iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** X **Month of publication:** October 2017

DOI: http://doi.org/10.22214/ijraset.2017.10039

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue X, October 2017- Available at www.ijraset.com

Influence of Curvature Ductility on Reinforced Concrete Beams under the Effect of Confinement

Matha Prasad Adari[1]
[1] *Assistant Professor, Dept. of Civil Engineering. NSRIT Visakhapatnam, Andhra Pradesh, 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 incrases 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.

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 ieffective 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 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 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 momet curvature relations. Moment curvature relation for an RCC beam can be determined if stress-strain relations for concrete and steel are known.

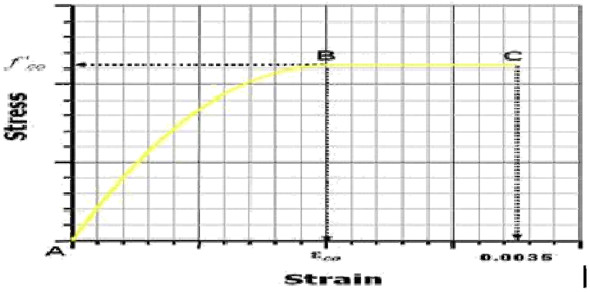
The ductility of RCC member can be drastically increased by suitable arrangement of stirrups causing confinement of core concrete. Hence during design stress-strain curve for confined concrete must be considered. Several models are available for stress-strain relation of confined concrete.

A. Stress-Strain Curves for concrete:

1) As per IS-456:2000:

a) Descending branch in the post-peak region not accounted for.

b) Enhancement/reduction in ductility (and/or strength) due to confinement, grades of concrete and steel, bond, shear, etc., not accounted for.



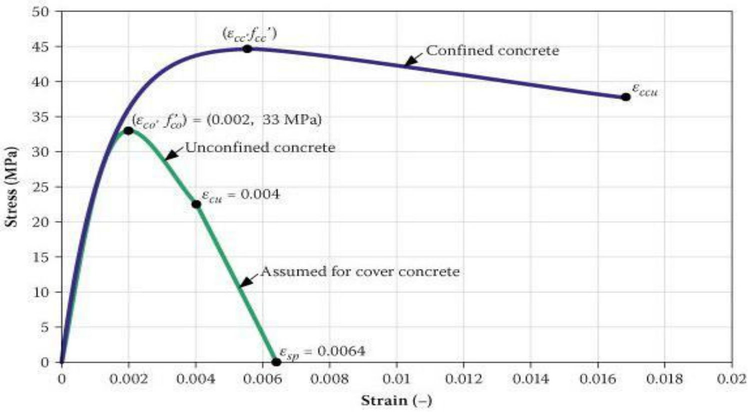
B. Modified Mander’s and Fardis et al. (2001)

1) Advantages of Mander’S Model:

a) A single equation defines both the ascending and descending branches of stress strain curve.

b) Model can also be used for unconfined concrete.

c) Model can be applied to any shape of concrete member section confined by any kind of transverse reinforcement.



III. THEORY AND FORMULATIONS.

A. Theory

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,

B. Introduction to OPENSEES

The modelling of the structure is done in Opensees (Open System for Earthquake Engineering Simulation) which is an object oriented open-source software framework used to model structural and geotechnical systems and simulate their earthquake response. Opensees is primarily written in C++ and uses some FORTRAN and C numerical libraries for linear equation solving, and material and element customs. Opensees has progressive capabilities for modeling and analyzing the nonlinear response of systems using a wide range of material models, elements, and solution algorithms. It is an open-source; the website provides information about the software architecture, access to the source code, and the development process. The open-source movement allows earthquake engineering researchers and users to build upon each other's accomplishments using Opensees as community-based software. Another advantage of using Opensees is that modeling frames with different ets of input variables can be done with the help of loops, whereas in conventional software's each case will have to be modeled separately.

Fiber Section modeling of element is done according to Spacone et.al, 1996 which can be employed using predefined command "section Fiber" in Opensees.

