Enhancement of Incarceration on Ductile Property of Concrete Beam

Amol Shekhar Gangwar[1] Anuj Verma[2]

[1]M. Tech Student, [2]Assistant Professor
[1,2]Department of Civil Engineering, Rajshree Institute of Management and Technology, Bareilly

***Abstract*: We are well aware of the fact that concrete's ductility and strength rely a lot on the amount of confinement offered due to lateral reinforcement. According to the latest codes of design, the strength design is offered separately against deformability. Evaluating the deformability does not depend on most of the key features of steel and concrete. In this study, RCC beams with curvature ductility and their distinct amounts of confinement are devised with analytical methods using the Hong K N and Han S H model of 2005 and Saaticioglu with Razvi Model of 1992 to compare the results of an experiment. A group of six RCC beams that are rectangular in shape has a similar cross-section and we analyze the major reinforcement with the help of OPENSEES software. Distinct lateral confinement levels of beams are introduced stirrups that have 2 and 3 legs which are offered with a trip of distinct spaces. For experiments only, a group of 6 RCC beans is formed with the help of stirrups offers at spaces of about 100mm, 150mm & about 250mm. A trio of beams has two legs only and another trio has three legs in the stirrups. According to analytics, we find that the ductility of curvature gets enhanced with the lessening of the space of stirrups and an enhancement in the number of stirrup legs, which means the curvature ductility in the beam gets enhanced due to lateral detention The deviation in accordance with the space is higher when you compare it with the legs that stirrups have. This has been devised using both the models. We can see the similar trends with the help of the results of the experiment. The results of the analytics follow the Razvi and Saatcioglu (in 1995) Model and were known to confirm the results of the experiment.**

Index Terms*—*Concrete, Beam, Compressive Strength, Tensile, Reinforcement.

I. INTRODUCTION:

It is well known that the strength and ductility of concrete are highly dependent on the level of confinement provided by level of the lateral reinforcement. In the flexural design of reinforced concrete (RC) beams, the strength and deformability, which are interrelated, need to be considered simultaneously. However, in current design codes, design of strength is separated with deformability, and evaluation of deformability is independent of some key parameters, like concrete strength, steel yield strength and confinement content. Hence, provisions in current design codes may not provide sufficient deformability for beams. In this thesis a detailed study is presented on ductility behavior of RC beams with confinement by experimentally and analytically. To investigate the influence of the transverse reinforcing ratio on the beam ductility, an experimental program is conducted. Six no's of beams are cast with varying c/c spacing between stirrups of two legged and three legged.

In the seismic design of reinforced concrete beams of structures, the potential plastic hinge regions need to be carefully detailed for ductility in order to ensure that the shaking from large earthquakes will not cause collapse. Adequate ductility of members of reinforced concrete frames is also necessary to ensure that moment redistribution can occur. Previous tests have shown that the confinement of concrete by suitable arrangements of transverse reinforcement results in a significant increase in both the strength and the ductility of the member. In particular, the strength enhancement from confinement and the slope of the descending branch of the concrete stress-strain curve have a considerable influence on the flexural strength and ductility of reinforced concrete beams.

The cover concrete will be unconfined and will eventually become ineffective after maximum allowed strain is attained, but the core concrete will continue to carry stress at high strains. The compressive stress distributions for the core and cover concrete are defined by confined and unconfined concrete stress-strain relations. Good confinement of the core concrete is essential if the beam is to have ductility. The deformability of RC flexural members depends upon a number of factors, including percentage of tensile reinforcement, percentage of compressive reinforcement, percentage of lateral reinforcement and strength of concrete. Investigation regarding ductility of flexural members utilizing normal weight aggregate and light weight aggregate has been explored in number of studies. Although adequate flexural ductility is essential for structures in high seismicity regions, many serious problems relating to the behavior of RC structures under severe seismic action can be traced due to the poor detailing of reinforced concrete. Knowledge of post peak deformation characteristics of reinforced concrete members are very desirable for proper understanding of the contribution of lateral reinforcement and to understand the failure mechanisms under seismic conditions where, higher ductility demands are placed on reinforced concrete members.

