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Precast self-compacting concrete (PSCC) panel with added coir fiber: An overview

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Abstract. Self-compacting concrete (SCC) is the alternative way to reduce construction time and improve the quality and strength of concrete. The panel system fabricated from SCC contribute to the IBS system that is sustainable and environmental friendly. The precast self-compacting concrete (PSCC) panel with added coir fiber will be overview in this paper. The properties of SCC and coir fiber are studied and reviewed from the previous researches. Finite element analysis is used to support the experimental results by conduction parametric simulation study on PSCC under flexure load. In general, it was found that coir fiber has a significant influence on the flexural load and crack propagation. Higher fiber incorporated in SCC resulted with higher ultimate load of PSCC.

1. Introduction

In the present, construction is a hugely important industry. In Malaysia the pace of development and construction activity achieved since last three decades is beyond the expectations. It has spurred the demand for fast, cost-effective and quality residential buildings. However, the supply of houses by both the public and private sectors are still far from meeting the demand. So that, it is difficult to have an affordable quality house. Conventional building construction that has been practiced in this country does not seem to be able to fulfil the high demand of affordable housing. As such, innovative construction system such as IBS need to be adopted to move away from this traditional construction technique in order to meet the demand.

A new alternative construction system is required to provide fast construction, safe and energy efficient structure to replace the conventional system. IBS is seen as one solution in the development of new technology in the construction industries. Thus, an extensive study have been carried out to develop a Precast Self-Compacting Concrete Panel (PSCC) with added agricultural waste material in order to maintain integrity and strength of the building. PSCC panel is a utilized techniques, products, components or building systems which involve prefabricated components and on-site installation. It provide better quality control, cost saving through fast speed of construction and ease of handling on site.
2. Self-Compacting Concrete (SCC)

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement [1]. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete. The elimination of vibrating equipment improves the environment on and near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction.

The consistency in the concrete’s fresh state is the biggest difference between traditional concrete and SCC. Figure 1 shows traditional slump concrete and SCC. It is clear that the slump of both concrete are totally different due to the flowability of each concrete. Slump flow measurement is used to indicate the consistency of the SCC. The flow properties of the SCC are described by its plastic viscosity [2].

![Figure 1. Slump for traditional concrete (left) and SCC (right) [2].](image)

High deformability of paste or mortar is not the only concern for achieving self-compact ability, but resistance to segregation between course aggregate and mortar when concrete flows through the confined zone of reinforcement bar also need to be monitored to make sure the SCC behave in right manner. Figure 2 shows the method for achieving self-compact ability that been developed by Okamura and Ozawa [3].

![Figure 2. Method for achieving self-compact ability [3].](image)

According to ASTM C29, the volume ratio of aggregate is about 52–58%, so that the remaining 42-48% is void in the loose aggregate. The strength of SCC is provided by the aggregate binding by the paste at hardened state, while the workability of SCC is provided by the binding paste at fresh state.
Therefore, the main factors that will be influencing the properties of SCC are the contents of coarse and fine aggregates, binders, mixing water and superplasticizer. The good batch of SCC that have flowability and segregation resistance can be obtained by selecting qualified materials, do the calculation, conduct mixing tests and make some adjustment [4]. Table 1 shows the specification of SCC proposed by Japanese Society of Civil Engineering (JSCE) that can be used as guide when mixing the SCC.

| Class of filling ability of concrete | 1               | 2               | 3               |
|-------------------------------------|-----------------|-----------------|-----------------|
| Construction condition               | Minimum gap between reinforcement (mm) | 30–60           | 60–200          | ≥200            |
|                                     | Amount of reinforcement (kg/m³)       | ≥350            | 100–350         | ≤100            |
| Filling height of U-box test (mm)    | ≥300(rank R1)   | ≥300(rank R2)   | ≥300(rank R3)   |
| Absolute volume of coarse aggregates per unit volume of SCC (m³/m³) | 0.28–0.30       | 0.30–0.33       | 0.30–0.36       |
| Flowability                          | Slump flow (mm) | 650–750         | 600–700         | 500–650         |
| Segregation resistance ability       | Time required to flow through V-funnel (s) | 10–20          | 7–20           | 7–20           |
|                                     | Time required to reach 500 mm of slump flow (s) | 5–25          | 3–15           | 3–15           |

Several previous study conducted on SCC with added other material such as fly ash, bottom ash and metakaolin to act as filler in mixture. The filler usually effected on the mechanical strength of the concrete that is compressive strength, tensile and flexural [5-7]. The study on effect of fiber added in SCC mixture are not commonly known due to flowability of SCC. But EFNARC [1] had stated the limit of fiber that been allowed to be added on SCC mixture is 1 kg/m³.

