip happened.

Besides that, a combination of polyurethane glue and steel bolt bond mechanism can be seen in the combination steel bolt + polyurethane glue samples. At the initial phase in which the small samples are imposed by the loading, the stress distribution will be taken by the polyurethane glue. When the polyurethane glue failed and detachment between fibre cemboard occurred, the steel bolt will resume the function to resist the loading until it reaches the rapture behaviour. This is caused by distribution of stress on the bolt.



(a) (b)

(c) (d) (e)

Figure 10 - Failure mode of push-out specimens, (a) Glue, (b) 2 bolts, (c) 2 bolts + glue, (d) 4 bolts, and (e) 4 bolts + glue

5. Conclusion

This study offers a comprehensive investigation on bearing resistance and bond-slip behaviour of bolted-layered cemboard sample. Meanwhile, steel bolt produces ductile behaviour that increase the bond-slip behaviour. the hypothesis can be made where steel bolt and polyurethane glue showed better performance. Polyurethane glue able to resist the loading and produce high value of bearing resistance while steel bolt become efficient feature in enhance the bond-slip behaviour. If the steel bolt is solely used as bond mechanism, the bearing capacity will rely on its quantity and capacity. Increasing the quantity of steel bolt will eventually lead to the higher value of bearing resistance. However, there is no consequence can be observed in the bond-slip behaviour as the values of maximum displacement and displacement upon failure remain unchanged. When the capacity of steel bolt undisturbed and the yield strength is higher than stress distribution, then the initiation of crack propagation will be at the weakens level. Steel bolt that well recognized with its ductile behaviour able to stretch and elongate before breaking. This cause steel bolt able to perform effectively in bond-slip behaviour, even when the absence of polyurethane glue.

Acknowledgement

Authors would like to thank Universiti Tun Hussein Onn Malaysia and Ministry of Education Malaysia for the continuous supports in term of facilities and financial. This research was conducted under Geran Penyelidikan Pascasiswazah (GPPS) No: H533.

References

[1] Yee, A. A. (2001). Structural and economic benefits of precast/prestressed concrete construction. PCI Journal, 46, 34–42.
[2] Kim, S., Hong, W. K., Kim, J. H., & Kim, J. T. (2013). The development of modularized construction of enhanced precast composite structural systems (Smart Green frame) and its embedded energy efficiency. Energy and Buildings, 66, 16–21.
[3] Ning, X., Lam, K. C., & Lam, M. C. K. (2010). Dynamic construction site layout planning using max-min ant system. Automation in Construction, 19, 55–65.
[4] Polat, G. (2008). Factors affecting the use of precast concrete systems in the United States. Journal of Construction Engineering and Management, 134(3), 169–178.
[5] Eastman, C. M., & Sacks, R. (2008). Relative productivity in the AEC industries in the United States for on-site and off-site activities. Journal of Construction Engineering and Management, 134, 517–526.
[6] Lim, C. Y., Joo, J. K., Lee, G. J., & Kim, S. K. (2011). In-situ production analysis of composite precast concrete members. Journal of the Korea Institute of Building Construction, 11, 501–514.
[7] Badir, Y. F., Kadir, M. R. A., & Hashim, A. H. (2002). Industrialized building systems construction in Malaysia. Journal of Architectural Engineering, 8(1), 19–23.
[8] Murari, S. S., & Joshi, A. M. (2017). Precast construction methodology in construction industry. SSRN Electronic Journal, 7, 1-9.
[9] Ranachowski, Z., Ranachowski, P., Debowski, T., Gorzelanczyk, T., & Schabowicz, K. (2019). Investigation of structural degradation of fibre cement boards due to thermal impact. Materials, 944, 1–14.
[10] Martins, J. A., Gomes, C. M., Fontanini, P., & Dornelles, K. (2019). Comparative analysis on thermal performance of MgO and fibre cement boards applied to light steel frame building systems. Journal of Building Engineering, 21, 312–316.
[11] Badr, A. R., Elanwar, H. H., & Mourad, S. A. (2019). Numerical and experimental investigation on cold-formed walls sheathed by fibre cement board. Journal of Constructional Steel Research, 158, 366–380.
[12] Beraldo, A. L., & Carvalho, J. V. De. (2004). Composito Eucalyptus grandis – cimento Portland Portland cement – Eucalyptus grandis composite. Scientia Forestalis, 65, 150–161.
[13] Faria, G., Chastre, C., Lucio, V., & Nunes, A. (2013). Compression behaviour of short columns made from cement-bonded particle board. Construction and Building Materials, 40, 60–69.
[14] Wan Badaruzzaman, W. H., Zain, M. F. M., Akhand, A. M., & Ahmed, E. (2003). Dry boards as load bearing element in the profiled steel sheet dry board floor panel system - Structural performance and applications. Construction and Building Materials, 17, 289–297.
[15] Gdoutos, E. E. (2019). Proceedings of the Second International Conference on Theoretical, Applied and Experimental Mechanics. In G. Emmanuel & M. Konsta-Gdoutos (Eds.) (pp. 1–385).
[16] Nordin, N., Wan Badaruzzaman, W. H., & Awang, H.. Connector stiffness of 'peva-cemboard' screwed connection in profiled steel sheet dry board (pssdb) panel. Collaboration and Integration in Engineering, Management and Technology, 2009, Istanbul, Turkey: CITC-V. pp. 1476–1482
[17] Henrique, G., Tonoli, D., Joaquim, A. P., Arsène, M., & Bilba, K. (2007). Performance and durability of cement-based composites. Materials and Manufacturing Processes, 22, 149–156.
[18] Opportunities and Solutions in Structural Engineering and Construction, 4–9.

