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Effect of Confinement on Ductility of RCC Beams

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Abstract : It is a fact that the strength and ductility of the concrete is highly dependent on the confinement level provided by the lateral reinforcement. In the current design codes design of strength is separated with deformability. Evaluation of deformability is independent of some key parameters of concrete and steel. In the present study curvature ductility of a RCC beams with different level of confinements are calculated analytically following Hong K N and Han S H (2005) Model and Saaticioglu and Razvi (1992) Model and compared with experimental results. Six rectangular RCC beams having same cross section and main reinforcements are analysed by using OPENSEES software. Different level of lateral confinement in beams is induced by two legged and three legged stirrups provided with three different spacing. For experimental study six RCC beams are cast with stirrups provided at spacing of 100 mm, 150 mm and 250 mm. Three beams are cast with two legged and three beams are cast with three legged stirrups. Analytical observation is that the curvature ductility increases with decrease in spacing of stirrups and increase in number of legs of stirrups i.e. lateral confinement increases the curvature ductility of beam . The variation with respect to spacing is more compared to number of legs of stirrups. It is proven by using both models. The same trends are observed through experimental results. Analytical results following Saatcioglu and Razvi (1995) Model are found to be in well agreement with the experimental results.

***IndexTerms* - Concrete, Beam, Compressive Strength, Tensile, Reinforcement.**

I. INTRODUCTION

We all know this well enough that the ductility and the strength of some concrete will depend on the amount of confinement offered by the amount of lateral reinforcement. While we see the flexural design of reinforced beams, the deformability and strength that seem to be related to each other, need to take place at one point. But in the latest design codes, the strength design goes away from deformability, and we evaluate the deformability by making it independent of parameters such as confinement content, the strength of concrete, and yield strength of the steel. Due to this, requirements in the latest codes of design may not offer you as much beam deformability. This thesis is a detailed analysis of the behavior of ductility on the concrete beams with the help of confinement with the help of experiments and analytics. To find out the effect of the ratio of transverse reinforcing on the ductility of the beam, we do an experimental program. A group of 6 beams is cast with distinct spaces in between the stirrups which have 2 and 3 legs. When we take the structures of concrete beams for their seismic design, the potent hinge of plastic areas needs to be detailed skillfully for the ductile nature so that there will be no collapse due to shaking from huge earthquakes. A good amount of ductility of the reinforced concrete members is quite important so that the redistribution of the moment can take place. A lot of past tests gave results that if we confine the concrete by some arrangements with transverse reinforcement, we can get a lot of increase in the ductility and the strength of the member. In general, the increase in strength due to confinement and the slide of the decreasing concrete stress and strain curve brand would have a lot of effect on the flexure strength of reinforced concrete and its ductility as well. The concrete in cover will not be confined and will turn less effective after some period when the max strain that is allowed is obtained, but the concrete in the core will still be carrying a lot of stress against the strains. The distribution of compressive stress for the cover and the core of the concrete can be defined by unconfined and confined relations of the stress and strain of concrete. It is essential to offer sturdy confinement of the concrete in the core of the beam is ductile. When we take the deformability of the flexural members of RC, it can depend on a lot of different factors such as the percent of reinforcement in tensile, compressive reinforcement percentage, lateral reinforcement percentage, and even the strength of the concrete. When we investigate the respect to the ductile nature of the flexural members that use normal aggregates in weight and aggregates that are light in weight. It can be seen in a lot of studies. We know that enough ductility in the flexural strength is needed in case of structures that are prone to seismic activities, a lot of important problems lie in association with the behavior of the structures in terms of a lot of seismic actions and it can be found because of the poor details of the reinforced concrete.We need to have knowledge of the deformation traits of post peak for the RCC members to understand the share of lateral reinforcement and to know the mechanism of failure in severe seismic conditions where we place high demands for ductility on the RCC members.

