Investigations on Some Properties of no-Fines Concrete

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Abstract

No-fines concrete is a form of lightweight porous concrete, obtained by eliminating the sand from the normal concrete mix. The advantages of this type of concrete are lower density, lower cost due to lower cement content, lower thermal conductivity, relatively low drying shrinkage, no segregation and capillary movement of water, better insulating characteristics than conventional concrete because of the presence of large voids.

This paper presents the results of an investigation to determine the performance characteristics of concrete mixes made without fine aggregates. Single sized course aggregates fraction 13.5-19 mm from Kgale Hill quarry and Ordinary Portland cement were used in the experiments. Concrete mixes with different aggregate/cement and water/cement ratios were prepared to find an optimum mix yielding the highest strength. The influence of the above factors on the density, dynamic modulus of elasticity, compressive, tensile and flexural strength were studied experimentally. It was found that the strength of no-fines concrete is lower that that of normal weight concrete, but sufficient enough for structural use. Due to its high ratio of continuous voids, this concrete has high water permeability.

The suggested mixtures can be used for cast in-situ walls in low-rise, low cost housing (later plastered externally to reduce air and water permeability).

Keywords: *No-fines concrete, density, dynamic modulus of elasticity, compressive, tensile and flexural strength.*

INTRODUCTION

No-fines concrete is a form of lightweight porous concrete. It is a two-phase material – single sized coarse aggregates, surrounded by a coating of thin layer of cement paste, without any fine aggregates. Thus, the coarse aggregates are in point-to-point contact with each other through a small fillet of cement paste, holding particles together and giving strength of concrete.

The advantages of this type of concrete are lower density (1600 – 2000 kg/m^3), lower cost due to lower cement content, lower thermal conductivity (k=0.7 W/mK for no-fines concrete in comparison to k=2.0 W/mK for dense concrete), relatively low drying shrinkage (one half of that of dense concrete), no segregation and capillary movement of water, better insulating characteristics than conventional concrete because of the presence of large voids according to Fulton's Concrete Technology (1994) and Neville (1981).

No-fines concrete has been used for walls in housing (later plastered) and as drainage medium, e.g. for quickly drained play areas and tennis courts. According to A. Everett (1993), no-fines dense aggregate concrete has been used in Germany for load-bearing walls up to 20 stories.

The main objective of this research was to investigate the performance characteristics of concrete mixes made without fine aggregates and to suggest possible applications of no-fines concrete for Botswana construction industry as cast *in-situ* walls in low-rise, low cost housing, drainage layers and paving.

MATERIALS AND METHODS OF TESTING

Concrete mixes with different aggregate/cement ratios varying from 6:1 to 10:1 by weight were prepared in a concrete mixer using Ordinary Portland cement and one sized ordinary dense course aggregates fraction 13.5-19 mm from Kgale Hill quarry with water absorption 0.58 %. Cubes with a side of 150 mm, beams 75 x 75 x 280 mm and cylinders with diameter and length 150 mm were prepared [BS 1881: Part 113: 1983] using gentle rodding only. Vibration and workability tests cannot be done due to very little cohesion between particles. Only a visual check to ensure even coating of all particles was used. The samples were cured in water, which is very important because of the small thickness of the cement paste involved.

The following tests were carried out: density (BS 648:1964), compressive strength (SABS 863:1994), splitting test (SABS 1253:1994) and flexural strength test (SABS 864:1994). For determination of dynamic modulus of elasticity ultrasonic pulse velocity test was used (BS 1881:Part 203).

TEST RESULTS AND DISCUSSIONS

Density

Single sized aggregates in no-fines concrete form large interconnected voids distributed throughout the body of the concrete. The porous structure of this type of concrete is responsible for the lower density of no-fines concrete in comparison with the ordinary concrete. The density of the investigated concrete varies between 1780 and 1890 kg/m^3, which is about 22 per cent lower than the density of normal-weight concrete (the density of ordinary concrete with river sand and coarse aggregates from Kgale Hill quarry is between 2340 and 2380 kg/m^3). The decreased density means lower dead load of the structure. Density decreases with the increase of aggregate-cement ratio as shown in Fig.1.