II. LITERATURE REVIEW:

A number of studies have generated very useful information on the strength and deformation characteristics of reinforced concrete members. However these studies are limited to ultimate load stage and failure modes, and there is no information available on post peak stage deformation of reinforced concrete members. It has been pointed by number of investigators that the testing methodology influences the mode of failure and post peak behavior of concrete. For example the failure of concrete under uncontrolled compressive loading cause brittle type failure whereas under controlled condition relatively ductile failure occurs. It would be too expensive to design a structure based on the “elastic” spectrum, and the code (IS 1893) allows the use of a “Response Reduction Factor” (R), to reduce the seismic loads. But this reduction will be possible, if sufficient ductility is in-built through proper design of the structural elements. Hence to get a correct response *non-linear analysis* of RCC structures should be carried out. The inelastic analysis exhibits behavior beyond the yielding stage which can be represented in terms of formation of plastic hinges, redistribution of moments etc. Ductility in a structure can be achieved by formation of plastic hinges at appropriate locations in the structural frame. The ductility of plastic hinge can be determined from the shape of the moment curvature relations. Moment curvature relation for an RCC beam can be determined if stress-strain relations for concrete and steel are known. The ductility of RCC member can be drastically increased by suitable arrangement of stirrups causing confinement of core concrete. Hence during design stress-strain curve for confined concrete must be considered. Several models are available for stress-strain relation of confined concrete.

HONG K N and Han S H (2005) Model: This model proposed two equations for ascending and descending branches of the stress-strain curve by considering the properties of the lateral reinforcement such as diameter, spacing, yield strength, configuration and longitudinal reinforcement. A graph is shown here which will differentiate between confined and unconfined concrete.

The non-linear static method or pushover analysis is performed by subjecting a structure to a monotonically increasing pattern of lateral forces, representing the inertial forces which would be experienced by the structure when subjected to ground motion. Under incrementally increasing loads various structural elements may yield sequentially. As result, the structure experiences a loss in stiffness at each event. The characteristic nonlinear force-displacement relationship is determined by using the pushover analysis and any force and displacement can be chosen. The first pushover load case is typically used to apply gravity load. a Then, subsequent lateral pushover load cases are specified to start from the final conditions of the gravity (Kadid and Boumrkik (2008), FEMA 440, 2005). The non-linear static procedure stated in EC8 (Eurocode 8, 2005). It requires development of the pushover curve by applying first gravity loads, and then followed by monotonical increasing lateral forces with a specified height-wise distribution. This method is relatively simple and provides information about strength, displacement, ductility and display mode of plastic hinges. This enables the identification of the critical elements, which may reach the limit states during an earthquake. Nonlinear static (pushover) analysis provides the curve capacity of the structure, which represents the horizontal effort at the base for the building according to the displacement of the later.

III. METHOD OF ANALYSIS:

Ductility is an essential feature of RC structures so that the structural integrity is ensured and you can do away with the brittle failures while flexure. You can get a ductile feature of some structures when you allow the position of plastic hinges at apt locations of the frames of the structure. The plastic hinges offer a lot of ductile structure so that the collapse of the structure can be prevented after you get the material’s yield strength. According to the curve of diagram that has momentum and curvature, you can get the ductility available in the structure.

We can define ductility the the ability to take deformations without even any changes in the capacity of flexure of the member. You can express any section’s ductility in a Curvature Ductility Form. We can offer Curvature Ductility by:

$$\mu\emptyset = \frac{\emptyset u}{\emptyset y}$$

Where $\emptyset u$ is the curvature at ultimate when the concrete compression strain reaches specified limiting value, $\emptyset y$ is the curvature when the tension reinforcement first reaches the yield strength. The definition of $\emptyset y$ shows the influence of the yield strength of reinforcement steel on the calculation of $\mu\emptyset$, while the definition of $\emptyset uu$reflects the effect of ultimate strain of concrete in compression.