II. LITERATURE REVIEW

A lot of experiments have given out some useful info on the deformation and strength features of the reinforced members of concrete. But these studies are affected by failure modes and ultimate load stages and there is no info known for the post peak stage of deformation of the members of concrete. We have been told by a lot of investigators that testing methods may affect the failure mode and the behavior of concrete post peak. For instance, when concrete gets failed due to non-controlled compressive loading, it may lead to failure which is brittle, and in controlled conditions, we may see ductile failures. It can be highly expensive to make design a structure with the help of an elastic spectrum and the IS Code 1893 also offers the usage of a factor known as Responsive Reduction Factor ® to lessen the seismic loads. But we can make sure this reduction takes place if only adequate ductility is built with the help of proper designs of the elements of the structure. So in order to get the best response, we need to get a non-linear study of the RCC structures that can be carried out, It is seen that the analysis of inelasticity offers behavior that is away from the yielding stage and can be shown in terms of plastic hinge formation and moment redistribution etc. To achieve Ductility in some structures, there should be plastic hinges formed at apt locations in the frames of the structure. The plastic hinge's ductile nature can be devised with the shape of the stress and strain relations for the steel and concrete to be known. The ductile nature of RCC members can be enhanced by making apt renditions of the stirrups that lead to core concrete and its confinement. So while designing, the stress and strain curve for the concrete in confinement should be taken into reference. A lot of models are known to occur for the stress and strain relation of the confined concrete.

HONG K N and Han S H (2005) Model: This is the model that came forward with a couple of equations for descending and the ascending branches of the strain and stress curve when we get the features of lateral reinforcement like the diameter configuration, yield strength spacing and reinforcement in the longitudinal reinforcement.

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. aThen, 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 *Opensees* (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

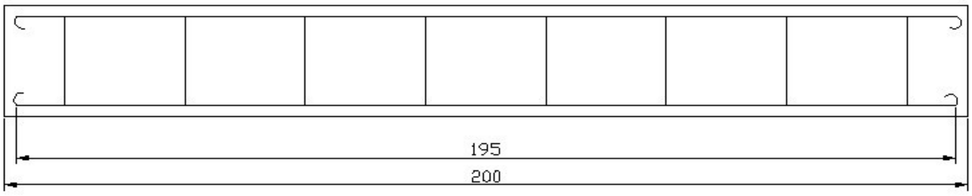
iv) epsU: Concrete strain at crushing strength

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,

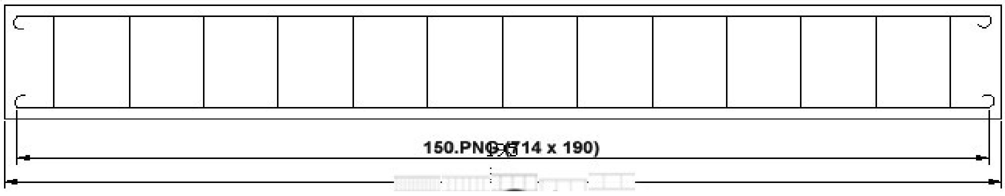
i) Yield strength of reinforcing steel

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

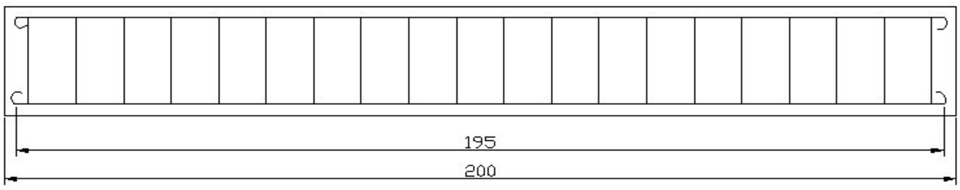
Case (I):
Beam with stirrup spacing @ 250mm c/c



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 centre 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

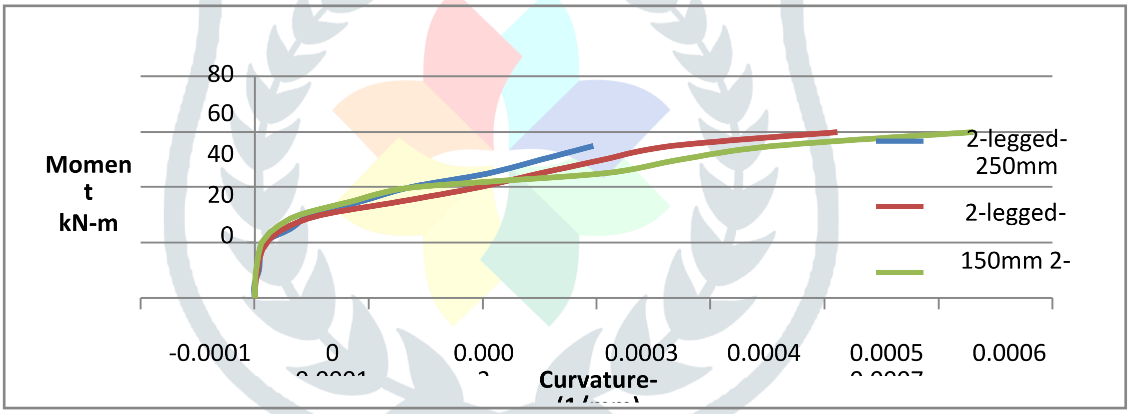
- Test result for Compression Analysis

S.No.	Beams	Cube Compressive Strength (N/mmmm²)	Cylinder Compressive Strength (N/mmmm²)
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