[19] Hume, C. I. (2017). Prima Flex Technical Manual.pdf. Selangor: Hume Cemboard Industries.
[20] Singh, A., Singh, J., & Ajay, S. (2018). Properties of natural fibre cement boards for building partitions. International Journal of Applied Engineering Research, 13, 8486–8489.
[21] Shawia, N. B., Jabber, M. A., & Mamouri, A. F. (2014). Mechanical and physical properties of natural fibre cement board for building partitions. Physic Science Research International, 2(September), 49–53.
[22] Pan, H., & Liu, Y. (2009). Properties of natural fibre cement boards for building partitions. Challenges, Opportunities and Solutions in Structural Engineering and Construction, 4–9.
[23] Chakartnarodom, P., Prakaypan, W., Ineure, P., Kongkajun, N., & Chuankrerkkul, N. (2018). Feasibility study of using basalt fibres as the reinforcement phase in fibre-cement products. Key Engineering Materials, 766, 252–257.
[24] Khorami, M., & Ganjian, E. (2011). Comparing flexural behaviour of fibre-cement composites reinforced bagasse: Wheat and eucalyptus. Construction and Building Materials, 25, 3661–3667.
[25] Luison, L., Pavarin, C., & Bella, A. Di. (2013). Dry systems for impact noise insulation of floors in laboratory Dry systems for impact noise insulation of floors in laboratory research. Products and Methods, 3, 759–761.
[26] Zeynalian, M., & Ronagh, H. R. (2015). Seismic performance of cold formed steel walls sheathed by fi bre-cement board panels. JCSR, 107, 1–11.
[27] Schabowicz, K., & Gorzelan, T. (2016). A nondestructive methodology for the testing of fibre cement boards by means of a non-contact ultrasound scanner. Construction and Building Materials, 102, 200–207.
[28] Rahmadi, A. P., Badaruzzaman, W. H. W., & Arifin, A. K. (2013). Prediction of deflection of the composite profiled steel sheet MDF-Board (PSSMDFB) floor system. Procedia Engineering, 54, 457–464.
[29] Ismail, M. (2007). Compressive and tensile strength of natural fibre-reinforced cement base composites. Al-Rafidain Engineering, 15, 44954.
[30] Evans, P. D. (2000). Adverse effects of heartwood on the mechanical properties of wood-wool cement boards manufactured from radiata pine wood. Wood and Fibre Science, 32, 37–43.
[31] Coutts, R. S. P., & Scientific, T. C. (2017). Bond between cellulose fibres and cement. The International Journal of Cement Composites and Lightweight Concrete, 7, 73–80.
[32] Melcher, J. J., & Karmazinova, M. (2012). Influence of atmospheric physical effects on static behavior of building plate components made of fibre-cement-based materials. International Journal of Structural and Construction Engineering, 6, 799–804.
[33] Mowrtage, W. (2015). Cyclic lateral load behavior of CFS walls sheathed with different materials. Thin-Walled Structures, 96, 328–336.
[34] Chakartnarodom, P., Prakaypan, W., Ineure, P., Kongkajun, N., & Chuankrerkkul, N. (2018). Feasibility study of using basalt fibres as the reinforcement phase in fibre-cement products. Key Engineering Materials, 252–257.
[35] Ahmed, E., Wan Badaruzzaman, W. H., & Wright, H. D. (2002). Two-way bending behavior of profiled steel sheet dry board composite panel system. Thin-Walled Structures, 40(11), 971–990.
[36] Al-Shaikhli, M. S., Wan Badaruzzaman, W. H., Baharom, S., & Al-Zand, A. W. (2017). The two-way flexural performance of the PSSDB floor system with infill material. Journal of Constructional Steel Research, 138, 79–92.
[37] Jaffar, M. I., Kamarulzaman, K., & Lias, M. R. (2018). Behaviors of Profiled Steel Sheeting Dry Board (PSSDB) Composite Floor System between Geopolymer Concrete and Normal Concrete Infill : Experimental and Finite-Element Modeling. Asian Journal of Technical Vocational Education and Training, 5, 15–33.
[38] Nordin, N., Hanizam, A., & Wan Badaruzzaman, W. H. (2009). Connector Stiffness of 'Peva-Cemboard' Screwed Connection in Profiled Steel Sheet Dry Board (PSSDB) Panel. In Collaboration and Integration in Engineering, Management and Technology (pp. 1476–1482). Istanbul, Turkey: CITC-V.
[39] Rahmadi, A. P., Wan Badaruzzaman, W. H., & Arifin, A. K. (2013). Prediction of deflection of the composite profiled steel sheet MDF-board (PSSMDFB) floor system. Procedia Engineering, 54, 457–464.
[40] Amir, S., van der Veen, C., Walraven, J. C., & de Boer, A. (2020). Bearing Capacity of Transversely Prestressed Concrete Deck Slabs. Structural Engineering International, 0(0), 1–11.
[41] Ding, Y., Wang, Q., Pacheco-Torgal, F., & Zhang, Y. (2020). Hybrid effect of basalt fiber textile and macro polypropylene fiber on flexural load-bearing capacity and toughness of two-way concrete slabs. Construction and Building Materials, 261, 119881.
[42] Korsun, V., Vinogradova, N., & Shvets, G. (2020). Load-bearing Capacity and Deformation of Reinforced Concrete T-Beam Elements of Prefabricated Monolithic Slabs with Thin-Walled Steel Profile. Construction of Unique Buildings and Structures, 88(3), 8803–8803.
[43] Zhu, X., & Fang, G. (2020). The Bearing Capacity of the Recycled Concrete Two-Way Composite Slab Tests. IOP Conference Series: Earth and Environmental Science, 446(2).
[44] Lisovsky, M., Kocab, D., Zitt, P., & Wunsche, D. (2020). Numerical and experimental analysis of behaviour of steel fibre reinforced selfcompacting concrete slabs under loading. In MATEC Web of Conferences (Vol. 313, p. 00038). EDP Sciences.

