International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 15 Issue 6, June-2026

Effect of Confinement on Curvature Ductility of Reinforced Concrete Beams

Varun Kumar Sikka[1], Arshad[2]

[1]Assistant Professor, Department of Civil Engineering, Rattan Institute of Technology and Management, Haryana, India
[2]Research Scholar, Department of Civil Engineering, Rattan Institute of Technology and Management, Haryana, India

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.

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 incurrent design codes may not provide sufficient deform ability 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.

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.

LITERATURE REVIEW

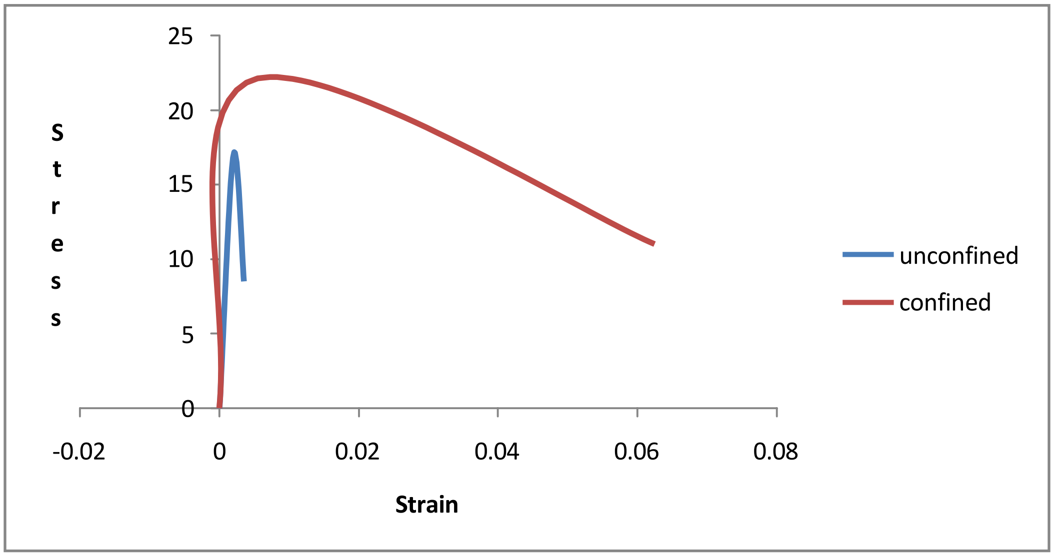
A number of studies have generated very useful information on the strength and deformation characteristics of reinforced concrete members. However these studies are limited to ultimate load stage and failure modes, and there is no information available on post peak stage deformation of reinforced concrete 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 where as 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 behaviour beyond the yielding stage which can be represented in terms of form at ion of plastic hinges, redistribution of moments etc.

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 KN and Han SH (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.

Graph2.2.Stress-StrainCurve



Advantages of Mander'S Model:

1. A single equation defines both the ascending and descending branches of stress strain curve.
2. Model can also be used for unconfined concrete.
3. Model can be applied to any shape of concrete member section confined by any kind of transverse reinforcement.

THEORY AND FORMULATIONS

Ductility is a desirable property of the reinforced concrete structures to ensure structural integrity in avoiding brittle failure during flexure. The ductile behavior of structure can be achieved by allowing the plastic hinges position at appropriate locations of the structural frame. These plastic hinges are designed to give adequate ductility to resist the structural collapse after yield strength of the material has been achieved. Based on the shape of the moment-curvature diagrams the available ductility can be found out. Ductility can be defined as the capacity to undergo deformations without a considerable change in the flexural capacity of the member. The Ductility of a section can be expressed in the form of Curvature Ductility. The Curvature Ductility is given by, 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 $\emptyset u$reflects the effect of ultimate strain of concrete in compression.

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.

