Pergamon

Cement and Concrete Research 31 (2001) 1319–1321

CEMENT AND CONCRETE RESEARCH

Long-term strengths of concrete with oil palm shell as coarse aggregate

M.A. Mannan, C. Ganapathy*

Civil Engineering Program, School of Engineering and Information Technology, Universiti Malaysia Sabah, 88999 Kota Kinabalu, Sabah, Malaysia

Received 26 August 2000; accepted 18 June 2001

Abstract

Concrete using oil palm shell (OPS) as coarse aggregate has been found useful as structural lightweight concrete. Long-term investigation up to 365 days on compressive strength of OPS concrete for different curing environments has been carried out. A comparative study has also been conducted on control concrete using crushed stone as coarse aggregate. In the six types of curing that includes some of the field and laboratory conditions of curing, the compressive strengths of OPS concrete range from 20 to 24 N/mm^2 for 28 days; this satisfies the strength requirement of structural lightweight concrete. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: OPS; oil palm shell; Curing; Compressive strength; Lightweight concrete

1. Introduction

Oil palm shell (OPS) is the hard endocarp that surrounds the palm kernel. It is light and naturally sized that it is suitable as aggregate in lightweight concrete. OPS concrete has a good potential to be used as lightweight concrete. In OPS concrete, OPS is used as coarse aggregate and it has been found [1,7,8] that it could be used as structural lightweight concrete.

The influence on compressive strength due to environments of moisture resulting from different curing conditions under long-term study up to 365 days has been investigated and results are reported in this paper.

2. Materials and testing

2.1. Materials and preparation of samples

The physical and mechanical properties of both coarse aggregates, OPS and crushed stone, are given in Table 1. Before mixing, OPS aggregates were washed with potable water mixed with detergent to remove the oil coating and dust from OPS aggregates, and finally it was washed again with potable water to remove the detergent. Due to higher water absorption capacity, OPS aggregate was used in saturated surface dry condition. The fineness modulus of river sand used was 2.56. The maximum size of both coarse aggregates was 12.5 mm. Based on the trial mix design, the amount of ordinary Portland cement used was 480 kg/m^3. The free w/c ratio for the mix was 0.41. For each batch of OPS concrete mix, the ingredients used were 13.20 kg cement, 22.57 kg sand, and 10.16 kg OPS. The volume of crushed stone for control concrete was identical with the volume of OPS aggregate for each batch. All samples were cast in 100 mm cubes and left with covered plastic sheet for 24 ± 3 h before demoulding in the laboratory. The fresh concrete properties are shown in Table 2.

2.2. Curing regimes

The object of curing is to keep concrete saturated, or as nearly saturated, to get the products of hydration of cement into water-filled spaces. Proper curing is one important measure to get durable concrete. In practical aspects, most of the concretes used in laboratory investigations are cured in potable water for up to 28 days [4]. At construction sites, most curing techniques used currently have practical drawbacks. Plastic wrappers around the concrete are seen to be a good curing method. Concrete immersed in with water is the closest method to laboratory curing method. Spraying of water on the concrete surface at sites is the usual method adopted in the field.

* Corresponding author. Tel.: +60-88-438440-3151; fax: +60-88-320348.

E-mail address: ganpathy@ums.edu.my (C. Ganapathy).

PII: S0008-8846(01)00584-1

Table 1
Physical and mechanical properties of OPS and crushed stone aggregates

Property	OPS aggregate	Crushed stone aggregate
Specific gravity (ssd)	1.17	2.61
Water absorption (24 h), %	23.32	0.76
Aggregate abrasion value (Los Angeles), %	4.80	24.00
Bulk density (compacted), kg/m^3	592	1472
Fineness modulus	6.24	6.33
Aggregate impact value (AIV), %	7.86	17.29

Six curing conditions, W-1 to W-3 and P-1 to P-3, were included to simulate the laboratory and field conditions. The details of curing conditions used in this investigation are shown in Table 3. In this investigation, the W-1 curing conformed to that recommended by Ref. [2] for Type I (ASTM) cement, while W-2 and W-3 conditions simulate the usual laboratory curing. Plastic film curing [5] was considered to minimize the moisture loss from the surface of concrete where continuous spraying of water is not possible especially during the early stages of curing. Two layers of plastic film were wrapped around the specimens of P-1 curing [6]. Similar to P-1 curing, two other types of curing, P-2 and P-3, were also chosen to observe the development of hardened concrete strengths. Two layers of plastic wrappers were used for each sample of P-2 and P-3 curing conditions. Concrete cubes, 100 mm in size, were stored in these six curing environments and tested. Samples were tested at the age of 3, 7, 28, 56, 90, 180, 270, and 365 days. The results reported are average of three samples.