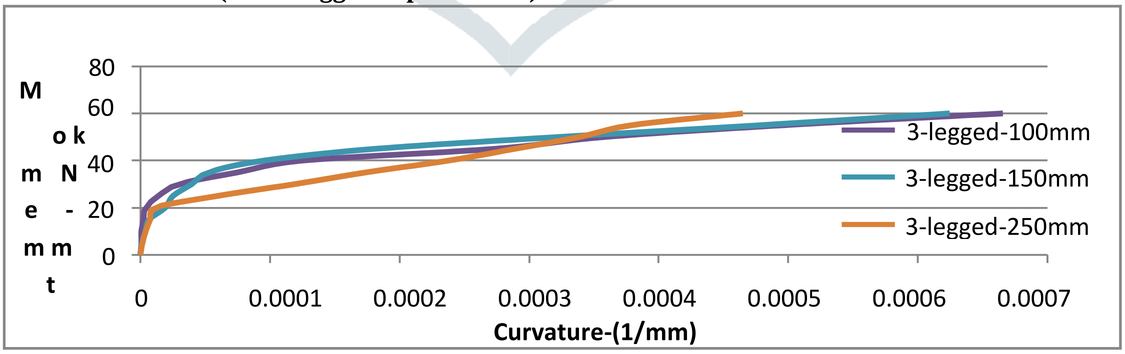
- Result for Tensile Strength of reinforcing steel bars

SI no of the sample	Diameter of the bar tested in mm.	0.2% proof stress (yield strength)N/mm²	Average yield strength N/mm²
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)**

