FLEXURAL BEHAVIOUR OF OIL PALM SHELL CONCRETE IN FULLY PRECAST AND SEMI-PRECAST CONCRETE SLABS

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ABSTRACT:.

Six precast and six semi-precast slabs with different toppings were cast and tested for determining the flexural behaviour of concrete made using OPS (oil palm shell) as coarse aggregate. The vertical cracks in the semi-precast slabs propagated almost to the top surface of the slab without any break or discontinuity at the interface, confirming a good composite action in the slab. The investigations revealed that the type of topping did not affect the strength of the slab significantly. While OPS concrete by itself failed the deflection criterion when tested as a fully precast slab, it satisfied the requirements when used as a topping for the semi-precast slab.

***Keywords**:* OPS, semi-precast, laboratory tests, toppings, cracks

1. INTRODUCTION

Malaysia is the main producer of oil palm in the world. The production of oil palm result in large quantity of waste which are harmful to the environment and thus to the ecosystem. The waste material is usually disposed by incineration or left to rot[1,2,3]. A research project funded by the Construction Industry Development Board (CIDB) Malaysia aims to utilise processed Oil Palm Shell (OPS) as aggregate in making OPS concrete precast and semi-precast flooring slabs. The use of OPS in concrete saves the problem of disposing the solid waste while conserving the natural aggregates[4]. Granite and sandstone are the conventional aggregates used for the precast and semi-precast slab[5,6].

Precast technologies namely fully precast and semi-precast have been widely used in the construction sector particularly in the developed countries[7]. It offers off-site production of high strength and durable units, fast erection of long-span slabs on site, reduction of the labour cost and high standard of quality. Semi-precast elements solve the problem of heavy precast slabs that are difficult to transport requiring heavy machineries for lifting[7]. Semi-precast panels serve as permanent formwork that composite with cast-in-situ concrete. Steel lattice girders are used to shear-connect the semi-precast bottom part and the cast-in-situ topping. In this study, precast and semi-precast slabs using coarse aggregates such as granite, sandstone and OPS, have been cast and tested with the objective of appraising the comparative performance of OPS concrete.

2. PROPERTIES OF CONCRETE

Six precast slabs 130 mm thick, two each made of granite, sandstone and OPS were cast. The density of granite concrete was 2400 kg/m^3, that of sandstone concrete was 2060 kg/m^3, and that of OPS concrete was1710 kg/m^3. Also, six semi-precast slabs were cast. The semi-precast bottom panel of 55 mm were made of sandstone concrete and were topped up with concrete made of granite, sandstone and OPS. The equivalent density of semi-precast slab for granite topping, sandstone topping and OPS topping worked out to 2250 kg/m^3, 2060 kg/m^3 and 1850 kg/m^3 respectively. It could be observed that the use of OPS topping resulted in a weight reduction of 23% for the whole slab, bringing it very close to the lightweight concrete density of 1800 kg/m^3.

The 28-day cube strength of the granite concrete was 60 N/mm^2, of the sandstone concrete was 42 N/mm^2 and that of the OPS concrete was 29 N/mm^2. Figure 1 shows the development of compressive strength of concrete made of sandstone, OPS and granite as coarse aggregates.

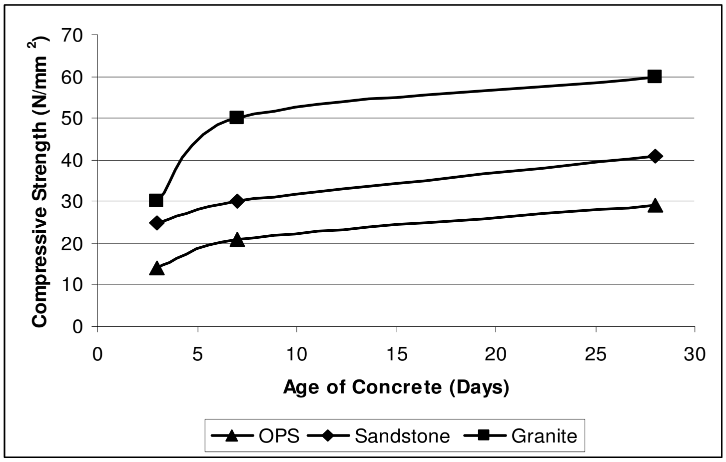

Figure 1: Development of Compressive Strength of Concrete

3. EXPERIMENTAL PROGRAMME AND SET UP

The testing programme included six precast slabs and six semi-precast slabs having precast part made of sandstone concrete. Slabs were 3 m long, 1 m wide and 130 mm thick. The semi-precast slabs were cast with bottom layer 55 mm thick and toppings 75 mm thick, while the precast slab was cast with 130 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 Figure 3. Two-point loading was applied.

