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A STUDY ON EFFECTS OF SIZE COARSE AGGREGATE IN CONCRETE STRENGTH

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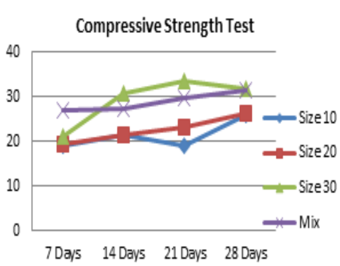
Graphical abstract



Abstract

The utilization of four types of aggregate for concrete work is investigated in this paper. Normal concrete is being produced from different types of aggregate and this imparts different property to the resulting concrete. The most important property of concrete is its compressive strength. For the purpose of this work, there are 4 types of aggregate size used for this study were classified as aggregate size 10, size 20, size 30 and mix aggregate. Concrete cube specimens of mix 1:1:2 were prepared with water-cement ratio of 0.5. The cubes were cured using methods water-submerged curing until testing ages of 7, 14, 21 and 28 days before the result determined. Some laboratory tests will be carried out in this study for the purpose of knowing the difference between the uses of different size aggregate in the concrete mix design. The tests carried out are as follows slump test, density test, flexural test, compression test, shrinkage and expansion test, ultrasonic pulse velocity test, water absorption test and permeability test. According to laboratory tests, we can conclude that size 30 and mix aggregates are the best choice in concrete design.

Keywords: Concrete, aggregate, compressive strength

Abstrak

Penggunaan empat jenis agregat untuk kerja-kerja konkrit dikaji dalam kertas kerja ini. Penggunaan konkrit biasa dihasilkan dari pelbagai jenis agregat dan ini menghasilkan sifat yang berbeza dengan konkrit yang biasa. Sifat yang paling penting dalam konkrit adalah kekuatan mampatan yang dihasilkan. Bagi tujuan kajian ini, terdapat 4 jenis saiz agregat yang digunakan untuk kajian ini telah dikelaskan sebagai sample agregat saiz 10, saiz 20, saiz 30 dan agregat campuran. Dalam kajian ini nisbah bancuhan konkrit 1:1:2 telah digunakan dengan nisbah air-simen 0.5. Setiap sampel akan melalui proses pengawetan iaitu rendaman air dan dibiarkan selama tempoh yang telah ditetapkan iaitu 7, 14, 21 dan 28 hari. Beberapa ujian makmal akan dijalankan dalam kajian ini bagi mengetahui perbezaan antara penggunaan saiz agregat yang berbeza dalam reka bentuk campuran konkrit. Ujian yang dijalankan adalah ujian kemerosotan, ujian ketumpatan, ujian lenturan, ujian mampatan, pengecutan dan pengembangan ujian, ujian halaju ultrasonik nadi, ujian penyerapan air dan ujian kebolehtelapan. Menurut ujian makmal, kita boleh membuat kesimpulan bahawa saiz 30 dan campuran agregat adalah pilihan terbaik dalam reka bentuk konkrit.

Kata kunci: Konkrit, agregat, kekuatan mampatan

1.0 INTRODUCTION

High strength concrete is a type of high performance concrete. The primary difference between high strength concrete and normal-strength concrete relates to the compressive strength that refers to the maximum resistance of a concrete sample to be applied pressure. Although there is no precise point of separation between high strength concrete and normal strength of concrete. The American concrete institute defines high strength concrete as concrete with a compressive strength greater than 41MPa (6000 psi).

High strength concrete is a superior product with increased modulus of elasticity, lower creep and drying, Shrinkage, excellent freeze thaw resistance, low permeability and increased chemical resistance high strength concrete is specified where reduced weight is important or where architectural considerations call for small support element by carrying load more efficiently than normal strength concrete [1]. High-strength concrete also reduces the total amount of materials placed and lower the overall cost of the structure, Although a 97 MPa (14000psi) concrete costs approximately three time as much as a 20 MPa (3000 Psi) concrete, its compressive strength is nearly five times greater, thus it is economical [2].