IV. 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.

A. : Concrete compressive strength at 28 days
B. *epsc0:* Concrete Strain at maximum strength: *epsc0*
C. *fpcu:* Concrete crushing strength
D. *epsU:* Concrete strain at crushing strength

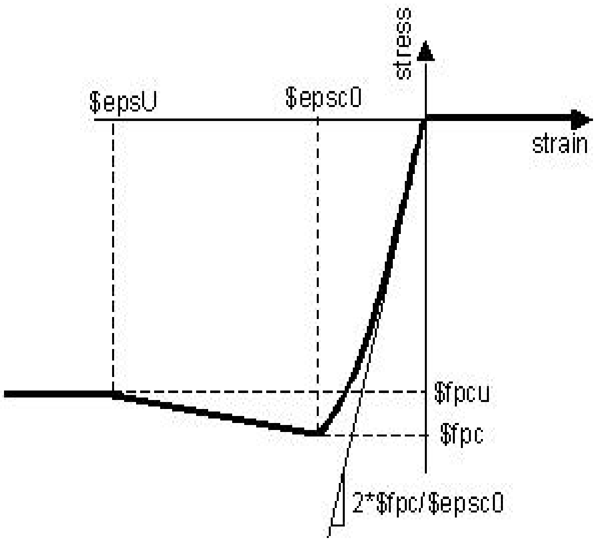


Figure 3.1 Parameters for OpenSees

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,

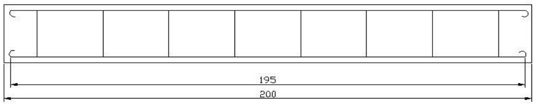
1) Yield strength of reinforcing steel

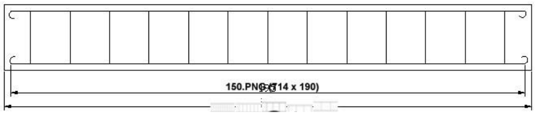
2) Young's Modulus.

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.

The drawings of various confinement models with 2-legged and 3-legged stirrups are given below.

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





E. Design parameters for analysis:

Serial Number	2-Legged	3-Legged
1.Concrete Strength	21.9	23
2.Grade of Steel	415	415

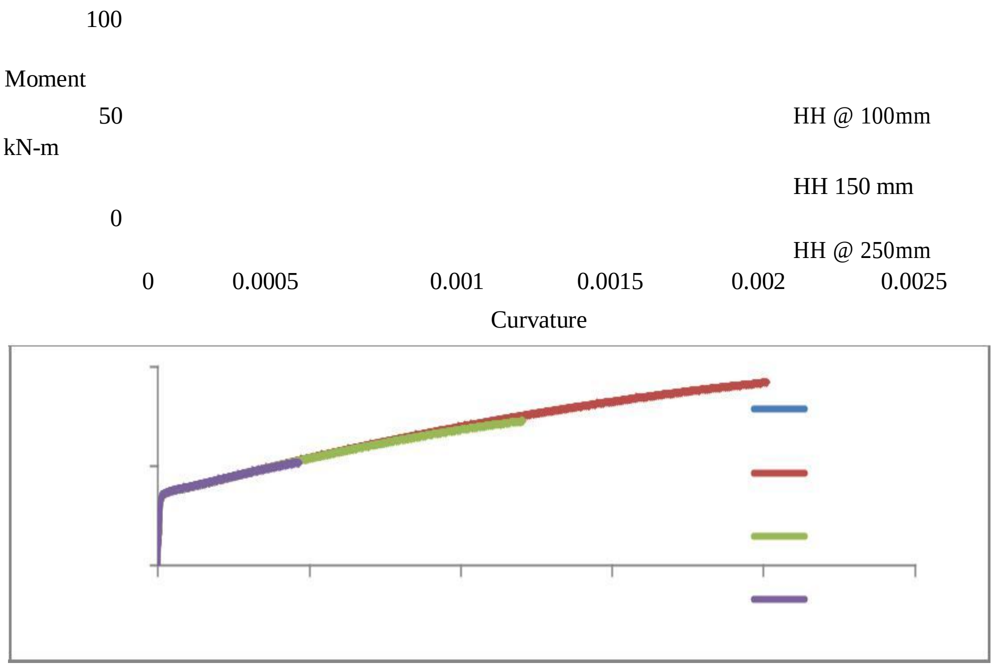
V. ANALYTICAL RESULTS AND DISCUSSIONS

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.

VI. 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-legged Beams



VII.EXPERIMENTAL SETUP

A. *Material Properties*

1) 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.

Table 5.1 Design Mix Proportion of Concrete

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

C. *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.

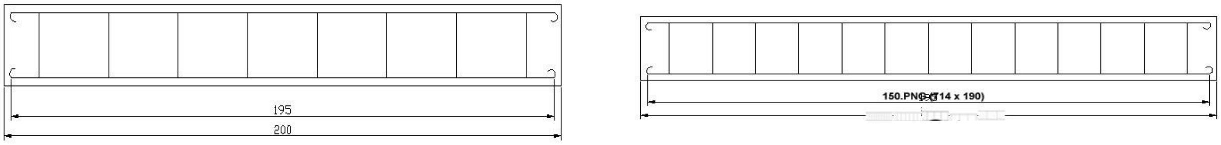


Fig.5.2.3 .Beam3 (Two legged) &Beam 6 (Three legged) with stirrups @ 100mm *c/c* spacing.

