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USE OF OPS CONCRETE IN SEMI-PRECAST CONCRETE SLAB

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ABSTRACT

Malaysia produces more than half of the world's output of palm oil, planted over 4.05 million hectares of land, yielding about 18.88 tonnes per hectare of fresh fruit branches (FFB). The palm oil extraction produces large quantities of waste namely fibre, shell and effluent which are usually disposed by incineration or left to rot. This pollutes the environment and is harmful to the ecosystem. The results reported here are from a research project funded by the Construction Industry Development Board (CIDB) Malaysia, that aims to utilise processed Oil Palm Shell (OPS) as aggregate in making OPS concrete semi-precast flooring slabs. Utilising OPS in concrete saves the problem of disposing the solid waste while conserving the natural aggregates that would have been used otherwise. Sandstone was used as coarse aggregate for the bottom layer of concrete in the semi-precast slab. Coarse aggregates such as granite, sandstone and OPS were used for the cast-in-situ top layer of concrete. The thickness of bottom and top layers were 50mm and 75mm respectively. A total of six slabs with different toppings were cast and tested. Data presented include the characteristics of deflection and cracking behavior. The results showed that the semi-precast slab with topping of OPS concrete deflected maximum (94 mm) compared to similar slabs with toppings of granite concrete (70 mm) and sandstone concrete (71 mm). The investigation also revealed that the type of topping did not affect the strength of the slab significantly. The flexural behavior of all the three types of semi-precast slabs complied with the requirements specified by the current Codes of Practice. Semi-Precast slab with the topping of OPS concrete has an added advantage that it is lightweight, thereby reducing the cost of construction.

Keywords: *OPS, semi- precast, experimental analysis*

INTRODUCTION

Malaysia is a major producer of oil palm with more than half of the world's production. The production of palm oil result in by products such as fibre, shells and effluent that pollute the environment and thus are harmful to the ecosystem. Utilising OPS in concrete saves the problem of disposing the solid waste while conserving the natural aggregates that would have been used otherwise. Due to the increased level of construction in Malaysia at present and in future, it is expected that suitable aggregates for use in concrete will become scarce or even expensive to produce. Therefore, in places with scarcity of suitable materials, economic consideration may necessitate experimenting with suitable locally available substitute materials.

MATERIALS

The cement used was ordinary Portland Cement (OPC), according to ASTM Type 1 [1]. The coarse aggregates used were granite and sandstone available locally in Sabah. The maximum size of coarse aggregate used was 15mm. The fine aggregates used were river sand and crushed sandstone sand with fineness modulus of 1.78.

Properties of Aggregates

Sandstone and granite are inorganic materials [2] while OPS is an organic material. The properties of granite and sandstone are shown in Table 1. From Table 1 it can be observed that the OPS aggregate is porous in nature and has low bulk density. The high value of water absorption necessitated special preparation of OPS to be used in concrete. The OPS was first soaked in water for 24 hours and then surface dried. The low bulk density is an

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advantage in producing lighter concrete. The aggregate impact value (AIV) for OPS aggregate was only about half of that for granite and sandstone and hence resulted in better capacity to absorb shock.

Table 1: Properties of Aggregates

Properties	Sandstone aggregate	OPS aggregate	Granite aggregate
Maximum Size	15 mm	15 mm	15 mm
Shell thickness	N/A	0.5-3.0 mm	N/A
Bulk Density	1450 kg/m^3	590 kg/m^3	1490 kg/m^3
Specific gravity (SSD)	2.58	1.17	2.63
Fineness Modulus	6.34	6.08	6.68
Los Angeles Abrasion Value	21.20	4.90 %	20.30 %
Aggregate Impact Value [3]	13.58 %	7.51 %	13.95 %
Aggregate Crushing Value [4]	21.20 %	8.00 %	19.00 %
24-hour Water Absorption	1.53 %	33.0 %	0.97 %

Properties Of Concrete

Three types of semi-precast slabs were used for this study varying the coarse aggregates used for the 75 mm thick topping, namely granite, sandstone and OPS. As the densities of these toppings were 2400 kg/m^3, 2060 kg/m^3 and 1710 kg/m^3 respectively and as the precast bottom portion 55 mm thick was made of sandstone concrete, these three semi-precast slabs worked out to have an equivalent density of 2250 kg/m^3, 2060 kg/m^3 and 1850 kg/m^3 respectively. Hence, it can be observed that the use of OPS topping resulted in a weight reduction of 23% for the whole slab, which is very close to the lightweight concrete (1800 kg/m^3).