The most common use of high-strength concrete is for construction of high-rise buildings. At 295 m (969 ft), chicag's 311 south wacker drives uses concrete with compressive strength up to 82 Mpa (12000 psi) and are the tallest concrete building in the United States [3].

Much research in recent years has been devoted to establishing the fundamental and engineering properties of high-strength concrete, as well as the engineering characteristic of structural member made with material [4-5] it is well known that the inhomogeneous structure of concrete can be described as three-phase system consisting of hardened. Cement paste, aggregate and the interfaced between aggregate and cement paste, the smaller nominal maximum size has a larger surface compared with the larger nominal maximum size and results therefore a high bonding strength at the interface zone around the aggregate particles when concrete is under loading. In consequence bond failure is avoided and the fracture surfaces pass through the aggregate as well as through the hardened cement paste both under compressive and under tensile loading [6].

The aggregate take a better part in transfer of sternness under loading. The interface one beams stranger, more homogeneous and dense , as a result of silica addition the concrete shows a more brittle behavior and Tran granular type of fracture, the cracks then usually pass through the aggregate [7]. In this research work the locally available constituents of concrete were selected for the purpose of investigating the effect of size of aggregate on the compressive strength of concrete.

2.0 LITERATURE REVIEW

Concrete is a mixture of compendious material, aggregate, and water. Aggregate is commonly considered inert filler, which accounts for 60 to 80 percent of the volume and 70 to 85 percent of the weight of concrete. Although aggregate is considered inert filler, it is a necessary component that defines the concrete's thermal and elastic properties and dimensional stability. Aggregate is classified as two different types, coarse and fine. Coarse aggregate is usually greater than 4.75 mm (retained on a No. 4 sieve), while fine aggregate is less than 4.75 mm (passing the No. 4 sieve). The compressive aggregate strength is an important factor in the selection of aggregate. When determining the strength of normal concrete, most concrete aggregates are several times stronger than the other components in concrete and therefore not a factor in the strength of normal strength concrete.

3.0 EXPERIMENTAL PROGRAM

In order to investigate the effect of size of aggregate on the compressive strength of aggregate an experimental program was carried out in the laboratory of Universiti Sains Malaysia. Four different sizes of aggregates were used in research work; the sizes of coarse aggregates were 10mm, 20mm, 30mm, and mix. Pure natural sand with fineness modulus of 3.67 was used as fine aggregate. Ordinary Portland cement was used as binding material. Different trails of mixing of coarse aggregate were made with using the mix proportions 1:1:2 used in the research.

The water cement ratio 0.5 was constant throughout the experiment. Cube of size 100 mm x 100 mm and prism size 100 mm x 100 mm x 500 mm were cast in laboratory and tested in the Universal testing Machine. Three cubes and three prism of each mix proportion were tested after 7 days, 14 days, 21 days and 28 days.

4.0 METHODOLOGY

There are four different mixtures were produced. A nominal mix ratio of 1:1:2 (Cement: Fine Aggregate: Coarse Aggregate) was adopted for the purpose of this work and a water-cement ratio of 0.6 was used. The required volumes of mix ingredient were measured and mixing was done thoroughly to ensure that homogenous mix is obtained. Before casting, the slump of the concrete is measured in accordance to BS 1881: Part 102 (1983). For each type of coarse aggregate 3 cubes (100 x 100 mm) and 3 prisms (100 x 100 x 500 mm) were cast in accordance to BS 1881: Part 108 (1983). After one day of casting, the concrete cubes were removed from the mold and were transferred to a water tank for curing until the time of test. The curing of the cube was done according to BS 1881: Part 111 (1983). The concretes were tested for compressive strength at 7, 14, 21, and 28 days. Three cubes were crushed using the testing machine and the average taken as the result of the concrete.