The cement used was ordinary Portland Cement. The coarse aggregates used were granite, sandstone and OPS available locally in Sabah. Coarse aggregate of maximum size 15 mm was used[8]. The fine aggregates used were river sand and crushed sandstone sand with fineness modulus of 1.78.

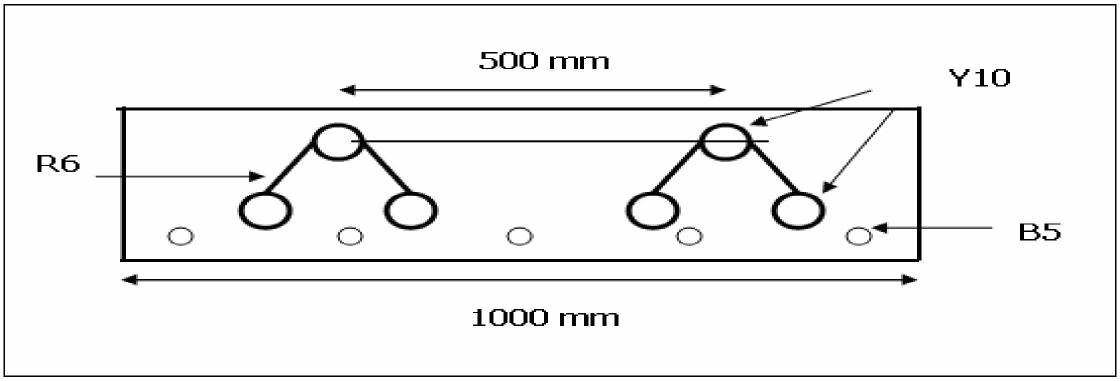

Figure 2: Arrangement of reinforcement

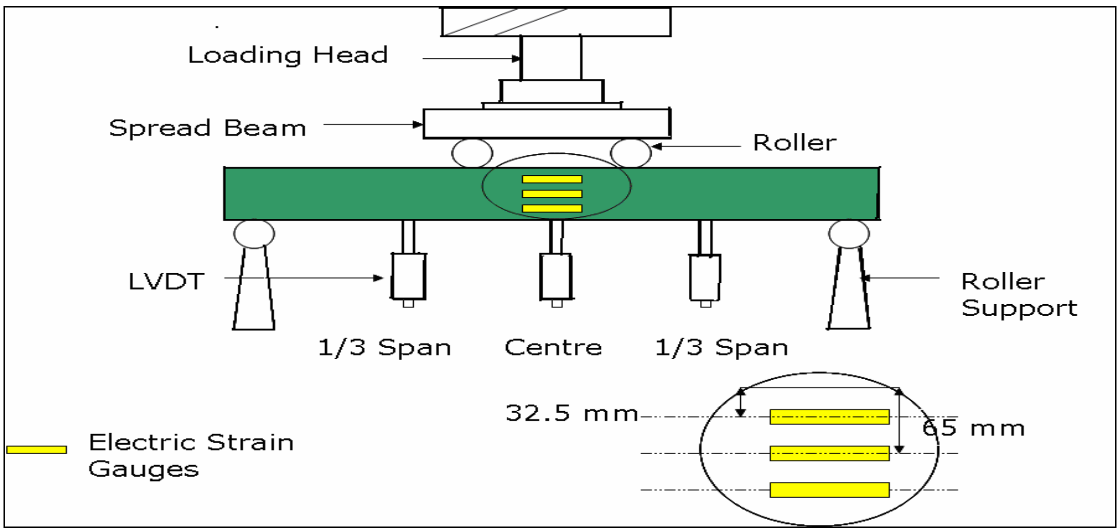

Figure 3: Experimental set up for slab test

4. TEST RESULTS AND DISCUSSION

4.1 Failure Loads

Table 1 shows the failure loads for precast and semi-precast slabs with concrete topping using different types of aggregates. The precast slab made of granite took a maximum load of 69 kN, followed by sandstone 60 kN and OPS 32 kN. It can be seen that the failure load was nearly same for all the three semi-precast slabs.