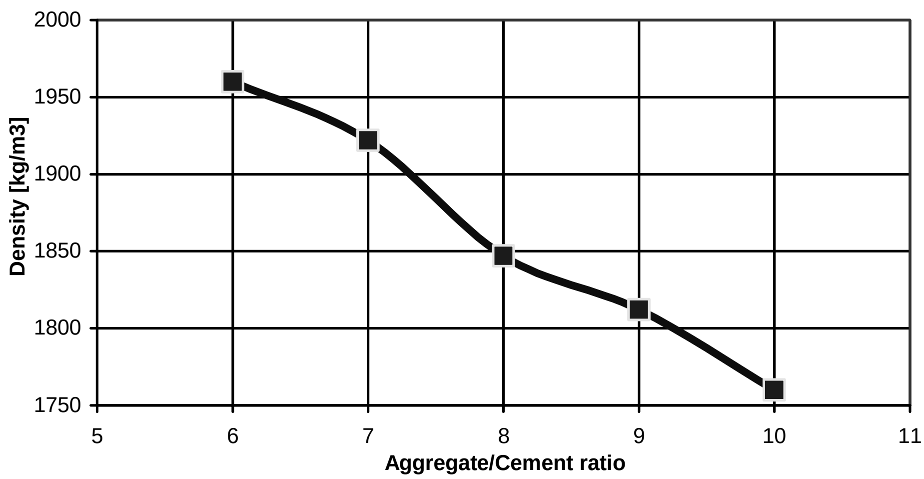

Fig.1 Influence of Aggregate/Cement ratio on density of no-fines concrete

Compressive strength

The compressive strength of non-fines concrete was determined after 7, 28 and 90 days of water curing. Fig. 2 shows the influence of aggregate/cement ratio on the compressive strength of no-fines concrete at different ages. Strength increases with the time in the same rate as in normal concrete (1.2 to 1.8 times during the investigated period of 90 days). Compressive strength of no-fines concrete at the age of 28 days varies between 1.1 and 8.2 MPa, depending mainly on aggregate/cement ratio and decreases with the increase of aggregate-cement ratio. Mix with aggregate/cement ratio 6:1 gives the highest strength. Compressive strength of no- fines concrete is lower then the compressive strength of conventional normal-weight concrete due to increased porosity. However, the strengths of no-fines concrete 6:1 and 7:1 are comparable to those of non-facing plastered bricks [SABS 227-1986] and are sufficient for the application of no-fines concrete as walling and drainage material. The structural recommendations for load-bearing walls require a minimum crushing strength at 28 days of 2.76 MPa.