1. fpc: Concrete compressive strength at 28days
2. epsc0: Concrete Strain at maximum strength: epsc0
3. fpcu: Concrete crushing strength
4. eps U: Concrete strain at crushing strength

Properties of reinforcing steel are given by,

1. Yield strength of reinforcing steel
2. Young's Modulus.

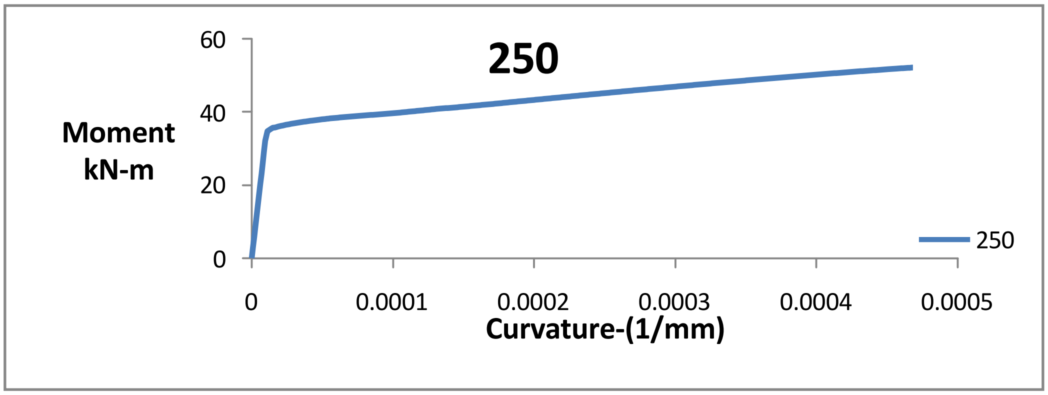
Parameters like cover dimension, area of steel in compression and area of steel in tension also required to analyze the moment-curvature of particular section.

ANALYTICAL RESULTS AND DISCUSSIONS.

To plot the curve of Moment vs. Curvature the analysis is stopped where the section reaches maximum strain as per confinement model. The stress- strain values of particular section can be obtained by using stress-stain recorder in analysis output part.

Moment vs. Curvature (HONG KN and Han SH(2005) Model):
Beam with two-legged stirrups@250mmc/c spacing:

A Graph is plotted between moment vs. curvature for beam with 2-legged stirrups @ 250mm c/c and shown in graph 4.1.

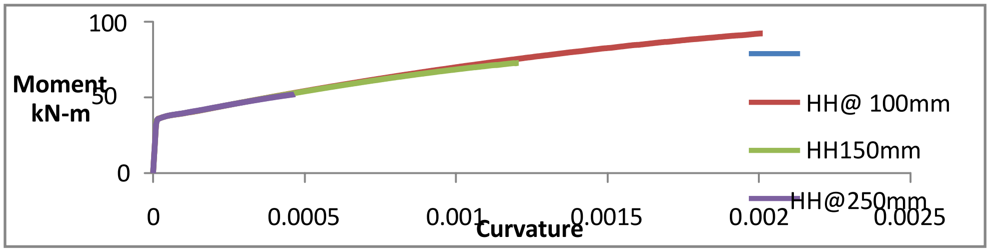


Graph4.1Moment vs.CurvatureforBeam1.

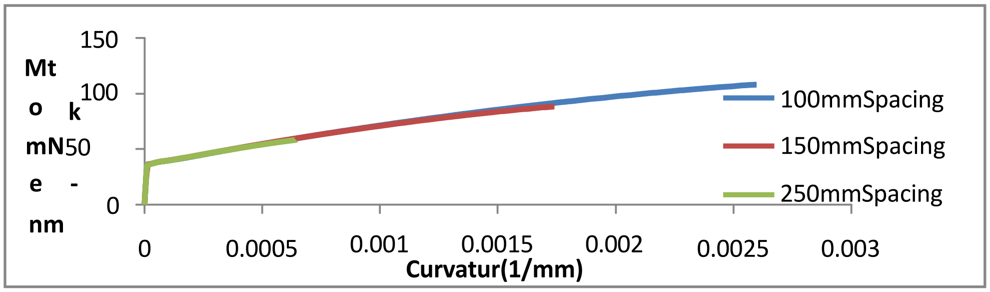
Comparison of Results:

In this section the analytical results are compared between both the models with 2- legged, 3-legged Stirrups and with different spacing of Stirrups.