5.0 RESULTS AND DISCUSSION

As discussed previously this study was undertaken in order to investigate the effect of different sizes of aggregate of high strength concrete. The parameters to be considered are slump test, compressive strength, flexural strength, density test and water absorption

5.1 Slump Test

Figure 1 depicts the variation of slump and compaction factor values with coarse aggregate size. The slump achieved is in the range of 17 mm to 20 mm which is qualified according to mixing design which is in the range of 10-30 mm. The slump for mix aggregates specimen shows the highest slump which is 20 mm and the size 10 show the lowest slump which is 17 mm. we can notice that the slump is gradually increase while using the biggest size aggregates in concrete design. As a result, the biggest size of aggregates in the mixing concrete will increase the slump test result.

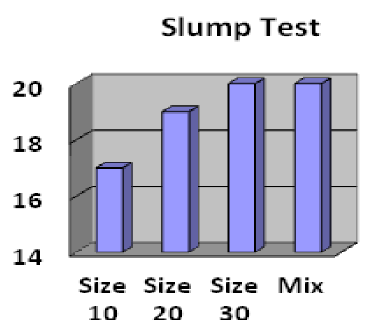


Figure 1 Slump test

5.2 Density

Figure 2 shows that the value of density for the normal concrete by using different sizes of aggregates. As we can see, the higher density along the entire 7 days to 28 days curing age achieved which is size 30 and followed by specimen mix aggregates, size 20 and the lowest size 10. The relationship between density and size of aggregates in concrete gives an inversely proportional result. The bigger size of aggregates in concrete design, the lower density of concrete achieved. From the graph we can see that the density at all specimen increase at age 7 days to age 21days and the value will decrease at age 28 days. The mix aggregate show increase from 2064.37 kg/m³ at age 7 days to 2544.66 kg/m³ at the age 21 days and decrease at age 28 day with value 2373 kg/m³. In conclusion, we can conclude that the density of the concrete will affects the strength of concrete. While the higher the concrete density achieved, the higher the strength of the concrete harden.

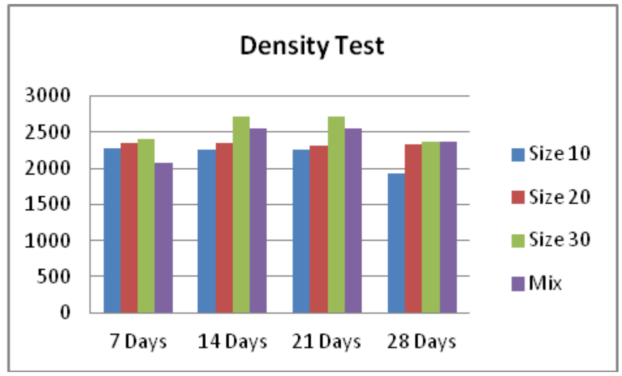


Figure 2 Density test

5.3 Flexural

Figure 3 above shows the value of the flexural strength of the normal concrete using size 10, size 20, size 30 and mix aggregate size. The value for all specimens shows ascending in reading during age 7 days of age 14 days of age and of age 21 days reading descend and increase back at age 28 days. The mix aggregates size show an increase from 4.15 N/mm at above 7 days to 5.31 N/mm² at the age 28 days. The size 20 show the highest increase flexural strength compare to other size specimens at 3.85 N/mm² at the 7 days age to 4.68 N/mm² at the age 28 days. As the conclusion, we can conclude as the uses different size of aggregate can affects the result of the flexural strength. As the result, the specimen mix aggregates show the increases value at the age 7 days to age 28 days.

