Stress-Strain Behavior of High-Strength Concrete Confined by Ultra-High- and Normal-Strength Transverse Reinforcements

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When high-strength concrete is used for reinforced concrete members subjected to seismic loading, it is more difficult to achieve ductile behavior of such members than when normal-strength concrete is used. In this paper, an experimental study of a number of quasi-static axial loading tests on high-strength concrete specimens confined by various amounts of transverse reinforcement is described. The main parameters were concrete strengths ranging from 35.2 to 82.5 MPa and yield strength of Grade 430 and 1300 transverse reinforcement. A stress-strain relationship for confined high-strength concrete is proposed that is found to give reasonably good prediction of the experimental behavior of circular and square specimens with high-strength concrete confined by either normal- or ultra-high-yield-strength with various configurations. An empirical formula for the ultimate longitudinal strain of confined high-strength concrete corresponding to the first hoop or spiral fracture is also proposed.

Keywords: column; confinement reinforcement; high-strength concrete; strains; stresses; tests.

INTRODUCTION

Reinforced concrete buildings are generally designed to behave in a ductile manner under the action of a severe earthquake. To achieve such ductile behavior, structural members of the buildings should be carefully detailed. In the case of buildings with moment-resisting frames, detailing of transverse reinforcement in the potential plastic hinge regions of the columns is a major consideration. For many years researchers have been investigating a method for detailing the transverse reinforcement to increase strength and ductility of reinforced concrete columns. It has been demonstrated that adequate confinement of the core concrete and tying of longitudinal reinforcement using transverse reinforcement can improve column ductility most effectively. Past and recent earthquakes have proved the validity of this philosophy.

The gradual development of concrete technology has promoted the use of high-strength concrete in the construction industry. Concrete technology has developed to an extent where concrete compressive strengths up to 100 MPa and higher can be reached without difficulties. There are, however, only a limited number of studies relating to the confining effects on high-strength concrete, even though the use of high-strength concrete has been increasing in recent years. Meanwhile, the strength of reinforcing steel has also been improved markedly. Normally the yield strength of reinforcement is approximately 300 to 500 MPa. Ultra-high-strength reinforcement with yield strength over 1000 MPa, however, has been recently used for transverse reinforcement of concrete columns in Japan. Some research work has shown that the use of ultra-high-strength steel for transverse reinforcement can effectively increase the ductility of reinforced concrete columns. Ultra-high-strength transverse reinforcement is especially used for columns with high-strength concrete.

RESEARCH SIGNIFICANCE

The most fundamental issue in predicting the behavior of reinforced concrete members is the stress-strain behavior of the constituent materials. Concrete is used to resist compression and its behavior in compression is important to the designer. If the behavior of concrete subjected to uniaxial compression is known, the flexural behavior of reinforced concrete can be estimated. The confinement steel requirements for normal-strength concrete are reasonably well established in current building codes. In recent years, the possible use of high-strength concrete for buildings constructed using reinforced concrete has been considered. Research findings for high-strength concrete, however, are relatively scarce in the literature.

SUMMARY OF MODELS

A number of stress-strain models have been proposed in the past 15 years. A detailed review of existing models was presented elsewhere. The following section provides an overview of these analytical models that cover high-strength concrete.

Martinez, Nilson, and Slate (1982)

Martinez, Nilson, and Slate conducted experiments on several small diameter cylindrical specimens of high-strength concrete confined by spiral reinforcement without concrete cover and longitudinal reinforcement. The concrete strength of the specimens ranged from 21 to 69 MPa and the confining pressure ranged from 1.7 to 2.1 MPa. The yield strength of the lateral reinforcement was approximately 414 MPa. They proposed a theoretical model for the complete stress-strain curve of spirally confined high-strength concrete columns based on their own test results.

Fafitis and Shah (1985)

Fafitis and Shah tested a large number of small concrete cylinders with practically no cover to the spiral steel and had no longitudinal reinforcement. The spiral wire was 3.2 mm