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Behavior of the Mass Concrete under Biaxial Loading

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ABSTRACT

Large aggregate concrete is usually used in the mass offshore concrete structures. This paper presents the behavior of large aggregate concrete and sieved concretes under biaxial stress states. The tests are carried out on large size specimens of 25 × 25 × 40cm and 25 × 25 × 25cm and small size concrete specimens of 15 × 15 × 30cm and 15 × 15 ×15cm respectively. The specimens were subjected to biaxial load combinations covering the two regions of compression–compression and compression–tension. The test data indicated that the deformation and strength of the mass concrete specimens were lower than those of the corresponding wet-screened concrete small specimens, but the initial tangent modulus of the stress-strain curve for the former was larger than that for the latter. The test results showed that the size effect of the specimens under biaxial loading was important so that it should be considered in the design for the mass concrete structures. Based on the test data, failure criterion of mass concrete under biaxial loading was established and it could provide effective references for the design and safety evaluation of the massive coastal and offshore structures such as offshore platform and concrete dock wall in which the multiaxial strength of the concrete must be taken into consideration.

KEY WORDS: Mass concrete; stress strain relationship; biaxial strength; deformation; failure criterion.

INTRODUCTION

For various purposes, in massive concrete structures such as concrete dams, water gates, docks, harbor constructions and nuclear power plants, large-sized coarse aggregates are used in the mix design of concrete (usually the maximum aggregate size reaches 80mm or more). Large coarse aggregates require less energy for size reduction with increased production rates (Tumidajski and Gong, 2006). And they help to reduce thermal cracking and shrinkage during mass concrete curing. In practical engineering, these large concrete buildings are generally working under biaxial or triaxial stress state. At present, a great deal of experimental research on the deformation and strength of the common small aggregate concrete has been carried out (Guo, 1997; Song, 2002;), but the multiaxial experiments of mass concrete, which are commonly used in offshore engineering are seldom done, except a few biaxial compression - tension experiments on fully-graded concrete carried out by Song and Zhao (1996). The uniaxial test data of the large concrete specimens (Li and Wang, 2002) indicate that the deformation and strength of the mass concrete specimens are lower than those of the corresponding small wet-screened concrete specimens, but the initial tangent modulus of the stress-strain curve for the former is larger than that for the latter. These test results show that the wet-screened effect and size effect of the specimens under uniaxial stress state are important so that they should be considered in the design for the mass concrete structures. But how these effects behave for the mass concrete specimen under complex stress state is unexplored. What's more, the nonlinear analysis and design for the mass concrete structures require reliable and accurate nonlinear material models of mass concrete. These models can only be achieved by multiaxial experiments on the "real" mass concrete.

In the present work, the behavior of deformation and strength of the large concrete specimens with three-graded aggregate 5-80mm under biaxial compression-tension (abbreviated as C-T) and biaxial compression-compression (abbreviated as C-C) stress states was studied experimentally. In comparison, corresponding wet-screened concrete specimens with two-graded aggregate 5-40mm (big-sized aggregates have been screened out of the concrete specimen) were also tested. This investigation will provide experimental failure behavior characteristics under complex stresses for offshore concrete.

EXPERIMENTAL PROCEDURES

Specimen and mix proportions

Large C-T specimens were 25×25×40cm prisms and small C-T specimens were 15×15×30cm prisms. All the C-T specimens are set by eight pieces of steel bar embedded in their two ends for connection between specimen and testing machine. For biaxial compressive tests, the specimens were 25×25×25cm cubes and 15×15×15cm cubes respectively. It is worth noting that all the specimens have followed such a rule: the specimen dimensions should be at least three times the nominal maximum size of the aggregate.

The concrete used in the study had the following proportions, per cubic meter: cement, 179.2kg; fly ash, 35.8kg; sand (0-5mm), 699kg; fine gravel (5-20mm), 407.1kg; medium gravel (20-40mm), 407.1kg; large gravel (40-80mm),542.8kg; water reducer,0.43kg;and water,129kg. Cement was Chinese standard (GB175-99) R32.5 Portland cement, fine aggregates were natural river sand (fineness modulus of 2.6), coarse aggregates were crushed limestone, and water was tap water. In