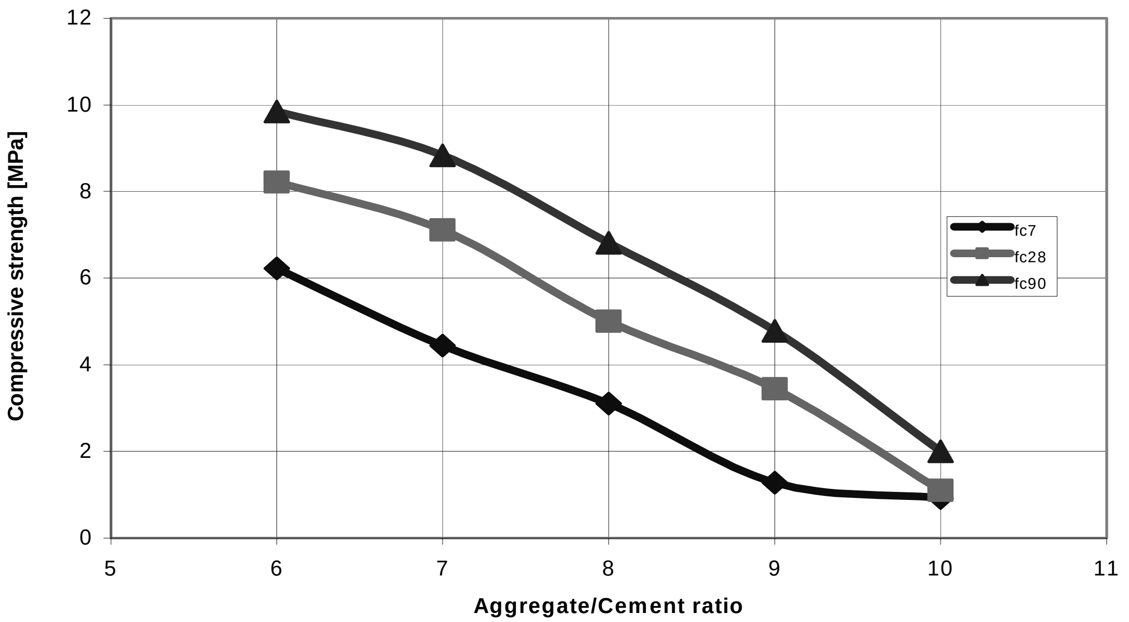

Fig.2 Influence of Aggregate/Cement ratio on the compressive strength of no-fines concrete

Tensile and flexural strength

Fig. 3 represents the influence of aggregate/cement ratio on the tensile and flexural strength of no- fines concrete. The highest strengths are at aggregate-cement ratio 7:1 and they decrease with the increase of aggregate/cement ratio. Tensile and flexural strengths of no- fines concrete are considerably lower than those of conventional concrete.

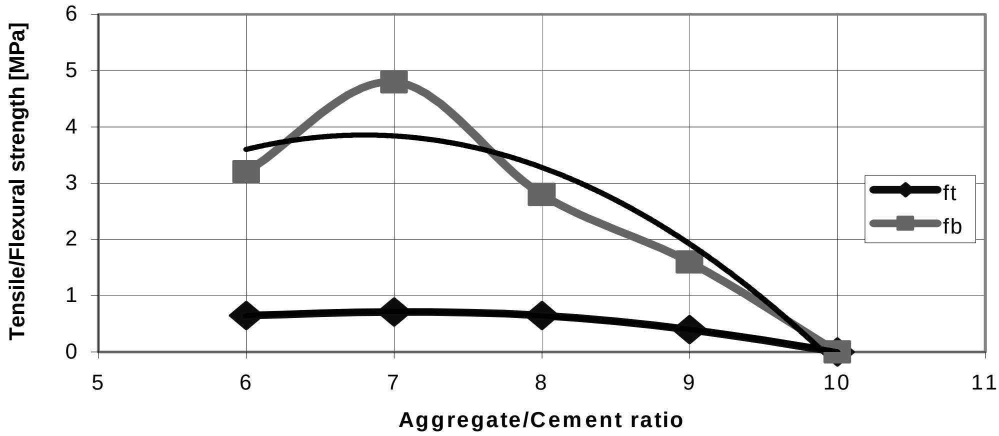

Fig.3 Influence of Aggregate/Cement ratio on the tensile (ft) and flexural strength (fb) of no-fines concrete

Dynamic modulus of elasticity

Fig. 4 is drawn using the results from the experimental relationship between dynamic modulus of elasticity and aggregate-cement ratio. The graph shows the same tendency as for the density and compressive strength (Fig.1 and Fig.2) – the dynamic modulus of elasticity (E_{dyn}) decreases with the increase of aggregate-cement ratio.