[45] Cajka, R., Mynarcik, P., Neuwirthova, Z., Marcalikova, Z., & Kropacek, M. (2020). Tests of fiber reinforced concrete composite slabs on the subsoil with horizontal load. International Journal of GEOMATE, 18(69), 143–150.
[46] Ahmed, I. M., & Tsavdaridis, K. D. (2020). Shear connection of prefabricated slabs with LWC - Part1: Experimental and analytical studies. Journal of Constructional Steel Research, 169, 106016.
[47] Alizadeh, S., MacRae, G. A., Bull, D., & Clifton, G. C. (2020). Composite gravity beams subject to slab lateral movement. Journal of Constructional Steel Research, 171, 106162.
[48] Eladawy, M., Hassan, M., Benmokrane, B., & Ferrier, E. (2020). Lateral cyclic behavior of interior two-way concrete slab–column connections reinforced with GFRP bars. Engineering Structures, 209(November 2019), 109978.
[49] Isufi, B., Cismasiu, I., Marreiros, R., Pinho Ramos, A., & Lúcio, V. (2020). Role of punching shear reinforcement in the seismic performance of flat slab frames. Engineering Structures, 207(September 2019).
[50] EN 1994-1-1 (2004) (English): Eurocode 4: Design of composite steel and concrete structures – Part 1-1: General rules and rules for buildings [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC]
[51] Gandomkar, F. A., Badaruzzaman, W. H. W., & Osman, S. A. (2011). The natural frequencies of composite Profiled Steel Sheet Dry Board with Concrete infill (PSSDBC) system. Latin American Journal of Solids and Structures, 8(3), 351–372.
[52] Harsoyo. (2004). Prestasi Sistem Baru Lantai Keluli Berprofil Papan Kering Dengan Isian Konkrit. PhD Thesis, Universiti Kebangsaan Malaysia.
[53] Jaffar, M. I. (2016). Prestasi dan Kelakuan Sistem Lantai Kepingan Keluli Berprofil Papan Kering Dengan Isian Konkrit Geopolimer. PhD Thesis, Universiti Kebangsaan Malaysia.
[54] Gandomkar, F. A. (2012). Penentuan Tahap Keselesaan Sistem Lantai Kepingan Keluli Berprofil Papan Kering. PhD Thesis, Universiti Kebangsaan Malaysia.