3. Results and discussion of compressive strength

The relationship between compressive strength and curing time of OPS concrete is shown in Fig. 1 for different curing condition. The highest compressive strength was obtained in W-3 curing condition. Samples under W-1 curing condition developed the lowest strength at all stages of test. The strength of concrete increases with the progress of hydration, which depends also on the moisture content in concrete. In W-1 curing condition, the wetness in concrete was the least compared to W-2 and W-3, and the strength reduction in W-1 curing was due to this fact, whereas W-2 and W-3 have shown higher strengths. The results revealed in this investigation are similar to those found earlier [7].

Table 2
Properties of fresh concrete

Mix type	Properties of fresh concrete: Slump (mm)	Compacting factor	Air content (%)
OPS concrete	7	0.82	5.1
Control concrete	3	0.79	4.2

Table 3
Curing conditions for both OPS and control concretes

Number	Curing symbol	Duration of curing with place (day): Mold	Water	Kept in normal room temperature
1	W-1	1	6	358
2	W-2	1	27	337
3	W-3	1	364	–
4	P-1	1	6	358 (with plastic wrapper)
5	P-2	1	27	337 (with plastic wrapper)
6	P-3	1	–	364 (with plastic wrapper)

Fig. 2 presents the relation between compressive strength and curing time for control concrete under six curing conditions. The rate of strength gain was substantial for the first 90 days whereas, a very slow rate of increase in strength was observed between 90 and 365 days of age. The increase in strength between 90 and 365 days was about 30% of 90-day strength for all curing conditions except W-1. For W-1, the increase in strength was only 15%. This was due to lesser moisture available for hydration.

The relationship between the compressive strength and curing age for the practical curing, W-1 condition of 6 days in water is given by the expression as

$$F_c = 2.28\log_e t + 12.11. \qquad (1)$$

In Eq. (1), F_c is the compressive strength, t is the curing time in days, and $\log_e$ is the base-e logarithm.

With the same w/c ratio for both OPS and control concretes, the higher strength of control concrete was due to the rough surface structure, strength, and density of crushed stone aggregates. At the early ages, up to 56 days, as observed from the broken cubes, the compression failure pattern in OPS concrete indicated that failure was due to the breakdown in the bond between the paste and OPS aggregates. This indicated that bonds between OPS and cement paste were not as strong as that of control concrete because of the smoothness of OPS surface. But in the later ages, 90 days and onward, the failure was due to breaking of OPS aggregate itself. It shows that the bond improves with time. Under all types of curing, the compressive strength of OPS concrete continued to develop with age, but remained below that of control concrete. The compressive strength in OPS concrete was about 49% to 55% lower than that of control concrete.

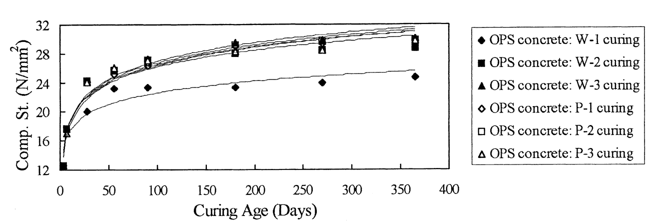

Fig. 1. Development of compressive strength of OPS concrete under different curing conditions.

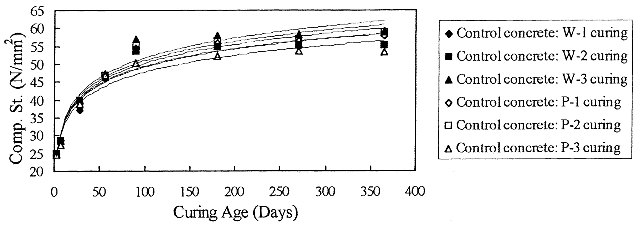

Fig. 2. Development of compressive strength of control concrete under different curing conditions.

The strength, thickness, and density of OPS aggregate are also lower than that of crushed granite stone aggregate (Table 1), which are the governing factors for the compressive strength in concrete. The strength and density depend on the type and shape of aggregate, the richness of mix, and compaction [5,8,9]. The porosity also affects the compressive strength. OPS concrete has higher porosity than the control concrete as indicated by air content of 5.1% in fresh OPS concrete (Table 2). The compressive strength for the 28-day samples depending on curing conditions was in the range of 20.10–24.20 N/mm^2, which is quite above the requirement for structural lightweight concrete [3].

4. Conclusions

Considering the results of the long-term investigation mentioned in this paper, the main observations are summarized as follows:

1. The 28-day compressive strengths of OPS concrete are between 20.1 and 24.2 N/mm^2 depending on the curing. The highest compressive strength of OPS concrete is obtained in W-3 curing followed by P-3, P-2 and P-1, and W-2 and W-1 curing conditions. W-1 curing condition is usually adopted in field condition and it fulfills the strength requirement of structural lightweight concrete.

2. The long-term behavior of OPS concrete in general, is very similar to control concrete, thereby confirming that there is no retrogression in strength due to any of the curing conditions.

3. Use of OPS concrete as structural lightweight concrete is recommended.

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