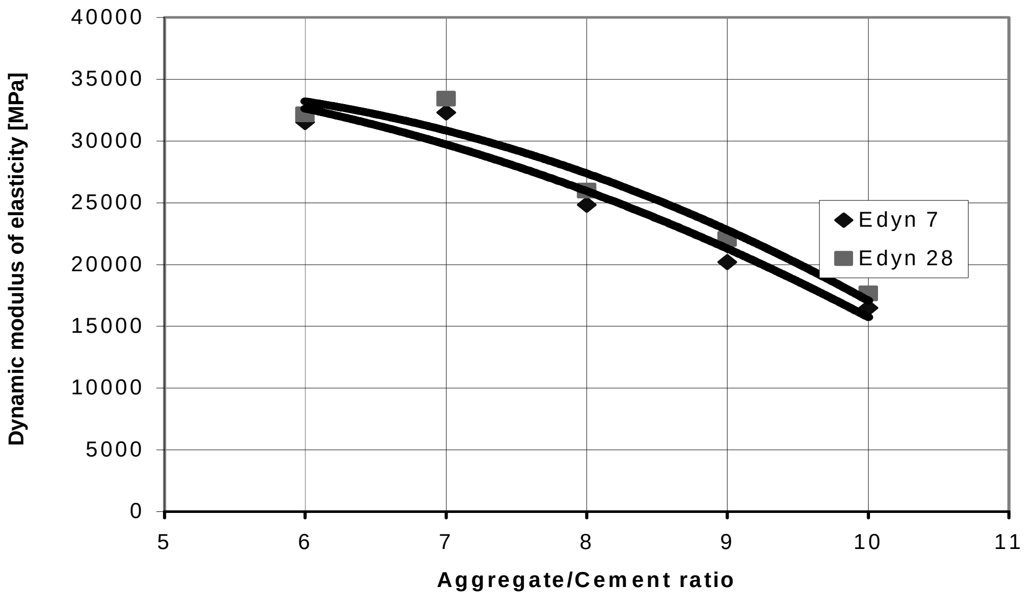

Fig.4 Influence of Aggregate/Cement ratio on dynamic modulus of elasticity of no-fines concrete

Influence of water/cement ratio on the strength properties of no-fines concrete

For no-fines concrete water/cement ratio is not the main controlling factor for the strength properties. More important factor is aggregate/cement ratio. Never the less, there is an optimum water/cement ratio giving maximum strength and density. Using higher water/cement ratio (W/C > 0.45) cement paste becomes too fluid, will drain away from the aggregate particles and cause settlement of the cement grout at the base. With lower water/cement ratio (W/C < 0.45) the paste would not be sufficient to coat the aggregates. The optimum water/cement ratio enables cement paste to coat the aggregates uniformly. Figures 5 and 6 represent the influence of aggregate-cement ratio on the compressive strength of no- fines concrete using two different aggregate/cement ratios - 6:1 and 7:1. The optimum water/cement ratio for both cases is around 0.45.