1) Analysis of Various Confinement Models:

Various confinement models have been analyzed in *Open sees* (Open System for Earthquake Engineering and Simulation). Confinement Models of beams with same cross-section with different spacing between stirrups of 2-legged and 3-legged are modelled and analyzed.

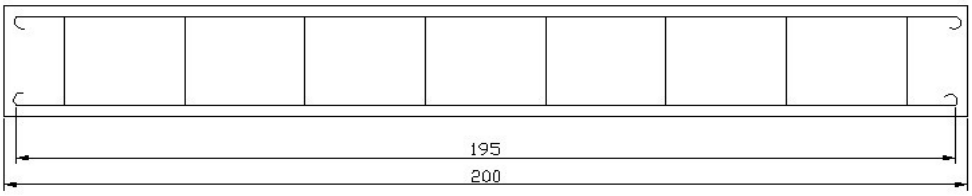
i) fpc: Concrete compressive strength at 28 days
ii) epsc0: Concrete Strain at maximum strength: *epsc0*
iii) fpcu: Concrete crushing strength
iv) epsU: Concrete strain at crushing strength

Above mentioned four parameters are required for both cover concrete and core concrete. These values can be calculated by the various confined models mentioned in literature review.
Properties of reinforcing steel are given by,

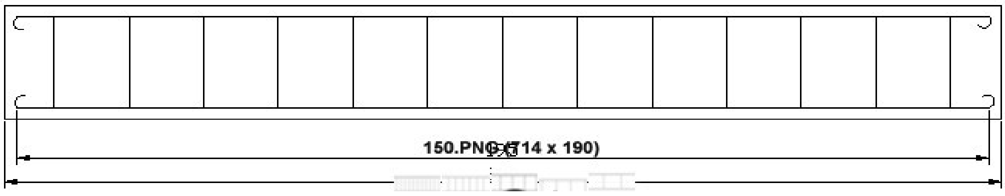
i) Yield strength of reinforcing steel
ii) Young’s Modulus.

Parameters like cover dimension, area of steel in compression and area of steel in tension also required to analyse the moment-curvature of particular section.
The drawings of various confinement models with 2-legged and 3-legged stirrups are given below.

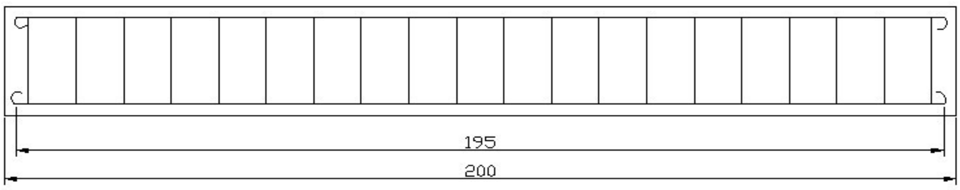
Case (I):
***Beam with stirrup spacing @ 250mm* c/c**



Case (II):
***Beam with stirrup spacing @ 150mm* c/c**



Case (III):
***Beam with stirrup spacing @ 100mm* c/c**



The Beam cross section for analysis is 230mm x 300 mm with 10 mm diameter hook bars in compression side and three 12 mm diameter main bars in tension side with a clear cover of 25 mm on all sides.

2) Procedure

- Preparation and Analysis of Material
  a) Concrete:
  A mix of concrete of M20 grade is designed by using Portland Slag cement of Konark brand, locally available sand confirming to Zone III and 20 mm down size aggregate for a slump of 30mm. The mix is designed following IS 10262-1988. The proportion of design mix adopted for the experiment is 1:1.7:3.8 by weight and water cement ratio is taken as 0.6.
  b) Reinforcing Steel:
  Steel bars of Fe415 grade of 8mm, 10mm and 12mm diameter are used for reinforcement. All bars are tested for Tensile strength, and they comply with the code IS 1786-1985.