3. Mechanical properties of coir fiber
Cracking of concrete due to plastic and drying shrinkage were often been control by applying the fibers in mixture. The concrete properties shown some significant effect after fibers been added in the mixture. As we know, the tensile strength of concrete is only about 10% of its compressive strength. Thus the addition of fibers to a concrete mixture is beneficial to tensile properties of concrete. It reduces propagation of cracks in plastic and hardened state [8].

Solid wastes from plantation have been producing a huge amount of waste material. In Malaysia, this problem is a huge issue which will cause the environmental problem if it is not managed properly [9]. One of the practical solutions to deal with this problem is to recycle these wastes. Agricultural waste is waste from plantation such as kenaf, coir, pineapple skin and pineapple leaves, rice husk and POFA. These waste can be used as concrete materials either as sand and cement replacement, additives or filler. Previous researchers have used plant fibres as an alternative source of steel and artificial fibres to be used in composites such as cement paste, mortar and concrete to increase its strength properties. These plant fibres include coir, ssal, jute, ramie bast, pineapple leaf, kenaf bast, sansevieria leaf, abaca leaf, date, bamboo, palm, banana, hemp, flax, cotton and sugarcane [10-16].
Coir fiber are obtained from coconut palm (Cocos nucifera) and consists hemicellulose and lignin as the bonding materials that form the cellulosic fibers [17]. Some physical, chemical and mechanical properties of coir fiber compared with other typical natural fibers such as flax, hemp, jute, ramie and sisal as shown at Table 2. Coir fiber has low cellulose and hemicellulose, high lignin content and high microfibrillar angle compared with other natural fibers.

Table 2. Physical, chemical and mechanical properties of coir fiber compared with other natural fibers [17].

| Properties/fibers       | Coir          | Flax          | Hemp          | Jute          | Ramie         | Sisal         |
|-------------------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Density (g/m³)          | 1.25–1.5      | 1.4           | 1.48          | 1.45          | 1.5           | 1.26–1.33     |
| Diameter (lm)           | 100–450       | 100           | 25            | 60            | 40–50         | 100–300       |
| Cellulose content (%)   | 36–43         | 62–72         | 67–75         | 59–71         | 68–76         | 74–75.2(B)    |
| Hemicellulose content (%)| 0.2           | 16–18         | 16–18         | 12–13         | 13–14         | 10–13.9       |
| Lignin content (%)      | 41–45         | 2–2.5         | 2.8–3.3       | 11.8–12.9     | 0.6–0.7       | 8–12(I)       |
| Microfibrillar angle    | 30–45         | 10            | 6.2           | 7–9           | 7.5–12        | 7.6–7.98(B)   |
| Tensile strength (MPa)  | 105–175(I)    | 800–1500      | 550–900       | 400–800       | 500–870       | 600–700       |
| Young’s modulus (GPa)   | 95–118(B)     | 4–6(I)        | 60–80         | 70            | 10–30         | 44            |
| Elongation at break (%) | 17–47(I)      | 1.2–2.4       | 1.6           | 1.16–1.8      | 1.2           | 3.64–5.12(I)  |
| Moisture absorption (%) | 23.9–51.4(B)  | 10            | 7             | 8             | 12            | 12–17         |

Coir fibers usually were treated before used using various chemical such as ethylene dimethylacrylate (EMA) and sodium hydroxide (NaOH) [17-19]. The treatment of coir fiber often decrease the tensile strength of the fiber. Tensile is the important element to control cracking in concrete structure. Eventhough the tensile of fiber decrease, the treatment of fiber improve the fiber/matrix adhesion [19-20].

The concrete structure also applied the coir fiber as the fiber-reinforcement. Lightweight, strong, cheap and green approach are the main reason why the coir fiber was chose [21]. Some previous studies
shown that the increase of fiber content resulting the decreasing of panel density and also increasing the flexural properties of concrete structure [22].

4. Precast Self-Compacting Concrete (PSCC) Panel

This paper focuses on the overview of the precast self-compacting concrete panel subjected to flexural load. The precast self-compacting concrete (PSCC) panel studied by the authors is added with coir fibers will be conducted to analyse the effect of coir fibers to the flexural strength and crack propagation.

The behaviour of precast panels are often extrapolated from the behaviour of the reinforced concrete solid panels. The studies on previous experimental works have a similar conclusion that is the slenderness ratio will determine type of failure mode. Slenderness ratio is determined by the height over panel thickness ratio, (H/t). It was reported that for small H/t ratios, crushing failures occurred, whereas for higher slenderness ratio, buckling or horizontal centreline failure were common. Crushing failure may occur either at the top or the bottom of the panel [23-24].

Previous studies regarding the precast panels indicates the importance of composite manners of panels fabricated. Precast sandwich wall panel shows the composite behaviour of combination of various materials that are foam concrete, normal concrete, steel reinforcement and polystyrene. The composition of these materials resulting the decreasing of mechanical strength of precast panel. The effect of slenderness ratio on the ultimate load of precast panel was also investigated [25-28].

