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The Strength and Permeability of No-Fines Concrete

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1. Introduction:

Throughout Japan, research centers are making efforts to evaluate NFC, with the aim of developing pertinent design methodologies compatible with environmental conditions, materials availability, and construction procedures [1]. The general objectives of this paper are to detail the properties of No-Fines Concrete(NFC) that satisfy the permeability and strength requirements. The specific objectives are: to relate aggregate type and water cement ratio to permeability requirements of NFC, and to evaluate the effects of NFC's components on its strength properties.

2. Experimental work

2.1. Preparation of specimens

Several mixes with Aggregate - Cement ratios by volume (A / C=4, 6, 8, and 12) were made. Crushed limestone (C) with different aggregate gradation, Pumice (P) and Scoria (S) were used as coarse aggregate. In this study ordinary portland cement (specific gravity of 3.15 and blaine of 3290 cm^2/g) was used. A pan-type forced circulating mixer of 50 liters of capacity was used, and the mixing procedure followed was that specified elsewhere [2]. No effort was required to consolidate or compact the freshly mixed NFC. A light hand tamping [3], which causes the least particle breakage compared with impact methods of laboratory compaction was sufficient.

2.2 Testing of specimens

All test specimens were kept under cover with wet jute bags in the laboratory until demoulding at 24 hr after which they were transferred to a water curing room at (20℃±2℃).
The void content and water permeability (ϕ=10 x h=10 cm) were measured according to reference [1].
The compressive strength was measured at the ages of 7, 28, and 91 days on cylindrical specimens of ϕ=10 x h=20 cm according to JIS A1108 specifications and the flexural strength at the ages of 28, and 91 days on prismatic specimens of 10 x 10 x 40 cm according to JIS A1106 specifications.

3. Results and discussion

Sets of curves showing the effects of aggregate type, cement and water content, and water cement ratio on the relationship between void content, compressive strength and permeability were constructed.

Fig. 1 shows the effect of cement content on void content. When the water cement ratio remains constant, the void percentage decreases by about 1% with a 30 kg/m^3 increment of cement content for NFC made with pumice or scoria. However for NFC made with crushed limestone it decreases by about 2% for the same cement content increment. This may be due to the aggregate's type and shape and compaction effect.

Fig. 2 shows the effect of water content on void content. The void content decreases by about 1, 1.7, and 2.3% with a 10 kg/m^3 increment of water for NFCs with 318, 239 and 159 kg/m^3 of cement content.

The above two figures show that varying the cement content leads to a decrease of 0.67‰/kg in the void content, whereas a change in water content provokes a decrease of 1.67‰/kg.

Fig.3 depicts a relationship between the cement content and compressive strength.

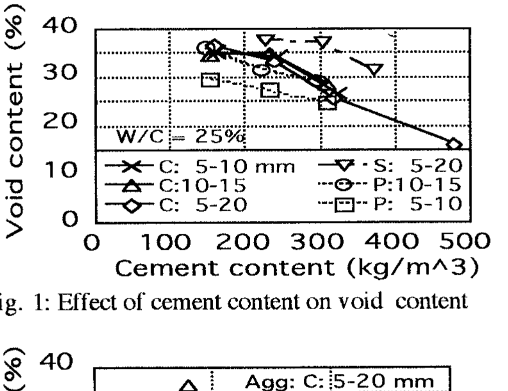

Fig. 1: Effect of cement content on void content

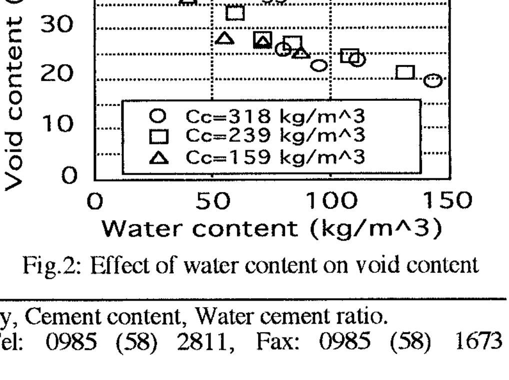

Fig.2: Effect of water content on void content

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The increment of compressive strength is not proportional to that of the cement content. For the first additional 77kg/m^3 of cement the compressive strength of NFC made with crushed limestone or scoria increases by about 50% while for the second 77 kg/m^3 it becomes double. As for NFC with pumice, no remarkable improvement on the compressive strength was recorded. The compressive strength of NFC with conventional aggregate is about 3 times of that with volcanic aggregate used in this study.