4.2 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 a value of 10 to 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 are shown in Table 1.

Table 1: Crack Behaviour in Different Slabs

	Semi precast / Precast	Concrete Topping	Average Crack Spacing (mm)	No. of cracks between load points	Average crack distance from the edge (mm)	Failure Load (kN)
S1	Sandstone (55mm)	Granite	142.5	8	716.0	63.55
S2	Sandstone (55mm)	Sandstone	125.5	9	558.5	60.70
S3	Sandstone (55mm)	OPS	126.8	9	554.5	59.00
S4	Granite (130mm)	N/A	160.3	8	498.5	69.12
S5	Sandstone (130mm)	N/A	148.0	10	498.2	59.64
S6	OPS (130mm)	N/A	82.0	19	554.0	31.76

In general, the precast slabs have higher average crack spacing. The crack behaviour of OPS concrete in precast and semi-precast slabs could be observed as much weaker compared to the other concretes.

Figure 4: Photograph of cracks propagation

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 interface between 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.

4.3 DEFLECTION

The deflections of the slabs were measured using two LVDTs (200 mm) 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 Vs deflection plots for the different slabs are shown in Figure 5. It could 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. All the slabs except the fully precast OPS slab satisfied the deflection requirements.

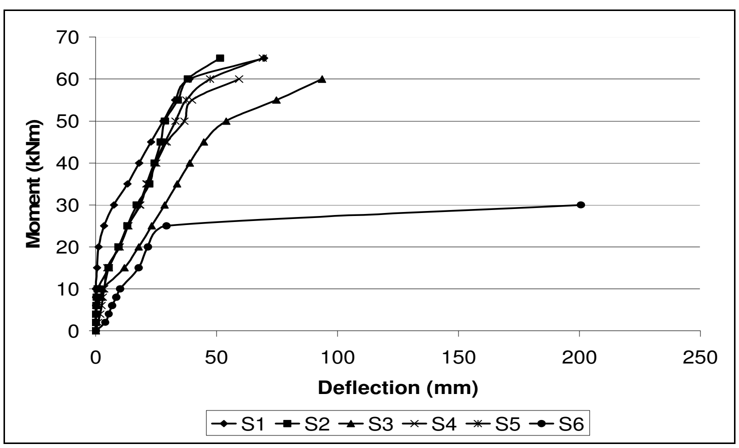

Figure 5: Moment at midspan Vs deflection for different type of slab

4.4 Strain Distribution

Strain gauges were fixed on the slabs at various distance along the thickness. From the readings of these strain gauges, the strain distribution along the depth of the slab at the mid span are plotted in Figures 6 to 11. The strain distribution confirms the composite behaviour of the semi-precast slab where the top layer and the bottom layer are integrating as one full composite section or monolithic.

