| | |
|---|---|
| *Project Title:* | Development of High Modulus Concrete for Tall Buildings |
| *Principal Investigator:* | Prof. Zongjin LI |
| *Project ID:* | CICR/04/12 |
| *Research Institution:* | The Hong Kong University of Science and Technology |
| *Subject Area:* | Construction Materials |

## Objective

This experimental research is to optimize mix proportion for high modulus concrete, to characterize the properties of the developed high modulus concrete, and to apply the high modulus concrete to practical structural elements.

## Background

Concrete is the most commonly used material for tall buildings, as it is economical, durable, fire resistant and energy efficient. While Hong Kong has been ranked the first in the most high-rise buildings, the key of designing such buildings is to control lateral deformation due to wind load and seismic load. Concrete stiffness is a key parameter in controlling lateral deformation of buildings. Therefore, development of high modulus concrete is important, and the use of high modulus concrete would help reduce lateral deformation of tall buildings.

## Data and Methodology

Using Ordinary Portland Cement, pulverized fly ash, condensed silica fume and some additional mineral admixtures, high modulus concretes were prepared, and then tested. Mechanical properties were measured by uniaxial compression tests and static elastic modulus tests, while the physical properties were studied by shrinkage and creep tests. In addition, bending tests of reinforced concrete beams were also conducted.

Uniaxial Compression Tests

During the preparation, aggregate is needed to be distributed evenly in the concrete mix to achieve high quality. Ultrasonic mixing technique was applied to ensure all binders could be distributed in the water for improving the mechanical properties. After mixing, slump tests were conducted to measure the workability with the lowest acceptable value of 100mm. Then, the concrete strengths were measured at the age of 7, 14, 28 and 56 days at a loading rate of 3 kN/s.

Static Elastic Modulus Tests

The method outlined in ASTM C469 was followed to measure the chord modulus of elasticity. Two longitudinal extensometers were installed to measure the elongation of the specimen while a circumferential extensometer was installed in the middle of the cylinder, to record the circumferential strain. Before applying a 0.25 MPa/s stress rate in compression, three cycles of pre-loading and unloading were applied to eliminate the abnormal deformation of the specimen.

Shrinkage and Creep Tests

Four different concrete mixes with various compressive strength and modulus of elasticity were cast, and total shrinkage and autogenous shrinkage were measured 24 hours after casting. For the measurement of autogenous shrinkage, the specimens were demoulded and sealed with aluminium waterproofing tape. Shrinkage was measured using CT-171M Demac strain gauges with an initial gauge length of 100±1.5mm. As for the creep test, ASTM C512 was followed using diameter 100mm × 200mm long cylinders, and four specimens were tested using a 40kN constant load, which equalled 20% of the compressive strength of a C45 concrete at the age of two days.

Reinforced Concrete Beam Bending Test

Rectangular reinforced concrete beams with the same dimensions (width =120mm, height = 220mm and length = 1800mm) were tested. They were casted using C45, C80, high stiffness concrete (HEC) and ultra-

high stiffness concrete (UHEC), respectively. All the test beams were loaded in four-point bending condition, with a constant loading rate of 0.02mm/s until the specimens failed. During the test, the vertical deflection at the midpoint of the specimens was measured.

## Results and Findings

The highest modulus of elasticity of concrete developed in the study is 53.5 GPa and the stiffness enhancement is almost 20% compared with the same strength level concrete in the Code of Practice.

With regard to shrinkage and creep, the test results indicated that high modulus concrete had a much smaller drying shrinkage value although its autogenous shrinkage was slightly larger than normal concrete. However, the total shrinkage measured on the unsealed specimens showed a different trend. The results indicated that C45 had the largest total shrinkage over 700 micro-strain while the UHEC only had 400 micro-strain.

A constant load of 40 kN was applied on concrete cylinders to study the difference of creep properties among different types of concrete. The C45 specimen had a creep value of over 1100 micro-strain at 28 days, which was much larger than an unloaded specimen. UHEC had a much better performance and its creep was only roughly 500 micro-strain.

From the bending tests of reinforced concrete beams, it was observed that the load carrying capacity of the UHEC concrete beam was about 30% higher than the C45 concrete beam.

## Recommendations

Although the unit price of high modulus concrete may be slightly higher than normal concrete, the total amount of concrete consumption will be less if high modulus concrete is applied for real constructions. However, more investigations are still required on its other properties, such as permeability, fire resistance and alkali-silica reaction.