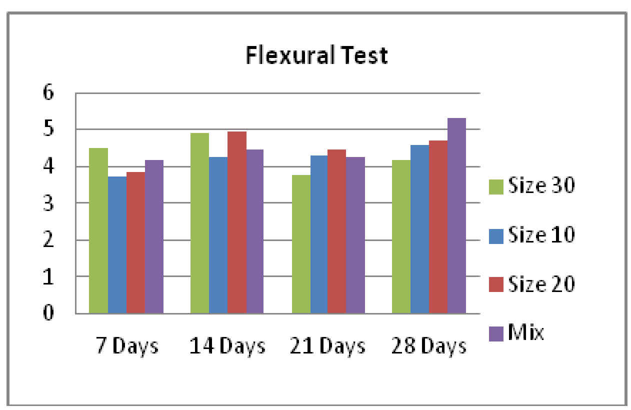


Figure 3 Flexural strength test

5.4 Compressive Strength Test

Figure 4 show the value of the compressive strength of the normal concrete using size 10, size 20, size 30 and mix aggregates size with same curing method at the age of 7 days, 14 days, 21 days and 28 days. From the figures we can see that the compressive strength at all specimens increases with the increasing age of curing but different with Size 10 when in age 21 days the value descend dramatically and increase at the age 28 days. The mix aggregates size show an increases from 26.870 M/mm² to 31.453 at the age at 56 days. The size 30 specimen shows the highest compressive strength compare to other specimens at above increases from 21.123 N/mm² at about 7 days to 31.797 N/mm² at the age at 28 days. The compressive strength of the concrete is affected by the age of concrete and size of aggregates in a concrete design. The compressive strength of the concrete is directly proportional with the age of concrete, while it is indirectly proportional with size of aggregates.

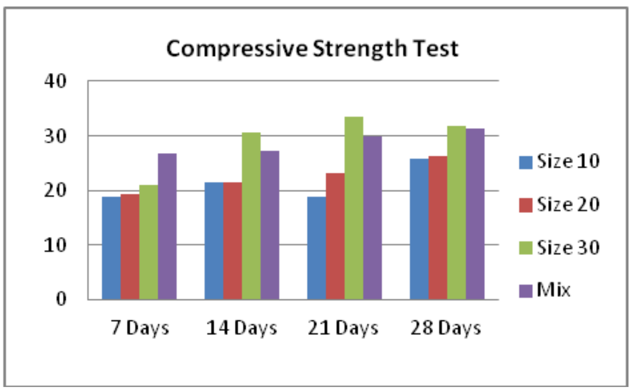


Figure 4 Compressive strength test

5.5 Ultrasonic Pulse Velocity Test

From Figure 5, we can see the velocity of the ultrasonic pulse velocity test is in the range of 3000 m/s to 5000 m/s. the reading between the specimens are inversely proportional to the velocity achieved. The higher size of aggregate in the concrete design, the lower velocity would be achieved. This is due that the higher size aggregate attached concrete that contains voids that affected the velocity of the test. The figures show that the ultrasonic pulse velocity on all cube specimens increasing with the increasing age at curing. The mix aggregates specimen show an increase from 3771.17 m/s at age 7 days to 3943.28 m/s at the age 28 days. The size 30 show the highest result compare to the other specimens at above 3819.00 m/s at the age 7 days to 4968.72 m/s the age of 28 days. As a result, ultrasonic pulse test can be used to understand the characteristics of the internal particles of concrete for predicting the quality of the concrete, by understanding the relationship between velocity achieved toward the characteristic of internal particles of concrete