A 1500 kN compression test machine was used to test the concrete cubes. The load was applied without shock and increased continously at a constant rate of 15 MN/m^2/mm until the concrete cube could not sustain any more loads. This test was conducted in accordance to BS 1881: Part 116:1983 [5,6]. Figure 1 shows the development of compressive strength of concrete made of sandstone, OPS and granite as coarse aggregate.

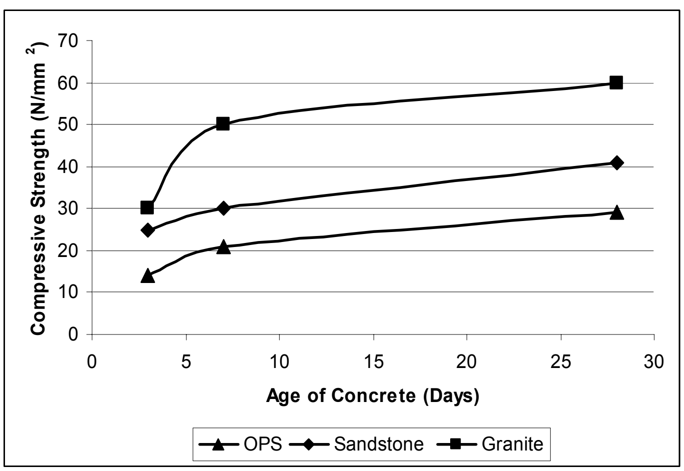

Figure 1: Development of compressive strength of concrete made with different aggregates

EXPERIMENTAL PROGRAMME AND SET UP

The testing programme included 3 slabs having precast part made of sandstone concrete. The toppings were different and are shown in columns 1 and 2 of Table 2. Slabs were 3 m long, 1 m wide and 130 mm thick. The slabs were cast with bottom layer 55 mm thick and toppings 75 mm thick. Four Y-10 bars at bottom and two Y-10 bars at top, connected by R-6 diagonals formed two lattice girders at a spacing of 500 mm as shown in Figure 2. B5 mesh was used as the bottom reinforcement. The experimental set up is shown in Figures 3 and 4.

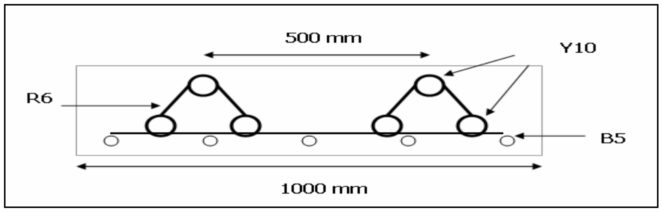

Figure 2: Arrangement of reinforcement

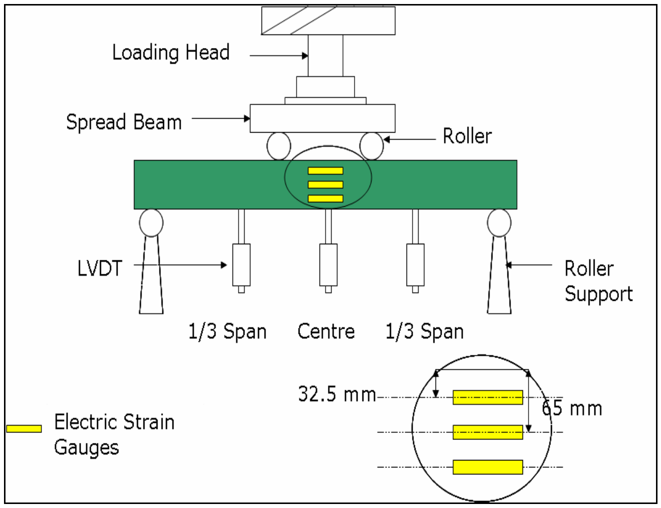

Figure 3: Experimental set up for slab test

Figure 4: Photograph of test set-up

RESULTS AND DISCUSSIONS

Maximum Loads

Table 2 shows the failure loads for the semi-precast slabs with concrete topping using different types of aggregates. From the observations, it is concluded that semi-precast slab with sandstone topping resisted a load of 64.70 kN, while the slabs with granite and OPS toppings resisted 63.55 kN and 59.00 kN respectively.

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Crack Behaviour

During the slab testing, at every 5 kN increment of loading, the cracks were observed using magnifier. It was observed that the cracks began to form when the load reached 10-15 kN. The number of cracks occurring between the loading points and outside the loading points was recorded at every interval of loading until the slab eventually failed. After the test, the spacing of cracks was recorded. The crack behaviour of the different slabs was as shown in Table 2. The slab with granite topping had the highest average crack spacing of 142.5 mm, while the slabs of OPS and sandstone toppings had an average crack spacing of 126.8 mm 125.5 mm respectively.