Noridah et. al. [29] had studied about precast sandwich panel subjected under flexural load. Various specimen with shear connector of 6mm and 9mm had been cast and tested to determine its flexural behaviour. After series of testing, researchers found that the ultimate flexural load was influenced by the compressive strength and thickness of the panel. The cracking of the panel was started at the midspan later spread towards left and right zone of panel.

There also previous research that studied about the composite behaviour of insulated concrete sandwich wall panels (ICSWP) subjected to wind pressure and suction [30]. The specimens was casts full-scaled with different type of insulation and number of glass-fiber-reinforced polymer (GFRP) shear grid. The results show that bonds based on insulation surface roughness were effective under both positive and negative loading test. The calculation of ICWSP’s design strength used the composite behaviour based on surface roughness due to those particular reason.

4.1 Finite element analysis

Finite element analysis (FEA) is an analytical tool that being used with aid of computer software or program. FEA is use to predict the behaviour and response of certain engineering system. The solution of FEA is obtain using the numerical approach that provides a powerful mean result by simulating the panel under various condition. The complicated structural structure under general loading can be predicted its field quantities by using the FEA. Besides, the large number of components in structure are not the problem when using the FEA. The accuracy of FEA is bounded by all assumptions it takes and the inherent numerical error it carries. There are several finite element analysis software that been often used by researcher such as LUSAS and ABAQUS. However, lab testing is still necessary to verify the accuracy of FEM model.

Some example of LUSAS software usage is the composite precast concrete sandwich panel under flexure [25]. Different aspect ratio of slabs were used as parametric of study. A two dimensional nonlinear model that acting as one-way panel and three dimensional nonlinear model acting as two-way panel with having shear connectors spanning in both directions were simulated. Placement of shear connectors in both direction resulting better load distribution in the panel. The increment of shear connectors increasing the ultimate load.

There also research used the ABAQUS software that studied the behaviour of reinforced concrete slabs subjected to impact loading [31]. The response such as time-impact force graph, damage wave propagation, effectiveness of mesh density, effect of projectile size and final crack pattern were verified against existing experimental results. It is shown that the FEA is able to simulate and predict the impact behaviour of structural systems satisfactorily.
Other researchers also used ABAQUS to study pre-stressed concrete sandwich panels subjected to blast loads [32]. FEA used to analyse static and dynamic behaviour of foam insulated concrete sandwich wall panels through ultimate capacity. The experimental program used for model development and validation involved both static and dynamic testing of full scale wall panels.

5. Conclusion

Nowadays, precast panel had been applied in construction industry widely via Industrialised Building System (IBS) due to its advantages. There are many research on the behaviour of precast panel under various condition and load. PSCC panel is a precast system that fabricated from self-compacting concrete with added of coir fibers. PSCC panel will be subjected to flexural load to study its flexural behaviour. The failure of PSCC panel under flexural load are influenced the crack propagation on the structure. The coir fibers addition are expected to control the crack propagation on the panel.