- Casting of Specimens:
  For the investigation six beams are cast. All beams are of same cross section 230mm x 300 mm, provided with 2 main bars of 12 mm diameter on tension side and 2 hook bars of 10 mm on compression side. Vertical stirrups of 8 mm diameter with varying spacing and no. of legs are provided. Spacing adopted are 250,150 and 100 mm c/c with 2 legged and 3 legged stirrups. All beams are designed to fail in flexure
  a) Beam1 (Two legged) & Beam 4(Three legged) with stirrups @ 250mm *c/c* spacing
  b) Beam2 (Two legged) &Beam5 (Three legged) with stirrups @ 150mm *c/c* spacing
  c) Beam3 (Two legged) &Beam 6 (Three legged) with stirrups @ 100mm *c/c* spacing.

- Measurement of Strain:
  For measuring stain in the beam two points are marked on both sides of the center line along the length of the beam. These points are marked in both compression and tension zones with cover of 25mm from top and bottom levels of the beam. The initial length between two points in each is 100mm and the distance between Markings of compression and tension zone is 250mm. While applying load, for every 10 kN increase in load the length between either sides of

the points are measured by using mechanical strain gauge in compression and tension zones and strains are calculated at each increment of loading.

- Calculation of Curvature:
  After getting strains in both zones, curvatures are calculated. The strains in compression and tension are combined to get the resultant strain. The ration of resultant strain to the lever arm will be the curvature. *Slope of Strain Diagram* is Curvature.

IV. RESULTS:

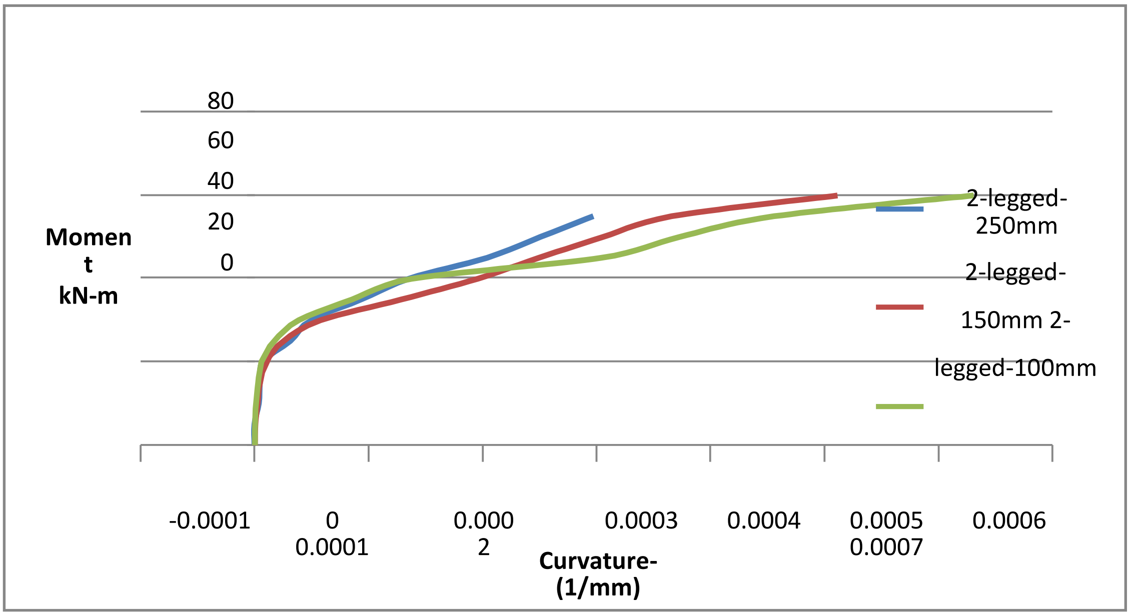
- **Test result for Compression Analysis**

