International Research Journal in Global Engineering and Sciences. (IRJGES)
ISSN : 2456-172X | Vol. 9 Issue 1 - March 2024 to May 2024| Pages 17-24

STUDY ON DUCTILITY BEHAVIOUR OF PALM KARNEL SHELL CONCRETE AND NORMAL WEIGHT CONCERETE

K. ARUMUGAM[1], SIVARAJAN[2], SHAUNMUGAM[1]

1- Assistant Professor, Department of Civil Engineering, Sethu Institute of Technology, Kariapatti, Virudhunagar

2- PG Scholar, Structural Engineering, Sethu Institute of Technology, Kariapatti, Virudhunagar

ABSTRACT

This paper presents the results on the structural behavior of palm kernel shell concrete and its comparison with normal weight concrete (NWC). The structural grade palm kernel shell concrete, a lightweight concrete (LWC) produced using palm kernel shell(PKS) an agricultural waste and by-product of the production of palm oil as lightweight aggregate, referred to hereafter as PKSC. The concrete is of grade 30 and the reinforced concrete beams of size 150 mm x 250 mm x 2100 mm were prepared to study the structural behavior. Similar grade concrete using NWC were also prepared and reinforced. The flexural behavior of under-reinforced concrete beams of grade 30 concrete has been studied and the results are compared with NWC beams which were also designed as grade 30 and under-reinforced similar to that of the PKSC beams. Ten percent of silica fume and five percent of class-F fly ash on cement weight were used as additional and cement replacement cementations materials respectively. Each beam was tested under two-point loading for flexure until failure. It has been observed from the experimental investigation of the beams, that the moment capacity of PKSC beams was higher than NWC beams by about three percent. In addition, the mode of failure observed in PKSC was ductile compared to the brittle failure of NWC beams. Thus, the PKSC beams showed a ductile failure, giving amble warning before failure happened. PKSC beams also exhibited a lot of cracking thus the crack width and crack spacing was small. The other advantage for PKSC beams was deflection. The PKSC beams exhibited higher deflection under constant load until failure, compared to NWC beams that failed in brittle manner without warning. Higher concrete strains for the reinforcement in the PKSC shows stronger bond between PKSC and the reinforcement. Ductility Behavior of Reinforced Palm Kernel Shell Concrete Beams.

INTRODUCTION

The high demand for concrete in the construction using normal weight aggregates such as gravel and granite drastically reduces the natural stone deposits and this has damaged the environment there by causing ecological imbalance (Short and Kinniburgh, 1978). Therefore, there is a need to explore and to find out suitable replacement material to substitute the natural stone. In developed countries, the construction industries have identified many artificial and natural lightweight aggregates (LWA) that have replaced conventional aggregates thereby reducing the size of structural members. This has brought immense change in the development of high rise structures using LWC. However, in Asia the construction industry is yet to utilize the advantage of LWC in the construction of high rise structures. Malaysia is the second largest palm oil producing country in the world and it produces more than half of world's palm oil. The requirement of vegetable oil is constantly increasing and more cultivation of palm oil is forecast in the near future (Ramli, 2003). At the same time, the production of palm oil result in by products such as empty fruit bunches (EFB), palm kernel shells (PKS) or oil palm shells (OPS), pericap and palm oil mill effluent (POME). These are waste materials and stockpiling such wastes have caused storage problem in the vicinity of the factories as large quantities of these wastes are produced every day. Also, these wastes are stockpiled in open fields and thus it had negative impact on environment. One of the ways of disposing these wastes would be utilization of some of these into constructive building materials. This will also help to prevent the depletion of natural resources and to maintain ecological balance. PKS are hard stony endocarps that surround the kernel and the shells come in different shapes and sizes. They are light and naturally sized; they are ideal for substituting aggregates in LWC construction. Being hard and of organic origin, they will not contaminate or leach to produce toxic substances once they are bound in concrete matrix. Normally, the shells are flaky and of irregular shape that depend on the breaking pattern of the nut. PKS are available in large quantities in palm oil producing countries in Asia and Africa. Malaysia alone produces nearly 4 million tones of PKS annually and this is likely to increase as more production is expected in the near future.

