STRESS STRAIN BEHAVIOUR OF FERRO LAYER TIE CONFINED SELF COMPACTING CONCRETE UNDER AXIAL LOAD

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ABSTRACT

The utility of concrete seems to be severely limited by its more brittle behaviour. stress-strain diagrams for self-compacting concrete confined with ferro cement layer in addition to lateral tie confinement is presented, Increase in the strength and strain of concrete confined with ferro cement shell and lateral tie confinement is found to be linear.

Ferro cement confinement is one of the oldest, efficient and cost effective techniques of re-strengthening of deteriorated and weak columns. Ferro cement is a form of thin walls and columns reinforced concrete using wire mesh and high strength mortar. Small diameter of wires used as reinforcement, leads to a higher specific surface, providing homogeneity to the ferrocement. Closely spaced wires provide more ductility and energy absorption capacity.

for concrete to develop adequate rotational capacity, more lateral steel is required, or there is a requirement for additional confinement. it is indicated that ferro cement shell can be provided as additional confinement.

the present investigation aims at studying the effect of ferro cement shell as an additional confinement provided above the lateral ties on self compacting concrete. in this study, m30 grade of concrete is used and cylinders of 150mm diameter and 300mm height were casted with varying ties spacing and galvanised iron (gi) wire mesh layers.

INTRODUCTION

Today, more and more structures are constructed with high strength concrete because it provides a number of advantages in strength and mechanical properties over normal strength concrete at a reasonable cost. HSC is most commonly used in the columns of high rise buildings where it is desirable for a number of reasons, including a higher modulus of elasticity, which results in higher stiffness and reduced sway under larglateralloads;

increase in free floor space due to the use of smaller column cross sectional areas. a reduction in the axial shortening due to concrete shrinkage and less weight being transmitted to the foundation.

HSC is still a relatively unexplored material, and many of the problems associated with its use arise from its brittle nature. This is because HSC fails suddenly when loaded beyond its peak and is more brittle in nature than normal strength concrete.

In elastic deformation of a reinforced concrete column is essential for the overall strength and stability of a structure during earthquakes and large wind loads. Increased ductility of columns made with HSC can be achieved through proper confinement of the concrete core. In fact ties in reinforced concrete columns play an important role in enhancing thestrengthandductility.

Under axial loads, concrete pressure in the lateral direction of the column section acts on the lateral ties and the resistance of the ties may restrain the core concrete. With the increase of axial loads, initial cracks are propagated in the parallel direction to the longitudinal bars at the corners of the column section. Around the yielding of the longitudinal bars, the concrete cover spalls off and begins to unload. The confined columns exhibit a more load carrying capacity after the spalling. When the maximum axial load is exceeded, the longitudinal bars buckle and hook of ties open.

Objective and Scope of Investigation

The objective of present investigation is to develop analytical stress-strain curves for the reinforced concrete prisms confined with rectilinear ties.

In order to determine the moment-curvature behavior of a reinforced concrete section, a stress-strain relationship of reinforcing steel and concrete is required. The stress-strain relationship of steel can easily be found from the direct tension test, whereas for a confined concrete, obtaining the stress strain behavior is quite complex. As confinement enhances both strength and ductility of concrete, use of code specified stress-strain relation for unconfined concrete would lead to very inaccurate prediction of moment-curvature behavior.

For the prediction of stress-strain relation of concrete confined with lateral ties, many confinement models based on experimental investigation have been reported in the literature during last three decades. Thus, study of applicability of such models in predicting moment-curvature relationship is a timely concern. In the present investigation five recent confinement models reported in the last decade (1995 to 2005) were selected for the study. The selected models were compared for their ability to predict the actual stress-strain behavior of confined concrete. The present investigation was thus carried out by the analytical prediction of the stress-strain behavior of the concrete confined with lateral ties. The models that were used in this investigation are:

- Daniel Cusson and Patrick Paultre (Cusson model) (1995)
- G. Rajesh Kumar and A. Kamasundara Rao (GRK model) (1998)
- Salim Razvi and Murat Saatciglu (Razvi model) (1999)
- P.Mendis, R. Pendyala and S. Setunge (Mendis model) (2000)
- Frederic Legeron and Patrick Paultre (Legeron model) (2003)

Confinement

To achieve a ductile behaviour, the structural members should also be carefully detailed. A careful detailing of transverse reinforcement is very important as the confining action it provides to the brittle concrete, enhances its strength as well as ductility.