S.No.	Beams	Cube Compressive Strength (N/$mmmm^2$)	Cylinder Compressive Strength (N/$mmmm^2$)
1	2-Legged-250mm	18	16.4
2	2-legged-150mm	24	21.2
3	2-legged-100mm	23.7	21.7
4	3-legged-250mm	23.6	22
5	3-legged-150mm	18.5	16.9
6	3-legged-100mm	26.9	20

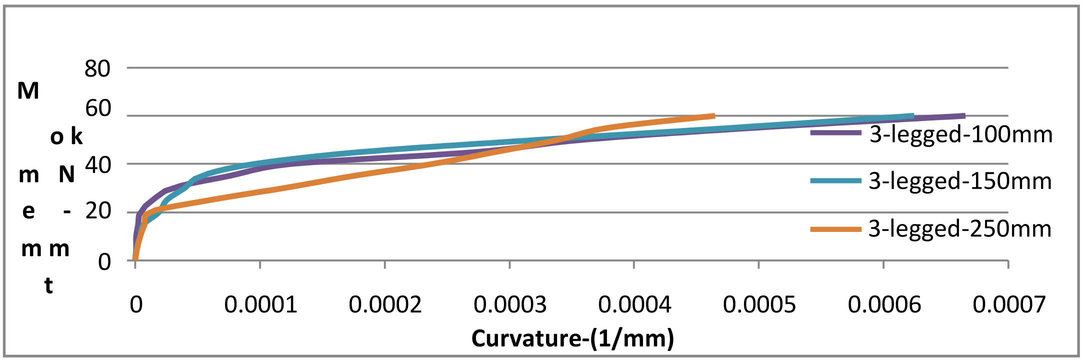
- **Result for Tensile Strength of reinforcing steel bars**

SI no of the sample	Diameter of the bar tested in mm.	0.2% proof stress (yield strength)N/mm^2	Average yield strength N/mm^2
1	8	524	523
2	8	522	
3	10	535	533.5
4	10	532	
5	12	590	580
6	12	570	