LITERATURE REVIEW

PKS possesses hard characteristics as coarse aggregates and there have been attempts by Abdullah(2003), Okafor (1988), Okpala (1990) and Basri et al., (1999) to use PKS as coarse aggregates replacing normal granite aggregates traditionally used for concrete production. Ata et.al., (2006) compared the mechanical properties of palm kernel shell concrete with that of coconut shell concreteand reported the economy of using PKS as lightweight aggregate. Generally, PKS consists of 60-90 % of the particles in the range of 5-12.7 mm (Okafor, 1988; Okpala, 1990). The specific gravity of PKS varies between 1.17 and 1.37, while the maximum thickness of the shell was found to be about 4mm. The density of PKSC varies in the range of 1700 to 2050 kg/m that depends on factors such as type of sand, and, sand and PKS contents. Generally, when the density of concrete is lower than 2000kg/m , it is categorized as LWC. Thus, the PKSC can be produced within this target density of 2000 kg/m and PKSC is a LWC. The 28 day cube compressive strength of about 15-25 MPa has been reported by them. Other properties of PKS and the PKSC have been studied and reported by these researchers. However, the structural behavior of PKSC is very limited. Teo et al (2006) carried out tests on reinforced PKS beams to study the flexural behavior and reported typical flexural failure of under-reinforced PKS beams. The moment capacities of PKS beams were found to be higher than the predicted values by between 4 and 35%. The ductility ratio, defined as the ratio of ultimate deflection to first yield deflection, was found in the range of 3 to 5 for the PKS beams. One of the important characteristics of PKSC is the compressive strength. Generally grade 30concrete is acceptable for structural members, though some of the codes of practice stipulate minimum strength of LWC as 15MPa (FIP Manual, 1983). The highest compressive strength produced by the researchers in the past though fulfils this minimum requirement, higher strength is desirable for the design of structural members. It has been found that the failure of PKS concrete is generally governed by the strength of PKS (Okafor, 1988). However, PKS as LWA can produce poor bond between their surfaces and cement matrix, as they possess smooth and convex surfaces. Silica fume (SF) has been used to produce high- strength concrete and SF particles are finer than cement particles. However, the use of the powder form of SF demands more water to maintain workability and therefore powders are most often used with plasticizers or superplasticisers. The extremely fine SF particles react with the liberated calcium hydroxide to produce calcium silicate and aluminate hydrates. These both increase the strength and reduce the permeability by densifying the matrix of the concrete (Robert et al., 2003; Neville, 1996). Thus the zone between aggregate and cement paste interface, which is called the zone of weakness, could be strengthened by the use of SF. At present there is no literature available on the properties of concrete SF as mineral admixture. This research work focuses on producing PKSC of grade 30 using ten percent of silica fume and five percent of fly ash as additional cementations material and cement replacement material, respectively and to study the structural behavior of the PKSC.

RESEARCH METHOD & MATERIALS RESEARCH METHOD

The methodology to produce and study the structural behavior of the PKSC is described here under. Since this investigation is experimental based, the following sections describe the methods to fabricateand test the reinforced PKSC and NWC beams for structural behavior.

MATERIALS

Ordinary Portland cement (OPC) conforming to MS 522; Part-1:2003 with specific gravity and surface area of 3.10 and 335 m / kg respectively was used for all mixes. The cementitious materials used in preparation of PKS concrete were: Five percent Class F fly ash (FA) and ten percent silica fume (SF) as cement replacement and additional cementitious materials on the cement weight respectively. The SiO content and specific gravity of class F fly ash (FA) used in this investigation were 65% and 2.10 respectively. Undensified Silica fume (SF) of specific gravity of 2.10 used in the investigation was supplied by Elkem materials, Singapore. No cementitious material was used in the NWC. Mining sand with specific gravity of 2.7 was used as fine aggregates. The particle size of the saturated surface dry (SSD) sand used was in the range between 0.15 – 2.36 mm. PKS used as coarse aggregates were obtained from local crude palm oil producing mill. Crushed granite aggregates were used as coarse aggregates for the NWC. Figs. 1a and 1b show the PKS and the granite aggregates respectively. The comparison of properties of PKS (ASTM C127:2003; ASTM C 138:2003) and granite aggregates are shown in Table 1. Ductility Behaviour of Reinforced Palm Kernel Shell Concrete Beams.