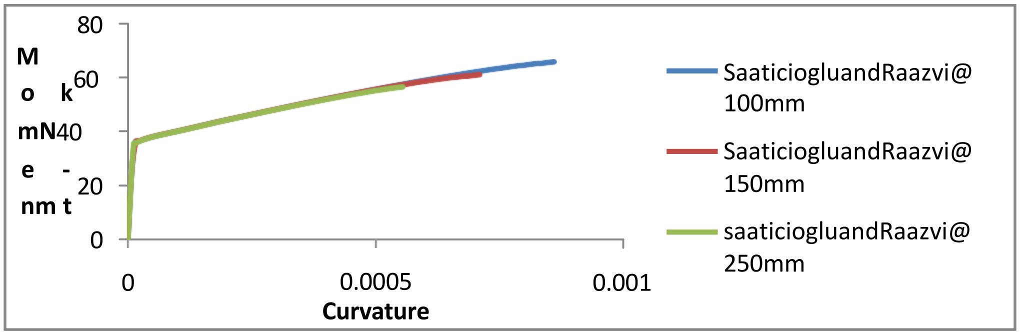
1) 2-leggedBeams



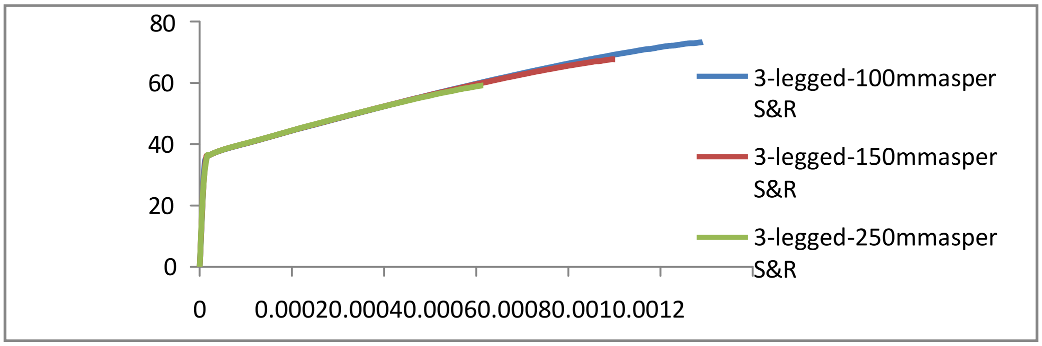
2) 3-leggedBeams



3) 2-leggedBeams



4) 3-leggedbeams



EXPERIMENTAL SETUP

Material Properties

Concrete:

A mix of concrete ofM20 grade is designed by using Portland Slag cement of Konark brand, locally available sand confirming to Zone III and20 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 is1:1.7:3.8byweightand water cement ratio is taken as 0.6.

Table5.1Design Mix Proportion of Concrete

Description	cement	Fine aggregate	Coarse aggregate	Water
Mix proportion	1	1.7	3.8	0.6

Table5.2TestResult ofspecimensafter28Days

S. No.	Beams	Cube Compressive Strength (N/mm^2)	Cylinder Compressive Strength (N/mm^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

Casting of Specimens:
For the investigation six beams are cast. All beams are of same cross section 230mmx 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 of8mmdiameter with varying spacing and no. of legs are provided. Spacing adopted are 250,150 and 100 mm c/c with 2 legged and 3legged stirrups. All beams are designed to fail in flexure.

CONCLUSIONS

Stresses in concrete increase because of confinement and the corresponding strains are increases because of confinement.
Hong K N and Han S H (2005) model is giving higher stresses and strains compared to the Saatcioglu and Razvi (1992) Model. Curvature ductility increases as the stirrup spacing decreases following both the confinement models. Experimental results are showing that the Curvature ductility increases as the stirrup spacing decreases.

REFERENCES

1. Mander,J.B.,Priestley,M.,J.,N.andPark.R.,"TheoreticalStress-StrainModelfor 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 Ductilityof confined concrete"Struct. Eng. .118:1590-1607.(1992)
4. Saatcioglu, M.,and Razvi, S.R.‘‘Strength and ductility of confined concrete.’’
5. J. Struct.Engg.,ASCE,118(6),1590–1607.(1992)
6. 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)
7. 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)