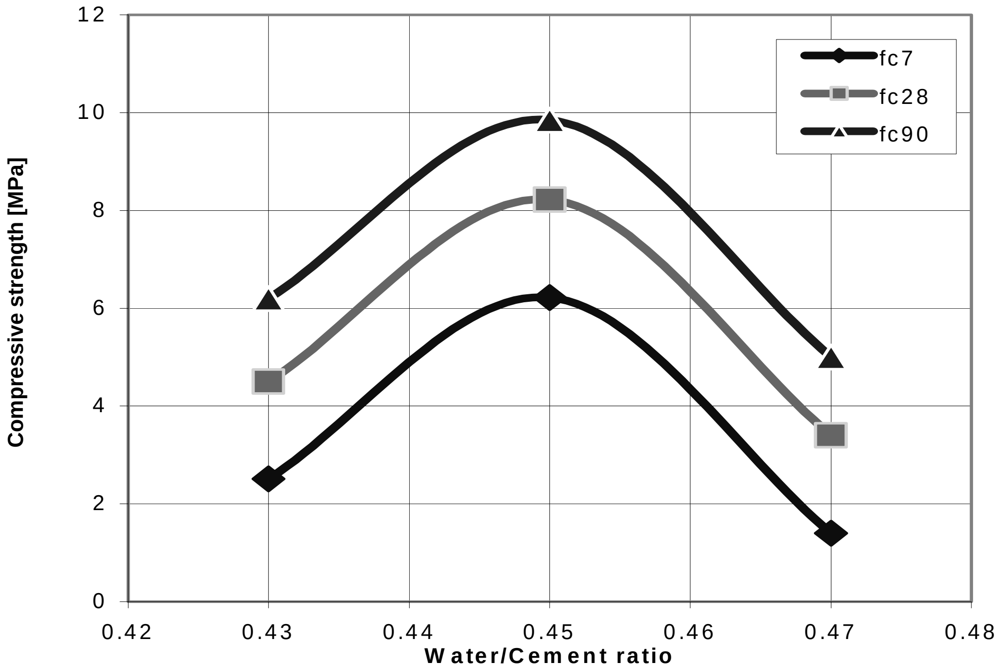

Fig.5 Influence of Water/Cement ratio on compressive strength of no-fines concrete (A/C = 6:1)

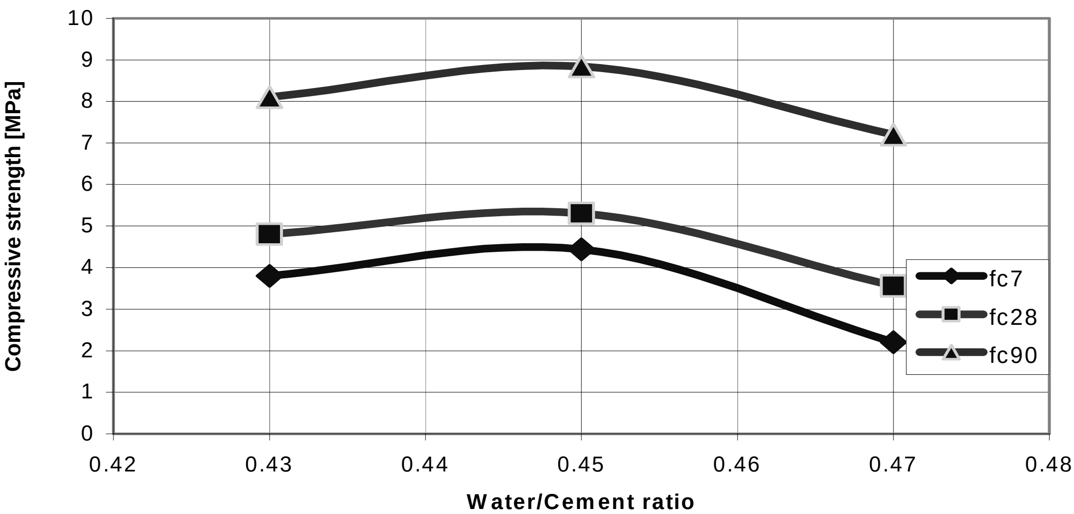

Fig.6 Influence of Water/Cement ratio on compressive strength of no-fines concrete (A/C = 7:1)

Capillary movement, water permeability, cohesion and segregation

Most of the problems, which commonly occur in buildings, are associated with the penetration of moisture and the most common means of admittance of water is by capillarity. In no-fines concrete no capillary movement of water can take place because of the large size of continuous pores and rough, open-textured structure. Due to the same reason this concrete has high water permeability.

No-fines concrete exhibits little cohesion and shows no segregation. Because of this, it can be dropped from a considerable height during placing.

Cost

The absence of sand particles in no-fines concrete leads to overall lower surface area of aggregates that would be coated with cement paste. Because of this, the cement content for this type of concrete is lower than that in the conventional concrete, e.g. for the investigated mixes 150 – 180 kg of cement per m^3 concrete was used. The increase of the amount of cement beyond this limits do not increase significantly the strength of concrete. The cost of no-fines concrete is comparatively low due to lower cement content.

CONCLUSION

The density and strength properties of the investigated no-fines concrete are lower that that of normal-weight concrete, but sufficient enough for structural use. For practical purposes mixes with aggregate/cement ratio 6:1 and 7:1 were recommended. The suggested mixtures could be used for cast *in-situ* walls in low-rise, low cost housing (later plastered externally to reduce air and water permeability), drainage layers and pavings after more extensive research.

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