EXPERIMENTAL INVESTIGATION OF HIGH PERFORMANCE CONCRETE UNDER REPEATED COMPRESSIVE LOADING

by

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Dedicated to the Everlasting

Memory of My

Grand Mother

Parents

And

Father-in-Law

Shri. M.H. Babakkanavar

CERTIFICATE

This is to certify that the thesis entitled **"Behaviour of High Performance Concrete under Repeated Compressive Loading"** being submitted by **R.B.Khadiranaikar** to the Indian Institute of Technology, Delhi for the award of the Degree of Doctor of Philosophy in Civil Engineering, is a record of bonafide research work carried out by him. **Mr. R.B.Khadiranaikar** has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our knowledge has reached the requisite standard.

This thesis or any part thereof, has not been submitted to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

In this study, an experimental investigation was conducted to study the behaviour of high performance concrete under repeated compressive loading. Stress-strain characteristics, energy dissipation characteristics, stiffness degradation, brittleness and mode of failure are discussed.

The cylinder concrete specimens with flared ends having 150 mm diameter and a height of 400 mm were tested to investigate the behaviour under repeated compressive loading. Three grades of high performance concrete were investigated. Three types of tests were conducted for each grade of concrete: (i) Monotonic tests where load is increased to failure; (ii) Repeated loading – unloading in which the peak of each loading cycle approximately coincides with the monotonic curve. The stress-strain hysteresis of this test possessed a locus of common points, which is a point of intersection of reloading curve with the previous unloading curve; (iii) Tests consisting repeated loading-unloading in which the repeated load was applied as in the second type except that in each cycle loading and unloading were repeated several times; each time the load was released when the reloading curve intersected the initial unloading curve. This point of intersection gradually descended and stabilised at a lowerbound point. Such lowerbound points are termed as stability points and the further cycling led to the formation of a closed hysteresis loop.

Single general mathematical expression is proposed for the determination of the envelope stress-strain curve, the locus of common points and the locus of stability points for all the three grades of concrete, which provides a reasonable fit with experimental data. Further a stability point curve for each grade of concrete is used in defining the permissible stress level of high performance concrete structures, where reduction of compressive strength due to the effect of repeated loading have to be taken in to account. It is found that the level of plastic (residual) strain in the material is an important factor in defining the permissible stress under repeated loading.

A study was also made on the energy dissipation characteristics of high performance concrete under repeated compressive loading. Empirical expressions were suggested for the variation of energy dissipation ratio with the envelope strain and plastic strain. The relation between energy dissipation and plastic strain can be used to identify the point of load history at which the process of strength deterioration begins. The total energy has been divided in to three components representing the energy dissipated in damage, energy dissipated in damping mechanism and elastic strain energy. Cumulative damage energy indicates the damage of the material. Lower strength concrete (i.e. M1 concrete) experienced more damage prior to peak strain and after the peak strain higher strength concrete indicated higher cumulative damage energy. Based on energy concepts brittleness indices were worked out for the three grades of concrete. Brittleness index increases with the increase in strength.

Stiffness degradation and strength deterioration under repeated compressive loading were presented and it was quantified by mathematical expressions with respect to envelope strain, plastic strain and energy dissipation ratio. High performance concrete experienced strength deterioration and stiffness degradation as the number and intensity of load repetition increased.

A mathematical model is proposed to obtain the stress-strain reloading and unloading curves for high performance concrete under repeated compressive loading. Both reloading and unloading curves were found to depend on the plastic strain level. It was shown that the reloading curves could be represented by exponential formula. The model for reloading curves involved plotting the reloading curves from a common origin by transferring them to a new normalised coordinate system. The unloading curve at any cyclic load level was modelled by a simple parabola. The model predictions compare well with the experimentally obtained stress-strain reloading and unloading curves.

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