Table 1: Physical and mechanical properties of aggregates in PKS concrete

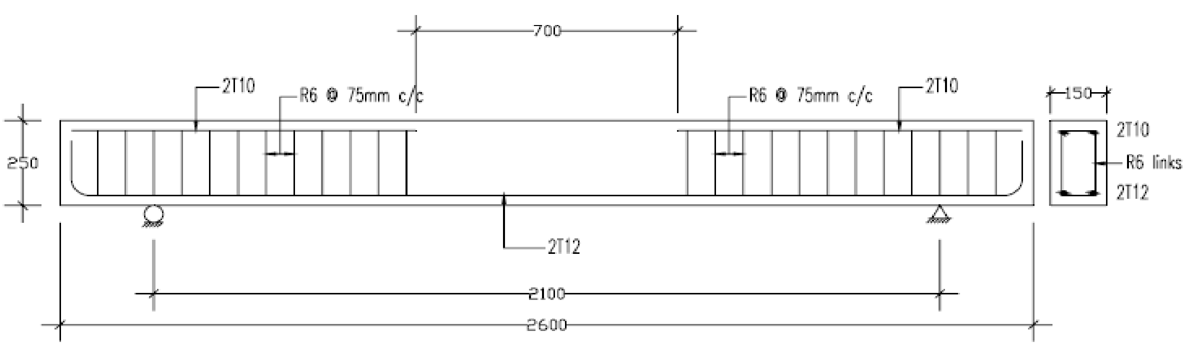
Properties	Granite Aggregate	PKS Aggregate
Thickness (mm)	15	0.7-3.00
Bulk density (kg/m)	1510	620
Specific gravity (saturated surface dry)	2.67	1.37
Fineness modulus	6.57	6.24
Water absorption– 1 hour (%)	<1	10-12
Water absorption – 24 hr (%)	<1	24.5

Aggregate impact value (%)	16.78	3.91

Fig :1 PALM KERNEL SHELLS (PKS)

Reinforcement gage, beam preparation and instrumentation

The reinforcement gage prepared for the study on both the flexural behavior is shown in Fig. 2. All beams were designed as under-reinforced in accordance with BS 8110:1997 to produce typical flexural mode of failure. The shear reinforcement for flexure was used only in the shear span at close spacing of about 75mm c/c and this has been done to ensure yielding of tension steel before crushing of concrete.



Note: All dimensions in mm
Clear Cover: 30 mm (all beams)

Figure 3: Reinforcement details of test beams

No compression reinforcement was provided in the flexural zone. The strain gauges were fixed at the bottom of the main reinforcement for the strain measurements in main steel. All beams were designed as under-reinforced using BS 8110-Part 1:1997 (1997) and cast in steel moulds. The width (b) and the overall depth of the beam were kept at 150 mm and 250 mm respectively for all beams. And using a clear cover of 30 mm, the effective depth of the beams was maintained at 209 mm. A total of four beams, two each on NWC and PKSC were cast. They were vibrated using internal vibrator and covered with jute clothes for curing. Afterwards the beams were kept under laboratory condition till the day of testing. The companion specimens for compressive and flexural strengths and modulus of elasticity were cast and tested for both NWC and PKSC beams. 100 mm cubes and 100 x 100 x 500 mm prisms were used respectively for cube compressive strengths and flexural strength. 150 mm diameter and 300mm height cylinders were used for static modulus test.