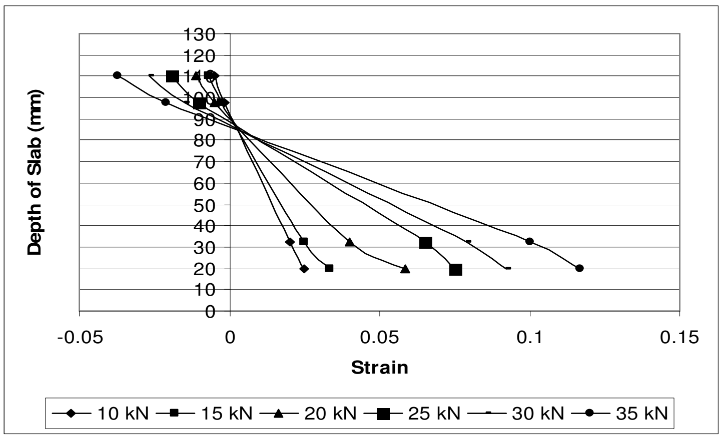

Figure 6: Strain distribution at mid span for granite topping slab

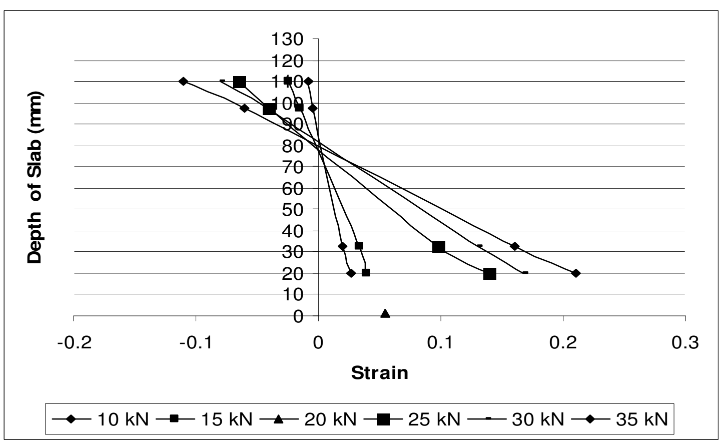

Figure 7: Strain distribution at mid span for sandstone topping slab

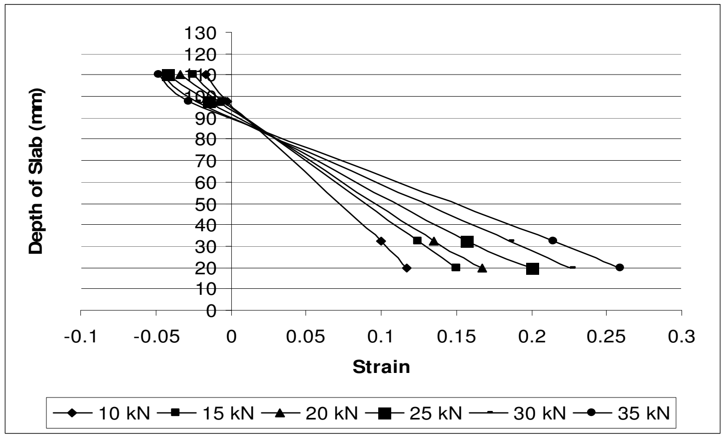

Figure 8: Strain distribution at mid span for OPS topping slab

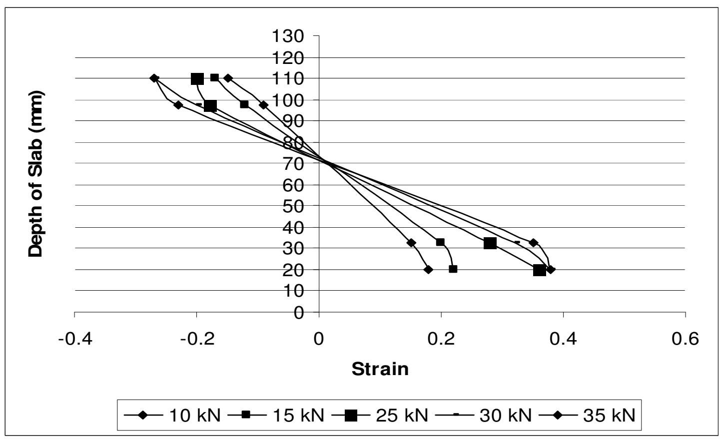

Figure 9: Strain distribution for granite precast slab

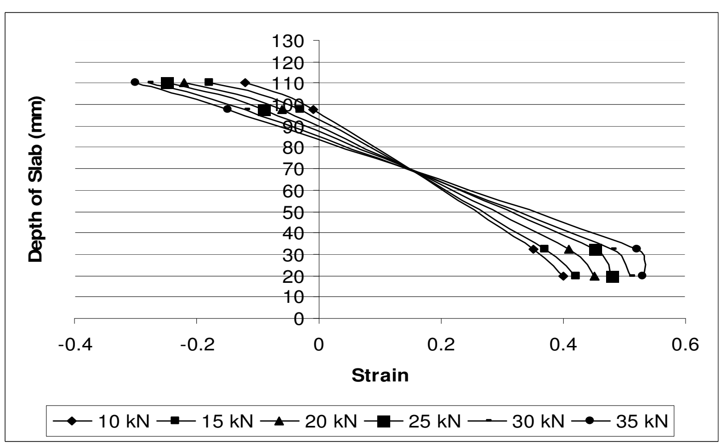

Figure 10: Strain distribution for sandstone precast slab

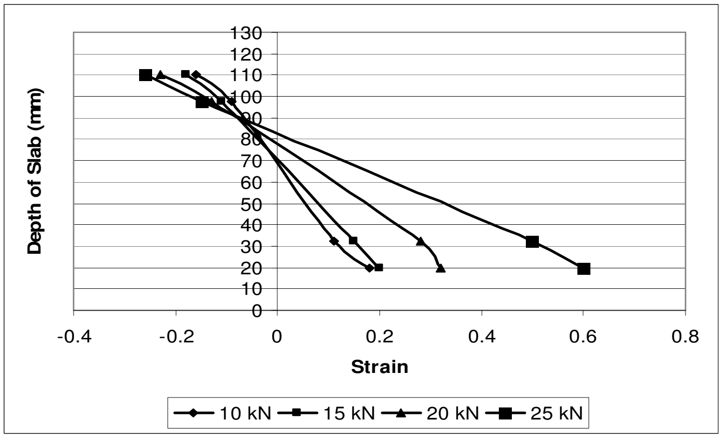

Figure 11: Strain distribution at mid span for OPS precast slab

4.5 Ductility Indices

Ductility is termed as the ability of a material to sustain deformation beyond the elastic limit while maintaining a reasonable load carrying capacity before failure. Ductility is measured by the ductility index which is the ratio of deflection and curvature at ultimate load to the corresponding values at yield[9]. The deflection ductility (μ_δ) and curvature ductility (μ_φ) are shown in Table 2. Moment-curvature relations for different slab are shown in Figure 12. The yield and ultimate values of deflection and curvature were obtained from the curves of load Vs deflection and load Vs curvature. The end rotation gradually reduces with the appearance of cracks until cracking reach a stabilized pattern. It could be observed that the ductility values are very high for fully OPS slab.

Table 2: Ductility and End Rotation for the Slabs