- **Moment vs. Curvature (Two legged-experimental)**

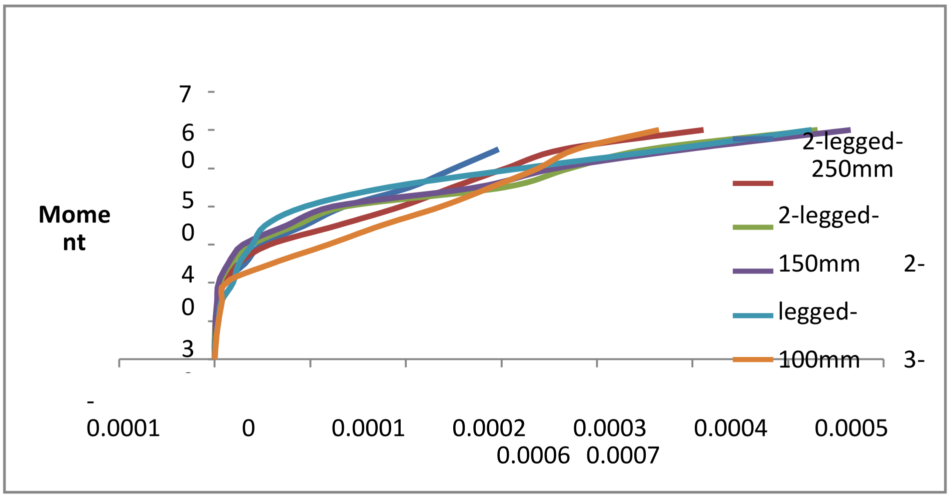


- **Moment vs. Curvature (Three legged-experimental)**

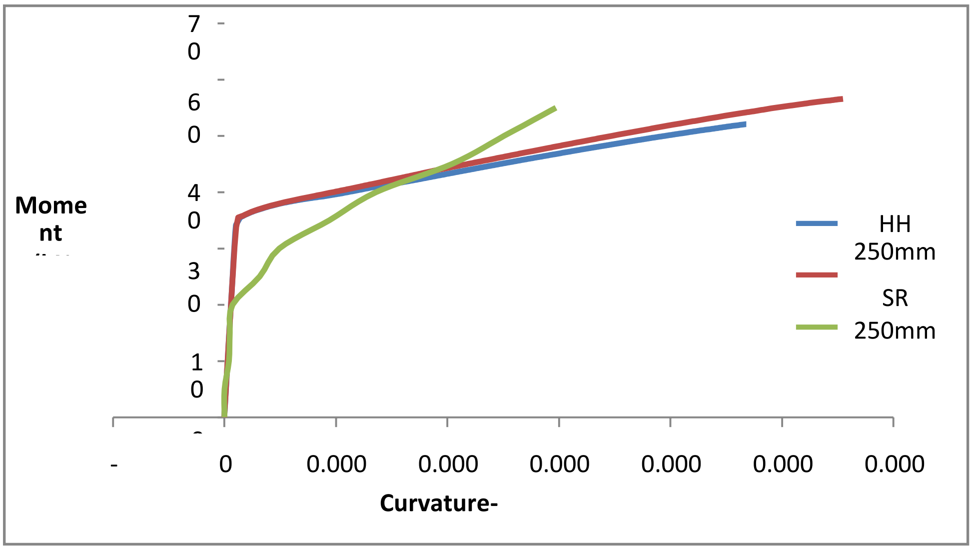


- **Comparison of Results**

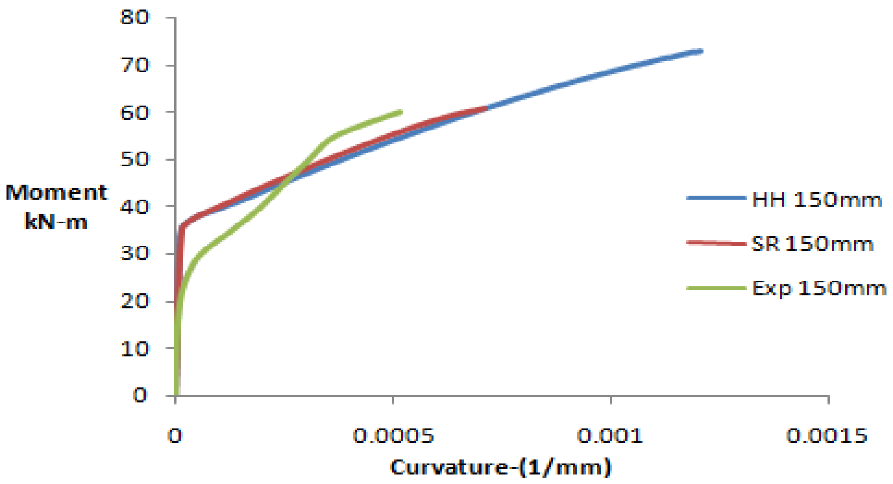
a) Experimental Moment vs. Curvature



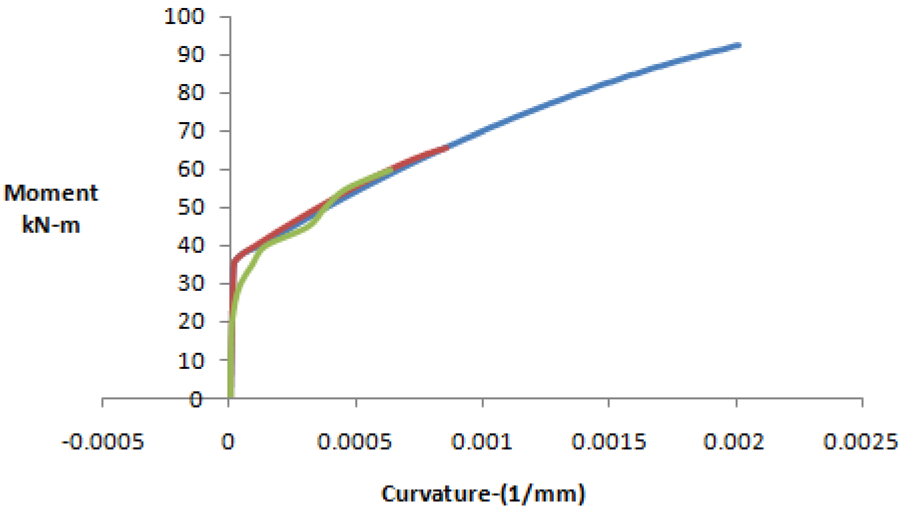
b) **Comparison of experimental and analytical results for 2-legged 250mm c/c**