The various methods available to confine the concrete are:

- By providing lateral ties, spirals
- Inclusion of steel fibres, carbon fibres
- Jacketing through Ferro-cement & fibre reinforced polymers

Lateral ties in concrete:

It is known that the ductility can be improved by confining action of lateral ties in concrete. As per IS: 13920 - 1993 the ties has to place in the concrete with 135^0 hooks to meet the requirements of seismic design. The beam-column joints are the places where high congestion of reinforcement exists, due to which the 135^0 hooks may create obstruction for placing the concrete. Thus, an alternative way of placing the ties is with welded ends with proper lap length.

Ferro cement:

Ferro cement is a composite material made up of cement mortar and reinforcement in the form of layer of mesh. The mesh may be made of metallic or other suitable materials. Unlike conventional concrete, Ferro cement reinforcement can be assembled into its final desired shape and the mortar can be plastered directly in place without the use of a form which results in a flexible and strong enough Ferro cement structures. Ferro cement is a form of reinforced concrete that differs from conventional reinforced or pre-stressed concrete primarily by the manner in which the reinforcing elements are dispersed and arranged. It consists of closely spaced, multiple layers of mesh or fine rods completely embedded in cement mortar. A composite material is formed that behaves differently from conventional reinforced concrete in strength, deformation, and potential applications, and thus is classified as a separate and distinct material.

Resistance to earthquake by ferrocement structures:

Ferrocement structures are highly ductile and energy absorbing material that can sustains large deformations without collapsing during earthquakes. Moreover the deformed building structures can be easily repaired at very low cost after deformation. Ferrocement structures resist the earthquake of Richter scale 7.2-7.4 whereas RCC structures collapsed. One such example of strong earthquakes that occurred in Mexico in 1999 twice Richer scale 7.2 & 7.4. These earthquakes destroyed or severely damaged thousands of houses, hundreds of schools and churches and took many lives. The Ferrocement structures such as school, all houses, the class room laboratory, the largest auditorium, all the bridges and small dams that have been designed and constructed were untouched. Ferrocement structures constructed on small scale in Bhuj, Saurashtra and Ahmedabad have performed very satisfactorily with no crack development at all. Ferrocement structures constructed in Orissa under direction of HUDCO, have withstood fury of cyclone very satisfactory.

Ferrocement Structural Elements:

Ferrocement confined beams and columns are constructed with ferrocement as a skin on the periphery surface. These skins consist of layers of wire mesh, welded wire mesh, high tensile strength wires, mild steel flats, etc. The core consists of high strength concrete. Due to its better crack arresting property and high ductility this arrangement increases the resistance to bending moment, shear, and torsion. The crack formation can be delayed further by addition of fibres on the surface if feasible. Ferrocement confined beams and columns can be further strengthened by welding the mild steel flats, rings in the form of flats angles etc. and round bars at each and every crossing. Therefore there is induced resistance to deflection during fabrication stage itself. This process makes the ferrocement structures highly energy absorbing, resilient and ductile. Ferrocement slab about 20 to 25mm thick consists of grid of Mild Steel flats, wire mesh layers on top and bottom. Welded wire mesh, High Tensile Strength wires can be used in case greater thickness is required.

Ductility:

Ductility of a material enables it to draw out into thin wire on application of the load. Mild steel isa ductile material. The wires of gold, silver, copper, aluminium, etc. are drawn by extrusion or by pulling through a hole in a die due to the ductile property. The ductility decreases with increase oftemperature.The per cent elongation and the reduction in area in tension is often used as empirical measures of ductility

The property which permits deformations under tensions with out rupture, values of elongation and reductions of area are generally taken as a measure of ductility.

Literature Review

General

Numerous studies were reported in literature regarding the behaviour of the concrete confined with laterals. Most of the experimental results were obtained from small-scale tests on simple tie configuration. The main factors considered in these studies are (1) Type and strength of concrete, (2) Amount and distribution of longitudinal reinforcement, (3) Amount, Spacing and configuration of transverse reinforcement, (4) Size and Shape of confined concrete, (5) Ratio of confined area to gross area, (6) Strain rate, (7) Supplementary cross ties and (8) Characteristics of lateral steel.