Fig.4 illustrates a relationship between the void content and permeability. The permeability does not depend on the aggregate origin. In case where the permeability is the primary required property, it is important to make a NFC with these volcanic coarse aggregates since it can be achieved at a reasonable cost.

Fig.5 shows that a decrease of the water cement ratio by 10 % increases the permeability by 0.25 cm/s. However as Fig.6 shows, the reduction of water cement ratio might cause the weakness of NFC. Therefore, unlike conventional concrete in which strength is primarily controlled by the water cement ratio (Abrams low), the strength of NFC depends on the water cement ratio and the cement content. For a given cement content there is a very narrow optimum range of water cement ratio that leads to maximum strength of NFC. Mizuguchi et. al. [4] and Kazuo et al. [5] have proved similar results.

Fig.7 illustrates a linear relationship between flexural strength and compressive strength of NFC. For conventional concrete the ratio of flexural strength to compressive strength varies from 1/8 to 1/5. However within this experiment, this ratio varies from 1/6 to 1/3.

4. Conclusion

(1) The permeability is independent of the coarse aggregate origin.

(2) The strength of No-Fines Concrete may need to be expressed in the following form:

$$\log S = \alpha_1 + \alpha_2 ((W+Vc)/C) + \alpha_3 C$$

where S is strength, α_i are experimental constants that depend on all the factors that can influence the strength of NFC, (W+Vc)/C is cement space ratio.

(3) The flexural strength of NFC is from 1/3 to 1/6 of compressive strength.

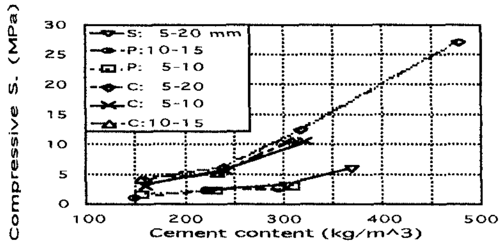

Fig.3: Compressive strength Vs Cement content

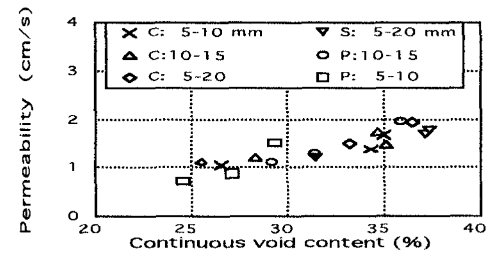

Fig.4: Permeability Vs Void content

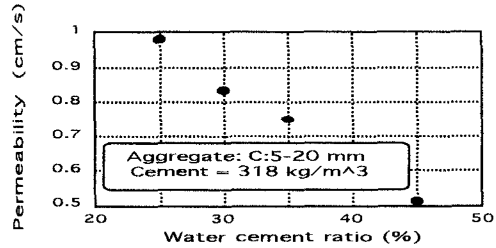

Fig.5: Permeability Vs W/C ratio.

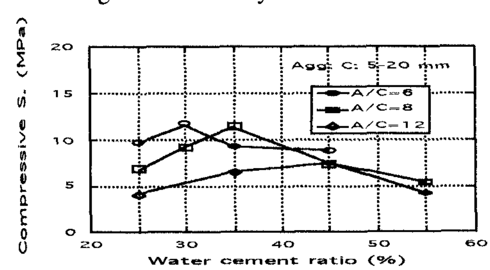

Fig.6: Compressive strength Vs W/C ratio

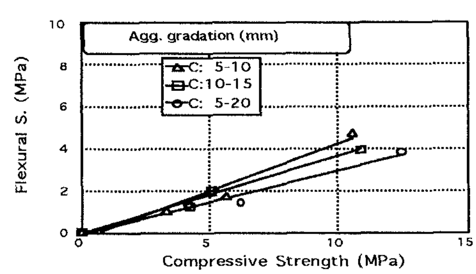

Fig.7: Flexural strength Vs Compressive strength

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