The tensile and compressive strains of both reinforcement and concrete were measured through electrical resistance gauges. All the strains were recorded using data logger. In addition, the strain distribution on the vertical face of the beams in the flexural zone was determined using de-mountable digital extensometer with a sensitivity of 0.001 mm. The test set up and the instrumentation is shown in the Fig.3. The concrete beams were simply supported and tested under two-point loading as shown. The load from the actuator was transferred to the beam by means of a spreader beam. All the beams were loaded under two-point loads that were kept at 700 mm apart on a span of 2100 mm. An In stron testing machine of capacity of 500 kN with built-in load cell was used in the testing. It has both manual and automatic controls and the options of load or position controls could be used in testing of the beam.

Three linear voltage displacement transducers (LVDT) were placed, one at centre of the beam , the other two under load points, to measure the deflections at centre and under load points. The crack widths at the level of tensile reinforcement were measured using hand held microscope with sensitivity of 0.02 mm. All strain, crack width and deflection measurements were measured at every load increment. The first crack load was noted immediately after the formation and all the cracks were marked as and when they propagated in the beam.

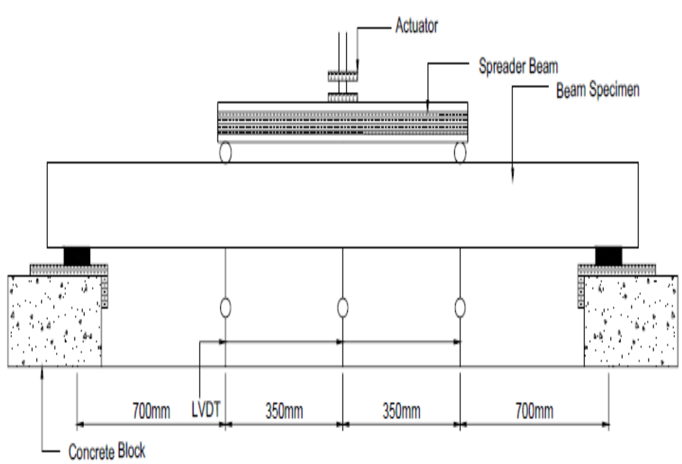


Figure 4: Test set up and Instrumentation

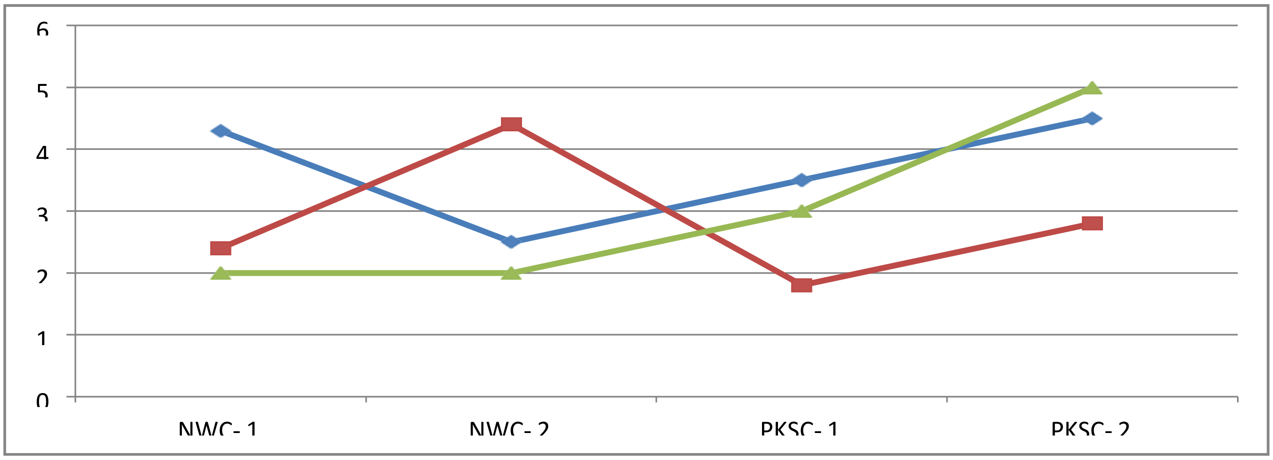


Table :3
Types of fine aggregates:

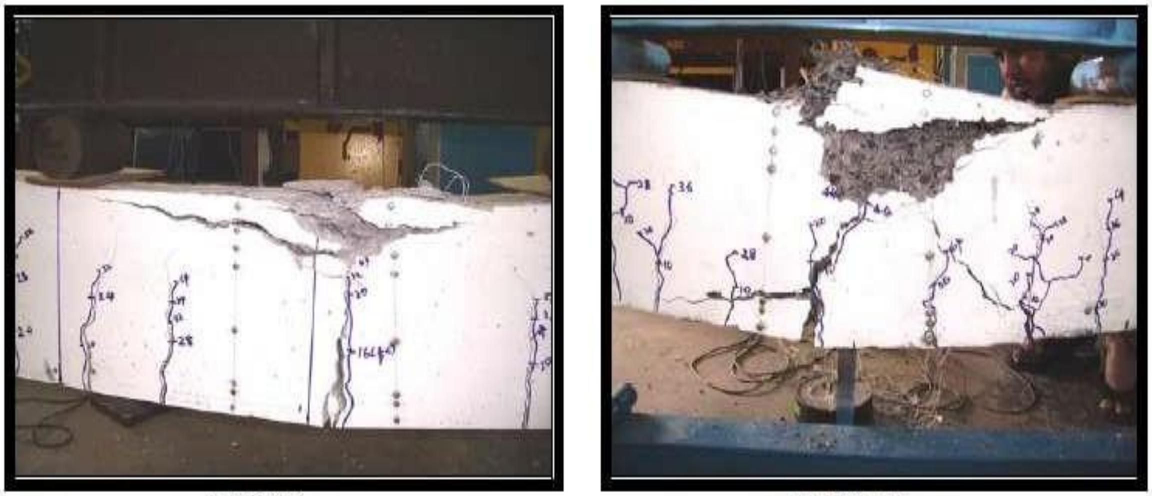
Fine Aggregates	**Size**
Coarse Sand	2.0mm – 0.5mm
Medium sand	0.5mm – 0.25mm
Fine sand	0.25mm – 0.06mm
Silt	0.06mm – 0.002mm
Clay	<0.002

Table 4: Details of beams (concrete strength, steel and beam size)

Beam no	Density (kg/m^3)	Slump (mm)	Cube strength (Mpa)	Flexural strength (mpa)	Young modulus (KN/mm^2)	Beam size(b*h)mm
NWC-1	2335	65	31.83	4.21	30.71	148*253
NWC-2			33.04	4.42	31.08	149*254
PKSC-1	1888	105	37.41	3.83	10.71	152*253
PKSC-2			36.40	3.50	10.02	152*253

MODE OF FAILURE

The flexural failure mode was observed for the both NWC and PKSC beams as shown in Fig. 4. The yielding of steel took place and this was followed by crushing of concrete in the compression zone. Since all the beams were designed as under- reinforced, the failure started by yielding of the tension steel bar before the compression failure of concrete as expected. As can be seen from Fig.2, in order to ensure typical flexural failure, the shear and compression reinforcements were not provided in the pure bending region. Also, the stirrup spacing was kept at 75 mm centers in the shear zone and thus all beams failed in typical flexural mode. For both types of concrete, failure started with flexural crack and extended to the neutral axis.The first flexural crack, after reaching the neutral axis, started to incline to form compression failure zone. And the crushing of concrete took place in that zone during failure. NWC concrete exhibited brittle failure; the prolonged deflection at maximum load of PKSC beam has given sufficient warning before final failure and thus the beam failed in ductile manner. However, the failure zone of PKSC was larger than NWC beams as seen from Fig.4.



a) NWC beam b) PKSC beam

Figure 4: Failure modes of beams

SUMMARY AND CONCLUDING REMARKS

The experimental results of four beams, two each in PKSC and the NWC are presented in this paper. The comparison of mechanical properties and structural behavior of the NWC and PKSC beams is discussed. The crack width, deflection, ultimate strength, concrete and steel strains are analyzed and compared for both beams. Based on the results, the following conclusions may be drawn:

1. The PKSC produced a density reduction and an increase in compressive strength of about 24% and 14%, respectively compared to that of the NWC.
2. The compressive strengths obtained for the PKSC were approximately 36 MPa and this was higher than the target strength of 30 MPa and hence PKSC can be produced as structural grade concrete of grade 30 with the addition of ten percent of silica fume.
3. The modulus of elasticity of the PKSC was found to be about
33 % as that of the NWC. Similarly, the PKSC produced flexural strength of about 15% lower than the NWC.
4. The overall flexural behavior of reinforced PKSC beams used in this study closely resembles that of equivalent beam made with NWC.
5. Lower modulus of rupture of PKSC resulted in early cracks in PKSC beam. However, the close spacing and large number of cracks in PKSC beams resulted in lesser crack widths than the NWC beams. The crack widths of the PKSC at service loads are within the durability requirements of BS 8110.
6. The deflection of the PKSC beams at service loads were close to the deflection of the NWC beams. However, the large deflections at near maximum load of the PKSC beams exhibited

high ductile behavior that gave ample warning before total collapse.

7. The ultimate moment of the PKSC beams were closer to that of the NWC beams and in the case of the PKSC-B2, the ultimate moment was higher than that of the NWC beams.
8. The PKSC beams had sufficient ductility and the failure zone was distinctly larger than the NWC beams.
9. Higher tensile steel strains of the PKSC beams show the existence of the stronger bond between the concrete and the steel
10. The overall flexural behavior of the PKSC beams shows better performance than the OPS beams reported earlier.

References

[1]. ASTM, 2003. *ASTM C 127: Standard Test Method for Density, Relative Density, and Absorption of Coarse Aggregate*. Annual Book of ASTM Standards.

[2]. ASTM, 2003. *ASTM C 138: Standard Test Method for Density, Yield, and Air Content*. Annual Book of ASTM Standards.

[3]. Ata, O., Olanipekun, E.A., & Oluola, K.O., 2006. "A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates." *Building and Environment*, 41, pp. 297–301.

[4]. Basri, H.B., Mannan, M.A., & Zain, M.F.M., 1999. "Concrete using waste oil palm shells as aggregates." *Cement and Concrete Research*, 29, pp. 619–622.

[5]. BS 8110-1:1997. *Structural Use of Concrete: Code of Practice for Design and Construction*. British Standards Institution, London.

[6]. FIP Manual, 1983. *FIP Manual of Lightweight Aggregate Concrete*. 2nd ed. London: Surrey University Press.

[7]. Neville, A.M., 1996. *Properties of Concrete*. Longman Group Limited, London.

[8]. Okafor, F.O., 1988. "Palm kernel shell as a lightweight aggregate for concrete." *Cement and Concrete Research*, 18, pp. 901–910.

[9]. Okpala, D.C., 1990. "Palm kernel shell as a lightweight aggregate in concrete." *Building and Environment*, 25, pp. 291–296.

[10]. Ramli, A., 2003. "Short-term and long-term projection of Malaysian palm oil production." *Oil Palm Industry Economic Journal*, 3, pp. 32–36.

[11]. Robert, L., Lindon, S., Peter, W., & Ray, R., 2003. "Cementitious additions." In: John N., Ban, S.C. (Eds.), *Advanced Concrete Technology*. Amsterdam: Elsevier Publications, pp. 43–45.

[12]. Satish, C., & Berntsson, L., 2003. *Lightweight Aggregate Concrete: Science, Technology, and Applications*. 1st ed. New York: Noyes Publications.

[13]. Short, A., & Kinniburgh, W., 1978. *Lightweight Concrete*. 3rd ed. London: Applied Science.

[14]. Teo, D.C.L., Mannan, M.A., & Kurian, J.V., 2006. "Flexural Behavior of Reinforced Concrete Beams Made with Oil Palm Shell (OPS)." *Journal of Advanced Concrete Technology*, 4, pp. 22-36.