On the basis of experimental data, various stress-strain curves for concrete confined with lateral ties have been proposed. A comparative study (Sheikh, S.A., 1982), shows that most of these analytical models are effective only to interpret their own test results or data used. This may be attributed to the differences in the details of test specimens used and variables considered in the development of analytical models. The models proposed, considering important variables are due to Park, R., et al., (1971), Reddy, S. R., (1974), Vallanas, et al., (1977), Sheikh and Uzmeri, (1982), Mander, et al., (1988), Razvi, et al., (1990), Nagashima, et al., (1992), Muguruma, et al., (1993), Li, et al., (1994), Cusson and Paultre, (1995), Legeron and Paultre, (2003), Weena et al. (2005) and Kaushik, et al., (2005), B.Bousalem, N. Chikh (2006).

Historical Development

Many confinement models have been proposed for confined concrete in uniaxial compression. Richart et al. (1928) were among the first to study the confinement of normal–strength concrete. Their work provided some of the basic information on modeling of confined concrete. Subsequently a number of analytical models were proposed for confined normal–strength concrete by various researchers such as Chan (1955), Roy and Sozen (1963), Sargin (1971), Kent and Park (1971), Vllenas et al. (1977), Sheik and Uzmeri (1980), park et al.. (1982), etc. The models reported up to the early 1980's had various limitations. Their biggest drawback was that the distribution of longitudinal reinforcement and the resulting lateral steel arrangement was not included in the models as a confinement parameter. A comparative study, conducted by Sheikh (1982) showed that the models did not account for reinforcement arrangement as parameters were not able to predict differences in response resulting from tie arrangement. The influence of this parameter was modeled for the first time by Sheikh and Uzmeri (1982) and the later by Mander et al. (1988) by utilizing the effectively confined core concept. Mander's model was the most unified, widely accepted and with wider scope than those of all previous models, but was only applicable to lower concrete strength ranges.the analytical models for normal strength concrete based on extensive experimental data are well established.

Reddy, S.R.[6], (1974):

Reddy, S. R., (1974), conducted tests on 432 prisms of size 100x100x200 mm and 150x150x300 mm to study the confining effect of rectangular binder(ties and helices) on concrete. Half of these prisms were aimed to study the confinement produced by rectangular ties. The ties were provided such that no cover is present in the specimen. Based on the above investigation, was proposed. A general equation for stress-strain curve for confined concrete and above stress block was validated by predicting the moments and curvatures of reinforced concrete beams by testing 56 simply supported beams.

Nagashima et al.[7] (1992)

Twenty-six prism specimens (225×716 mm) of high strength concrete of strengths 59 and 118 MPa and laterally reinforced with ties of yield strengths 784 and 1374 MPa were tested by Nagashima et al. Based on the test results a two-part stress-strain relationship was proposed for confined high-strength concrete columns. The variables taken into account were concrete strength, yield strength of lateral steel, tie configuration and spacing of lateral steel.

Muguruma et al[8]. (1993):

Muguruma et al. proposed a three-part stress strain model for confined concrete based on their previous studies. A wide range of concrete strength ranging from 40 to 130 MPa was covered. They tested small square specimens confined laterally by square helix hoops of different yield strengths and with various volumetric ratios. The yield strengths of the hoops ranged from 161 to 1353 MPa.

Hsu and Hsu[3] ,(1999):

Hsu & Hsu (1999), conducted compression tests on 76.2x152.4 mm cylindrical specimen with compressive strength exceeding 69 MPa. They observed that the normal concrete gradually fails after reaching its peak load, whereas the high strength concrete suddenly explodes at peak load, due to which complete stress strain curve for high strength concrete could not be obtained. An analytical model is proposed to predict the stress strain response. The model is nearly similar to the one proposed by Caeira and Chu (1985), but wit h some modifications.

Cusson and Paultre[1] ,(2001):

Cusson and Paultre (2001), conducted experiments on 27 large scale high strength concrete columns (235x235x 1400 mm), confined by rectangular ties under concentric loading. The variables considered are, the concrete compressive strength, tie yield strength, its configuration, lateral reinforcement ratio, its spacing, longitudinal reinforcement ratio and influence of concrete cover. Their findings suggest that only the area of the concrete core should be considered in calculating the axial compressive strength of high strength concrete columns. They also concluded that reduction of tie spacing result in an increase of the strength and toughness.