Table 2: Crack Behaviour in Different Slabs

Slab	Type of Topping	Average Crack Spacing (mm)	No. of cracks between load points	No. of cracks outside loading points	Average crack distance from the edge (mm)	Failure Load (kN)
S1	OPS	126.8	9	7	554.50	59.00
S2	Granite	142.5	8	7	716.00	63.55
S3	Sandstone	125.5	9	6	558.50	64.70

From Figure 5, it can be observed that the vertical cracks propagated almost to the top surface of the slab without any break or discontinuity at the interfacebetween the precast part and the topping. This proves a very good composite action. In similar slabs tested without the lattice girders, cracks were observed to develop horizontally at the interface indicating lack of composite action.

Figure 5: Photograph of cracks propogation

Deflection

The deflections of the slabs were measured using four LVDTs [7]. Two LVDTs (50 mm maximum displacement) were placed at the one-third span points of the slab while the other two LVDTs (100 mm maximum displacement) were placed at the mid span. The deflections of the slab were recorded at load increments of 2 kN up to 12 kN load and at load intervals of 5 kN after that. The moment at mid span versus deflections at mid span and at one-third span for the semi precast slabs with different types of topping are shown in Figures 6 and 7. It can be observed that the slab with OPS topping had the maximum deflection at all load values at both mid span and at one-third span of the slab. This is because of the low value of the modulus of elasticity for OPS concrete.

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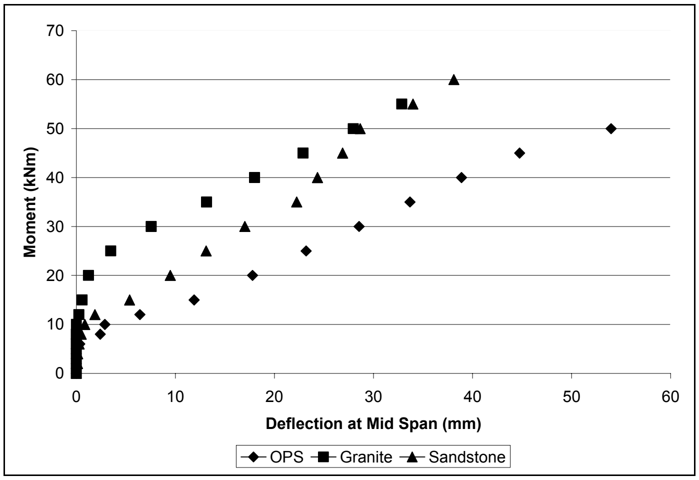

Figure 6: Moment at midspan Vs deflection for different types of topping

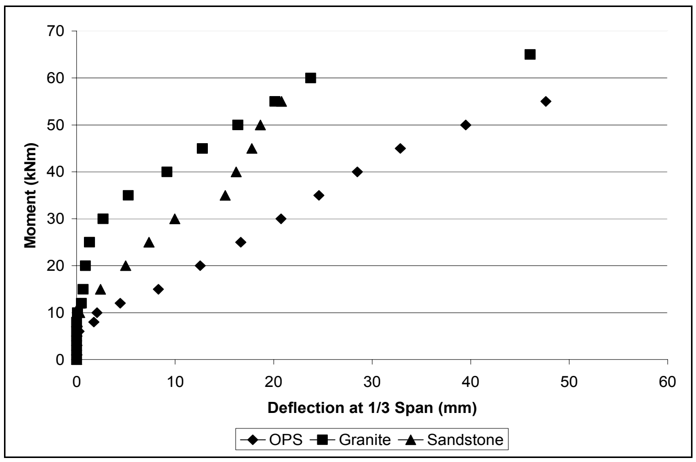

Figure 7: Moment Vs deflection at 1/3 Span for different types of topping

Strain Distribution

Strain gauges were fixed on the slabs at mid span at 1/3, centre and 2/3 of the slab thickness. Also, two strain gauges were placed on the bottom and top steel bars at 1/3 span and at midspan [7]. From the readings of these strain gauges, the strain distribution along the depth of the slab at the mid span is plotted in Figures 8 to 10. The strain distribution confirms the composite behaviour of the slab. In other words, the top layer and the bottom layer are integrating as one full composite section. From the figures, it can be observed that the distance of the neutral axis from the top of the slab is about 44 mm for OPS topping, about 47 mm for granite topping and about 58 mm for sandstone topping.