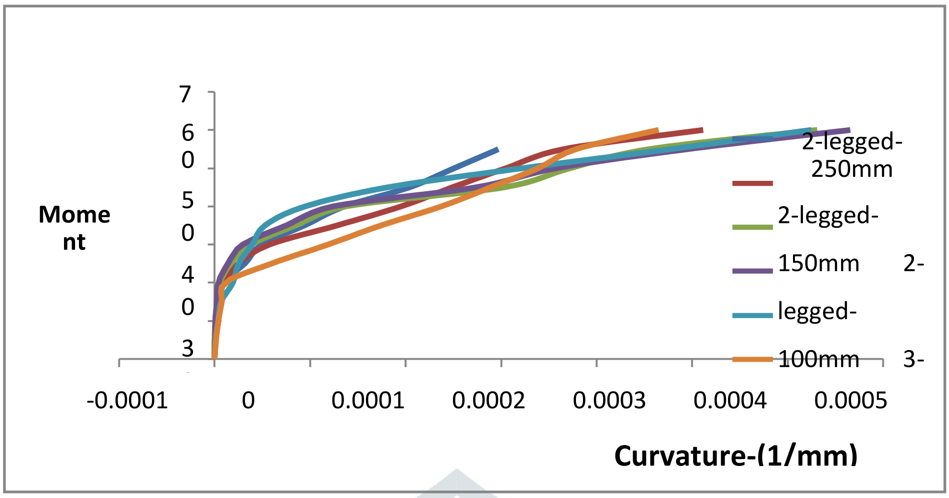


- **Moment vs. Curvature (Three legged-experimental)**

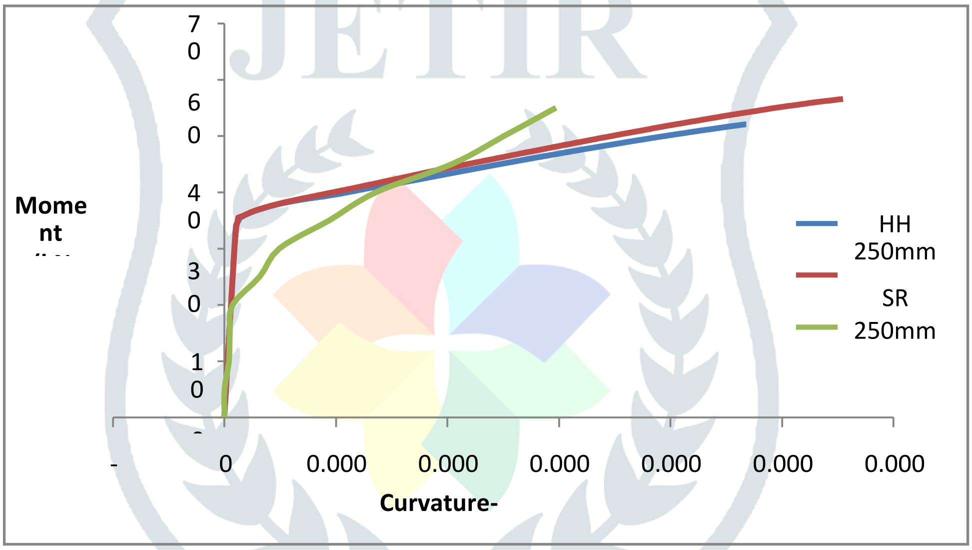


- Comparison of Results

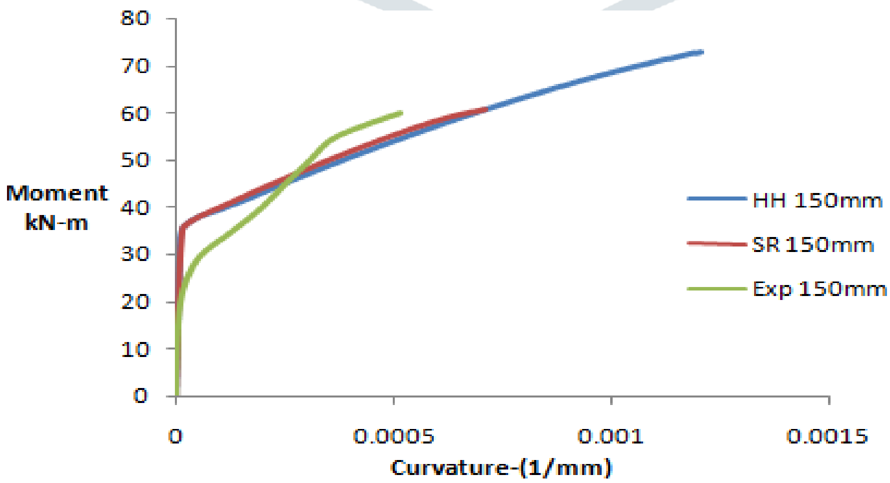
a) Experimental Moment vs. Curvature



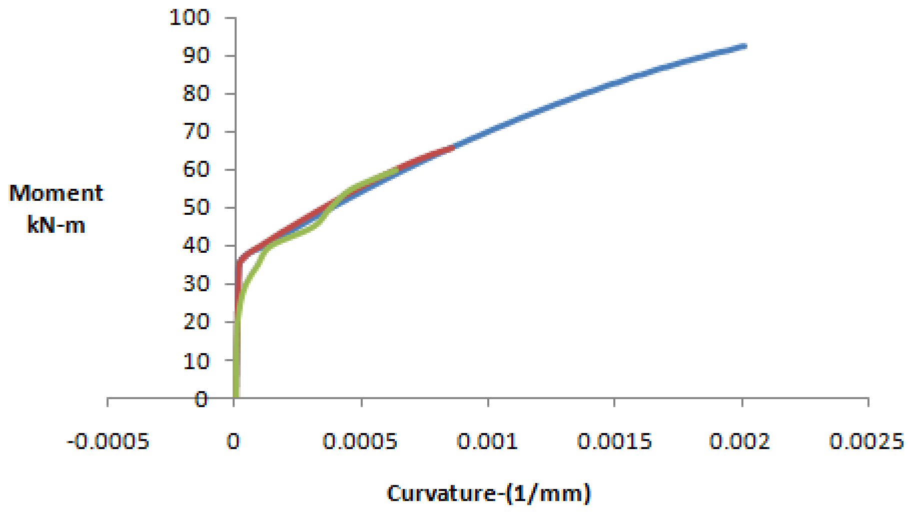
b) **Comparison of experimental and analytical results for 2-legged 250mm c/c**



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.

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