Cusson and Paultre[2] ,(2002):

Cusson and Paultre developed a confinement model for high-strength concrete on the basis of test results of 50 large-scale high-strength concrete tied columns tested under concentric loading. Out of them, 30 high-strength concrete tied columns (235×235×1400 mm) were tested by authors themselves and 20 high-strength concrete tied columns (225×225 ×715 mm) were tested by Nagashimaetal.

The concrete compressive strengths of the specimens ranged from 60 to 120 MPa. The ties with yield strength from 400 to 800 MPa were used. The proposed model takes in to account tie yield strength, tie configuration, transverse reinforcement ratio, tie spacing, and longitudinal reinforcement ratio. The two-part stress-strain relationship included separate expressions for ascending and descending parts.

Kumar, G.R.[5], (2004):

Kumar, G.R., (2004) developed a confinement model for high strength concrete on the basis of test results of 126 prisms (size 150 x150 x 300 mm) tested under concentric load at strain rate control. The variables in the proposed

study were the grade of concrete (30 to 50 MPa), the diameter of tie reinforcement (6 and 8 mm), the type of tie spacing and the spacing of ties (225,150, 100, 75, 50 and 25 mm). A stress– strain model and the rectangular stress block were developed for tie confined high strength concrete.

Yong et al. (1988):

Yong, Y. K., Nour, M. G., and Nawy, E. G. proposed a model for rectilinearly confined high-strength concrete columns. They tested 24 square prisms that were made of high-strength concrete with compressive strength ranging from 83.6 to 93.5 MPa, confined with square ties with yield strength of 496 MPa. The variables considered were volumetric ratio of lateral ties, concrete cover and distribution of lateral steel. A three-part stress-strain relation was proposed to predict the constitutive behaviour of confined high-strength concrete.

Foster and Attard (2002)

Foster and Attard (2002) conducted test on 68 end haunched concrete columns with varying concrete strengths (40, 55, 75 and 90 MPa), load eccentricities (8, 20 and 50 mm), tie spacing (30, 60 and 120 mm) and longitudinal steel volumes (2 and 4 percent). The ultimate strength of the columns was compared to the strength predicted based on ACI 318 – 89 rectangular stress block parameters. Ductility is calculated based on the area under the load versus average strain plus curvature times eccentricity relationship. They concluded that for the same confinement parameter, the higher strength concrete specimens recorded considerably lower ductility than their lower strength counterpart for the same load eccentricity. The maximum strain that they could obtain in their work was of the order of 0.015.

Li et al. (1994)

Li et al. proposed a three-part stress–strain model for confined high-strength concrete based on their experimental results. Forty reinforced concrete short columns of both cylindrical (240×720 mm) and square (240×240× 720 mm) cross-sectional shapes were tested. The main parameters were in place concrete strength (35.2 to 82.5 MPa) and lateral steel grade (445 and 1318 MPa) in addition to other parameters such as spacing, volumetric ratio and configuration of lateral steel.

Bjerkli et al. (1990):

Bjerkli, L., Tomaszewicz, A., and Jansen, J. J. proposed a three-part stress-strain curve for high-strength concrete columns for both circular and rectilinear cross-sectional shapes based upon their test results. They tested a large number of plain and confined high-strength concrete columns with compressive strength ranging from 65 to 114 MPa. Both cross-sectional shapes, namely cylinders (150 mm diameter and 500 mm high) and prisms (150×150×500 mm and 300×500×2000 mm) were included. The test specimens contained longitudinal steel but no concrete cover.

Subramanian and Chattopadhyay:

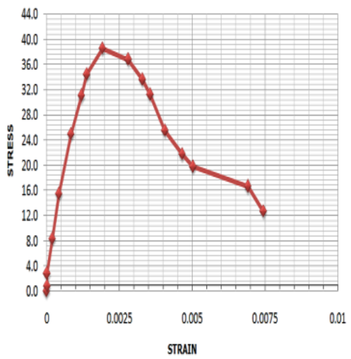
Both members are research and development engineers at the ECC Division of Larsen & Toubro Ltd (L&T), Chennai, India. They have over 10 years of experience on development of self-compacting concrete, underwater concrete with anti washout admixtures and proportioning of special concrete mixtures. Their research was concentrated on several trials carried out to arrive at an approximate mix proportion of self-compacting concrete, which would give the procedure for the selection of a viscosity modifying agent, a compatible super plasticizer and the determination of their dosages. The Portland cement was partially replaced with fly ash and blast furnace slag, in the same percentages as Ozawa has done before and the maximum coarse aggregate size did not exceed 25mm.