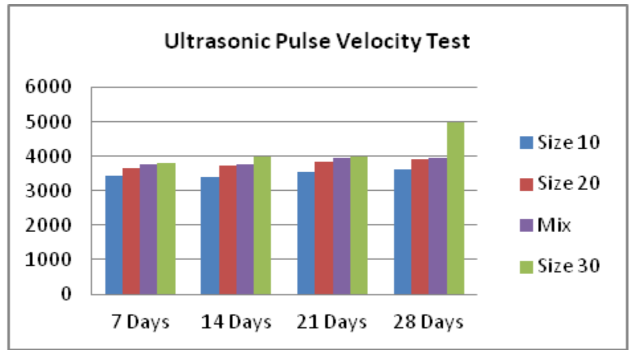


Figure 5 Ultrasonic pulse velocity test

5.6 Water Absorption Test

Water absorption of concrete is naturally related to the nature of the pore system within the hardened concrete. Aggregate can also contain pores, but these are usually discontinuous. Moreover, aggregate particles are enveloped by the cement paste, which is the only continuous phase in concrete so that the pores in aggregate do not contribute to the water absorption of concrete. Thus, the influence of aggregate is quite small. The hardened cement paste has the greatest effect on the absorption of fully compacted concrete. Water absorption value of the concrete specimens do not show any significant comparison in the reading while it just share major characteristics in term of most the water absorption reading show increase in reading in age.

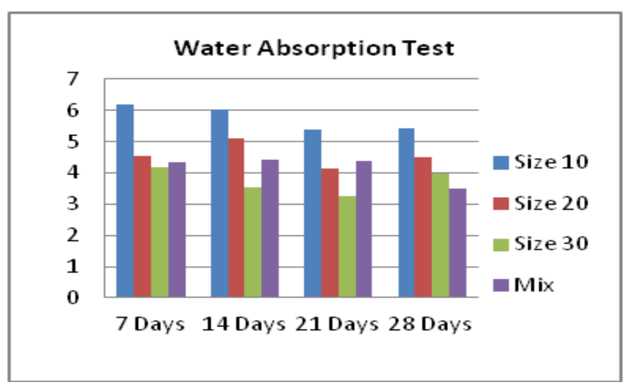


Figure 6 Water absorption test

While the reading of normal concrete with mix aggregates show ascending in reading during 7 days of age to 14 days of age and the reading descend during 21 days of age to 28 day of age descend dramatically. From Figure 6, it can be seen that the water absorption is drop while the age of the concrete increased. This is due to internal properties of the concrete is harden due to the hydration process is directly proportional to the age of the concrete.

6.0 CONCLUSION

The following conclusions are drawn based on the results obtained from the various tests and discussion of findings:

- The bigger size of aggregates in the concrete mixing will increase the slump test result.
- The higher the age of the concrete, the density of the concrete will increased.
- The bigger size of aggregates in concrete, the lower flexural strength will be achieved.
- The Aggregate of sizes 10 mm & 5 mm show higher strength than all other sizes of aggregates.
- The ultrasonic pulse test can be used to understand the characteristics of the internal particles of concrete for predicting the quality of the concrete, by understanding the relationship between velocity achieved toward the characteristic of internal particles of concrete.
- The water absorption of the concrete will be decrease in time as the internal void of the concrete is decreasing time.

References

[1] A. E. Florato. 1989. PCA Research an High Strength Concrete, International. 11(4): 44-50.

[2] Burnet & Wolsifer. 1989. High-strength Concrete in Melbourne Australia Concrete International April, 54-56.

[3] N. J. Carine, J. R. Clifton. 1991. High Strength Concrete, Research Needs to Enhance Its Use. *Concrete International.* 13(9): 70-76.

[4] Higginson, H. A., Wallace, G. B., and Ore, E. L. 1963. Effect of Maximum Size Aggregate on Compressive Strength of Mass Concrete. Symposium on Mass Concrete, Denver, Colo., 14-15 March American Concrete Institute, Detroit, Mich. SP-6. 219-246.

[5] Victor, E., Saouma, J. J., Brühwiler, B. E. and Boggs, H. L. 1991. Effect of Aggregate and Specimen Size on Fracture Properties of Dam Concrete. *Journal of Materials in Civil Engineering.* 3(3): 204-218.

[6] Chen, B. and Liu, J. 2004. Effect of Aggregate on the Fracture Behavior of High Strength Concrete. *Construction and Building Materials.* 18(8): 585-590.

[7] Tumidajski, P. J. and Gong, B. 2006. Effect of Coarse Aggregate Size on Strength and Workability of Concrete. *Canadian Journal of Civil Engineering*. 33(2): 206-213.