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References

[1] EFNARC. 2005 Specification and guidelines for self-compacting concrete The European Federation of Specialist Construction Chemicals and Concrete Systems. May 2005 www.efnarc.org
[2] Consortium S C C. 2008 Guidelines for execution of SCC Danish Technological Institute. https://www.dti.dk
[3] Okamura H and Ouchi M 2003 Self-Compacting Concrete, J. Adv. Concr. Technol., 1, 5–15.
[4] Su N, Hsu K C, and Chai H W 2001 A simple mix design method for self-compacting concrete, Cem. Concr. Res., 31, 1799–1807.
[5] Kumar V 2015 Study of Mix Design of Self Compacting Concrete, Int. Res. J. Eng. Technol., 2, 1076–1078.
[6] Zainal Abidin N E, Wan Ibrahim M H, Jamaluddin N, Kamaruddin K, and Hamzah A F 2015 The Strength Behavior of Self-Compacting Concrete Incorporating Bottom Ash as Partial Replacement to Fine Aggregate, Appl. Mech. Mater., 773–774, 916–922.
[7] Murthy N K, Rao A V N, Reddy I V R, and Reddy M V S 2012 Mix Design Procedure for Self Compacting Concrete, IOSR J. Eng., 2, 33–41.
[8] Rahim N H A, Mohamad N, Samad A A A, Goh W I, Jamaluddin N 2017 Flexural Behaviour of Precast Aerated Concrete Panel (PACP) with Added Fibrous Material: An Overview. MATEC Web Conf. 103
[9] Yusof M F 2006 Study on Construction & Demolition Waste Management in Construction Site. Bsc, Thesis Universiti Malaysia Perlis Malaysia.
[10] Ramakrishna G and Sundararajan T 2005 Impact Strength of a Few Natural Fibre Reinforced Cement Mortar Slabs: A comparative Study. J. Cement Concrete Composite, 27, 547-553.
[11] Ramakrishna G and Sundararajan T 2005 Studies on the Durability of Natural Fibres and the Effect of Corroded Fibres on the Strength of Mortar. Cement Concrete Composites, 27, 575-582.
[12] Agopyan V, Savastanojr H, John V, and Cincotto M 2005 Developments on Vegetable Fibre-cement Based Materials in Sao Paulo, Brazil: An Overview. J. Cement Concrete Composite, 27, 527-536.
[13] Fernandez J E 2002 Flax Fibre Reinforced Concrete - A Natural Fibre Bio Composite for Sustainable Building Materials, in High Performance Structures and Materials. Editors Seville. 193-207.
[14] Li Z, Wang L, and Wang X. Cement Composites Reinforced with Surface Modified Coir Fibres.
Li Z, Wang X, and Wang L 2006 Properties of Hemp Fibre Reinforced Concrete Composites. Composite, Part A. Appl. Sci. Manuf., 37 497-505.
[16] Toledo Filho R D, Khosrow G, Sanjuan M A, and George L E 2005 Free, Restrained and Drying Shrinkage of Cement Mortar Composites Reinforced with Vegetable Fibres. J. Cement Concrete Composite. 27, 537-546.
[17] Nam T H, Oghiara S, Tung N H, and Kobayashi S 2011 Effect of alkali treatment on interfacial and mechanical properties of coir fiber reinforced poly(butylene succinate) biodegradable composites, Compos. Part B Eng., 42, 1648–1656.
[18] Rahman M M, and Khan M A 2007 Surface treatment of coir (Cocos nucifera) fibers and its influence on the fibers’ physico-mechanical properties. Composites Science and Technology, 67, 2369–2376.
[19] Gu H 2009 Tensile behaviours of the coir fibre and related composites after NaOH treatment. Materials and Design, 30, 3931–3934.
[20] Asasutjarit C, Charoenvai S, Hirunlabh J, and Khedari J 2009. Materials and mechanical properties of pretreated coir-based green composites. Composites Part B: Engineering, 40, 633–637.
[21] Harish S, Michael D P, Bensely A, Lal D M, and Rajadurai A 2009 Mechanical property evaluation of natural fiber coir composite. Materials Characterization, 60, 44–49.
[22] Azmi M A, Yusoff M F C, Abdullah H Z, and Idris M I 2012 Rigid Polyurethane Foam Reinforced Coconut Coir Fiber Properties. International Journal of Integrated Engineering, 4, 11–15.
[23] Mohamad N 2010 The Structural Behaviour of Precast Lightweight Foamed Concrete Sandwich Panels As Load Bearing Wall. Ph.D Thesis. Universiti Teknologi Malaysia.
[24] Goh W I 2015 Structural Behaviour of Precast Lightweight Foamed Concrete Sandwich Panel (PLFP) With Shear Truss Connectors. Ph.D Thesis. Universiti Tun Hussein Onn Malaysia.
[25] Benayoune A, Samad A A A, Abang Ali A A and Trikha D N 2007 Response of pre-cast reinforced composite sandwich panels to axial loading. Construction and Building Materials, 21, 677-685.
[26] Liew H K 2010 The Strain and Stress Distribution of Precast Lightweight Foamed Concrete Sandwich Panel under axial loading. Bsc, Thesis. Universiti Tun Hussein Onn Malaysia.
[27] Mohamad N, Omar W and Abdullah R 2011 Precast Lightweight Foamed Concrete Sandwich Panel (PLFP) Tested Under Axial Load: Preliminary Results. Advanced Materials Research. 250-253, 1153-1162.
[28] Mohamad N and Mahdi M H 2011 Testing of Precast Lightweight Foamed Concrete Sandwich Panel With Single and Double Symmetrical Shear Truss Connectors Under Eccentric Loading. Advanced Materials Research. 335-336, 1107-1116.
[29] Mohamad N, Khalil A I, Samad A A A, and Goh W I, 2014 Structural behavior of precast lightweight foam concrete sandwich panel with double shear truss connectors under flexural load, ISRN Civ. Eng.,
[30] Choi I, Kim J H and Kim H R 2015 Composite behavior of insulated concrete sandwich wall panels subjected to wind pressure and suction, Materials (Basel), 8, 1264–1282.
[31] Mokhtar S N and Abdullah R 2012 Computational analysis of reinforced concrete slabs subjected to impact loads. Int. J. of Integrated Engineering. 4, 70-76.
[32] Newberry C M, Hoemann J M, Bewick B T and Davidson J S 2010 Simulation of prestressed concrete sandwich panels subjected to blast loads. Preprint.