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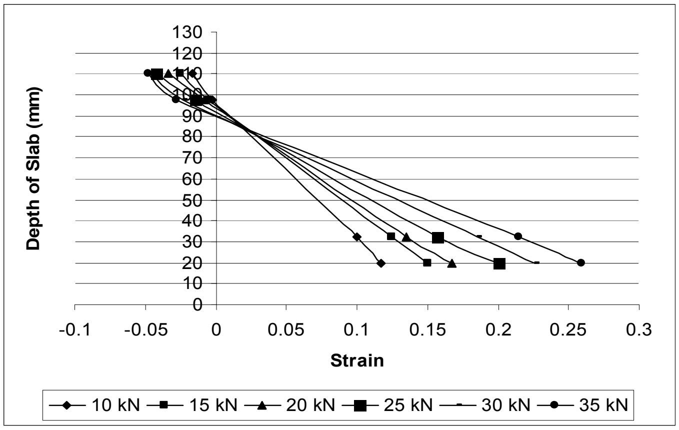

Figure 8: Strain distribution at mid span for OPS topping slab

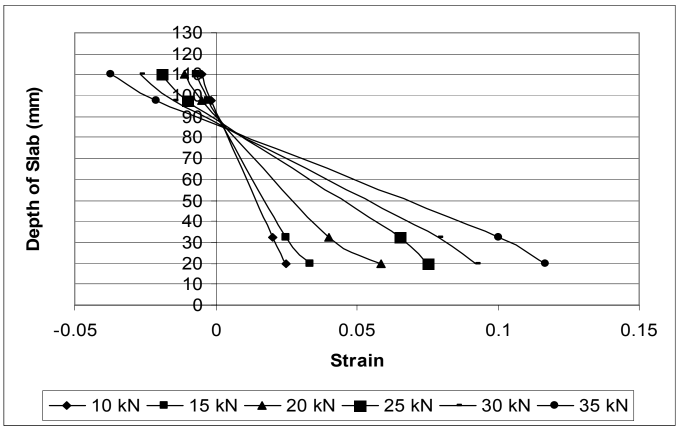

Figure 9: Strain distribution at mid span for granite topping slab

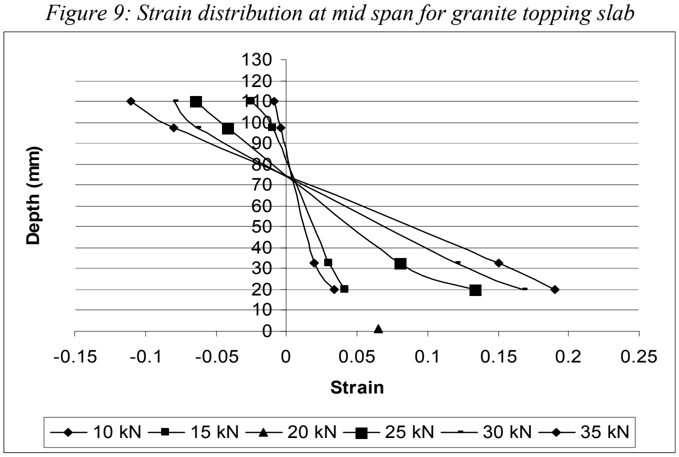

Figure 10: Strain distribution at mid span for sandstone topping slab

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CONCLUSIONS

From the results discussed above, it is concluded that

a. The usage of OPS as coarse aggregates for the topping layer of the semi-precast slab resulted in a reduction of only 10% in the load capacity when compared to that with sandstone and granite toppings. Therefore, OPS concrete can be a potential topping as it fulfils the minimum criteria for compressive strength of concrete used in slab which is >25 N/mm^2.
b. The average crack spacings of the slab with OPS toppings were very close with the spacings given by the slabs with sandstone topping.
c. The semi-precast slab with concrete topping made of OPS aggregate had more deflections compared with the slabs with the other two toppings. Yet, the deflections were within permissible limits.
d. The crack pattern and the strain distribution of the semi-precast slabs tested confirmed a very good composite action between the precast part and the toppings.

ACKNOWLEDGEMENT

The authors express their sincere gratitude to the Universiti Malaysia Sabah for the facilities for the research and to Universiti Teknologi PETRONAS for registering this paper to be presented at WEC2007. This project was funded by Construction Industry Development Board Malaysia (project no. LPIPM: CREAM/UPP04-02-10-04-11).

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