The two researchers were trying to determine different coarse and fine aggregate contents from those developed by Okamura. The coarse aggregate content was varied, along with water-powder (cement, fly ash and slag) ratio, being 50%, 48% and 46% of the solid volume. The U-tube trials were repeated for

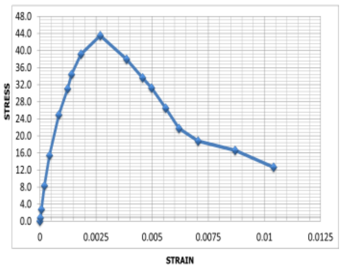
different water-powder ratios ranging from 0.3 to 0.7 in steps of 0.10. On the basis of these trials, it was discovered that Self-Compatibility could be achieved when the coarse aggregate content was restricted to 46 percent instead of 50 percent tried by Okamura. In the next series of experiments, the coarse aggregate content was fixed at 46 percent and the sand content in the mortar portion was varied from 36 percent to 44 percent on a solid volume basis in steps of 2 percent. Again, the water-powder ratio was varied from 0.3 to 0.7 and based on the U-tube trials a sand content of 42 percent was selected. In order to show the necessity of using a viscosity-modifying agent along with a super plasticizer, to reduce the cast a few trial specimens. In these trials, viscosity-modifying agent was not used. The cast specimens were heavily reinforced slabs having 2400x600x80 mm and no vibration or any other method of compaction was used. However, careful qualitative observations revealed that the proportions needed to be delicately adjusted within narrow limits to eliminate bleeding as well as settlement of coarse aggregate. It was difficult to obtain a mixture that was at the same time fluid of aggregate may result either in a mixture with in adequate flow inability.

RESULTS

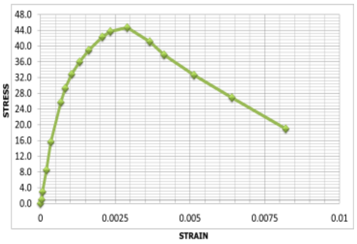
1. Stress-strain curve of M30 grade of normal concrete:



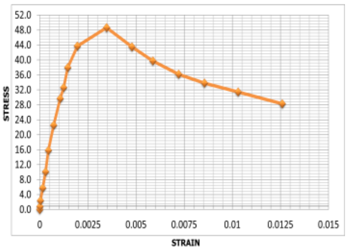
2.Stress-strain curve of 4 Ties + M30 grade concrete:



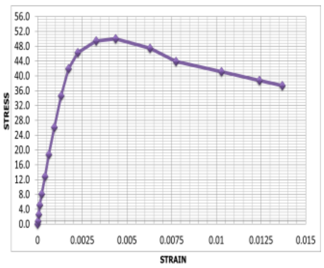
3.Stress-strain curve of 2 Layer Ferro + 4 Ties + M30 grade concrete:



4.Stress-strain curve of 3 Layer Ferro+ 4Ties + M30 grade concrete:



5.Stress-strain curve of 4 Layer Ferro + 4 Ties + M30 grade concrete



CONCLUSIONS

From the analytical study of different models for the high strength concrete confined with ties the following conclusions may be drawn:

- The peak strength, corresponding strain and ductility increases with the increase in the level of confinement. Ferrocement confinement increased the ultimate load carrying capacity of columns.

- As the confinement level increases, the enhancement of peak strength, corresponding strain and ductility decreases with the increase in the strength of concrete.
- The analytical behaviour of the ascending portion, predicted by all the five models, is found to be similar.
- Ferrocement confinement increased the ultimate load carrying capacity of columns.
- A Ferro cement shell, with high particle strength mortar between Ferro cement layers is an effective way of providing additional confinement of concrete in axial compression and has the advantage over lateral tie confinement of improving material performance under large deformations..

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