c) **Comparison of experimental and analytical results for 2-legged 150mmc/c**



d) **Comparison of experimental and analytical results for 2-legged 100mmc/c**



V. CONCLUSION:

- Stresses in concrete increase because of confinement and the corresponding strains are increases because of confinement.
- Curvature ductility increases as the stirrup spacing decreases following **both t**he confinement models.
- There is no significant increase in Curvature ductility if the stirrup's vertical legs increase.
- Experimental results are showing that the Curvature ductility increases as the stirrup spacing decreases.
- Hong K N and Han S H model is giving higher Curvature ductility values than the experimental findings.
- Saatcioglu and Razvi Model (1992) is found to be in good agreement with the experiment results.

REFERENCES:

1) Mander, J. B., Priestley, M., J., N. and Park. R., "Theoretical Stress-Strain Model for Confined Concrete," Journal of Structural Engineering, ASCE, Vol.114, No.8, pp.1804-1826, (1988).
2) Shin, S., Ghosh, S.K. & Moreno, J. "Flexural ductility of ultra-high strength concrete members" *ACI Structural Journal* 86: 394-400. (1989)
3) Murat Saatcioglu, 1 Member**,** ASCE, and Salim R. Razvi**.**J. "Strength and Ductility of confined concrete" Struct. Eng. . . .118:1590-1607. (1992)
4) Saatcioglu, M., and Razvi, S. R. ''Strength and ductility of confinedconcrete.'' *J.Struct. Engg.*, ASCE, 118(6), 1590–1607. (1992)
5) Mandal, P., "Curvature ductility of reinforced concrete sections with and without confinement", Master Thesis Department of Civil Engineering, Kanpur: Indian Institute of Technology Kanpur. (1993)
6) Razvi, S., and Saatcioglu, M. ''Confinement model for normalstrength and high strength concretes.'' *Rep. No. OCEERC 96-04*, Ottawa Carleton Earthquake Engineering Research Centre, Ottawa, ON,Canada. (1996)

7) Razvi, S. and Saatcioglu, M., "Confinement Model for High-Strength Concrete," Journal of Structural Engineering, ASCE, Vol.125, No.3, pp.281-289, (1999.)
8) IS 456:2000 "Indian Standard "PLAIN AND REINFORCED CONCRETE CODE OF PRACTICE", fourth revision?
9) Li Bing, Park, R. and Tanaka, H., " Stress-Strain Behavior of High-Strength Concrete Confined byUltra-High- and Normal-Strength Transverse Reinforcements," ACI Structural Journal, Vol. 98, No.3,pp.395-406, (2001)
10) Ki-Nam Hong and Sang Hoon Han. "Uniaxial Compression Behavior of high strength concrete confined by low volumetric ratio lateral ties" Journal of Korea Concrete Institute, Vol 17 No.5, pp843-352, October, (2005)
11) Monita Olivia, ParthasarathiMandal. "Curvature Ductility of Reinforced Concrete Beam". (2006)
12) S Unnikrishna Pillai and Devadas Menon, book "Reinforced Concrete Design" third edition.
13) Nonlinear Analysis by Dr. Devadas Menon.