Slab	At yielding		At ultimate load		$\mu_\delta = \delta_u / \delta_y$	$\mu_\varphi = \varphi_u / \varphi_y$	End Rotation (degree)
	Deflection δ_y (mm)	Curvature φ_y (rad/m)	Deflection δ_u (mm)	Curvature φ_u (rad/m)			
OPS Top	74.70	0.0208	93.60	0.0300	1.28	1.44	2° 21’ 00”
Sandstone Top	38.12	0.0225	51.48	0.0500	1.35	2.22	2° 25’ 22”
Granite Top	38.83	0.0250	69.67	0.0480	1.79	1.92	2° 35’ 38”
OPS	36.26	0.0039	200.57	0.0170	5.53	4.36	1° 56’ 50”
Sandstone	38.86	0.0123	59.31	0.0230	1.53	1.87	2° 34’ 56”
Granite	39.47	0.0255	69.12	0.0469	1.15	1.84	2° 35’ 45”

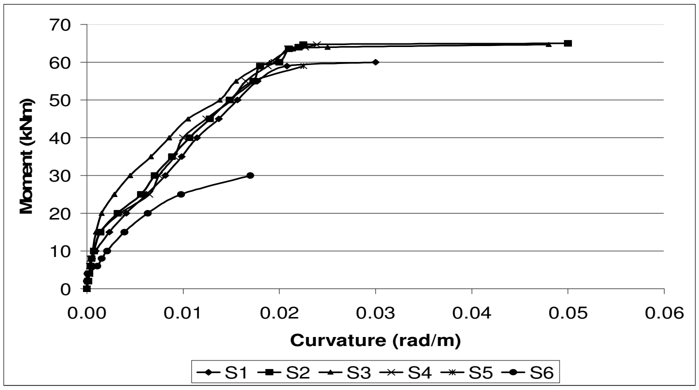

Figure 12: Moment-Curvature Relations for Semi Precast Slabs

6. CONCLUSIONS

From the results discussed above, it is concluded that

a. Although the OPS precast slab fulfils the minimum criteria for compressive strength of concrete used in slab which is >25 N/mm^2, the deflection and ductility values are high and fail to meet the criteria. Hence, OPS concrete has no potential to be used for making fully precast slabs.

b. The use of OPS as coarse aggregate for semi-precast topping did not affect the load capacity significantly. Also, it satisfied the deflection criteria. Hence, OPS concrete has very good potential to be used as topping for semi-precast slabs. It has the added advantage that it maked the slab lighter by about 25%.

c. The semi-precast slabs having bottom panels and toppings shear-connected with lattice girders have good composite action as observed from the crack behaviour and the strain distribution.

7.

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