Beams are cast in rectangular moulds. These moulds are removed after 24 hrs and also the beams are taken out and cover with jute bags for curing for 28 days. Along with beam standard specimens are cast to get the properties of the concrete, these include 3 numbers of cubes and 3 numbers of cylinders. These are tested for cubical compressive strength ( ) and cylindrical compressive strength ( ).

D. *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.

Beam-1 (Two legged stirrups at 250mm c/c spacing):
Beam-2 (Two legged stirrups at 150mm c/c spacing):
Beam-3 (Two legged stirrups at 100mm c/c spacing):

First Crack was observed at 50kN and beam failed in flexure at 120kN.
First Crack was observed at 75kN and beam failed in flexure at 130kN.
First Crack was observed at 60kN and beam failed in flexure at 145kN.
The Beam has completely collapsed in flexure. The breaking of tensile reinforcement below the load point has occurred which is clearly visible in the Figure 5.3.

E. Beam-4 (Three legged stirrups at 250mm c/c spacing):

First Crack was observed at 70kN and beam has partially failed in flexure at 135kN.

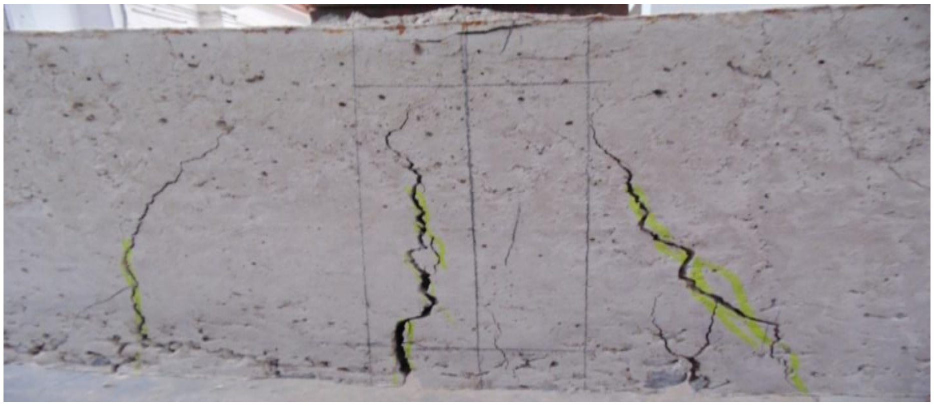


Figure 5.4

F. Beam-5 (Three legged stirrups at 150mm c/c spacing):

First Crack was observed at 80kN and beam has failed in flexure at 150kN.

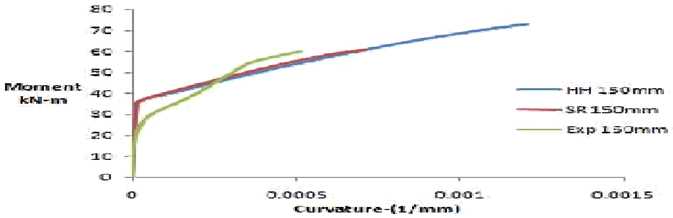
Figure 5.5

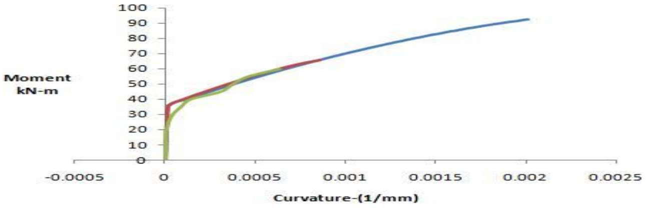
S.No.	Moment (kN-m)	Tension zone Readings (mm)	Compression zone Readings (mm)	Strain $*^{-}$	Curvature (1/mm) $*^{-}$
1	0	100	100	0	0
2	5	100.03	100	0	1.2
3	10	100.09	100.01	1	4
4	15	100.13	100.04	1.7	6.8
5	20	100.36	100.12	4.8	19.2
6	25	100.47	100.16	6.3	25.2
7	30	100.76	100.23	9.9	39.6
8	35	100.95	100.37	13.2	52.8
9	40	101.84	100.44	23.8	95.2
10	45	103.97	100.58	45.5	182
11	50	107.33	100.74	80.7	322.8
12	55	110.69	101.27	119.6	478.4
13	60	114.10	101.52	157.8	624.8

Table 5.8

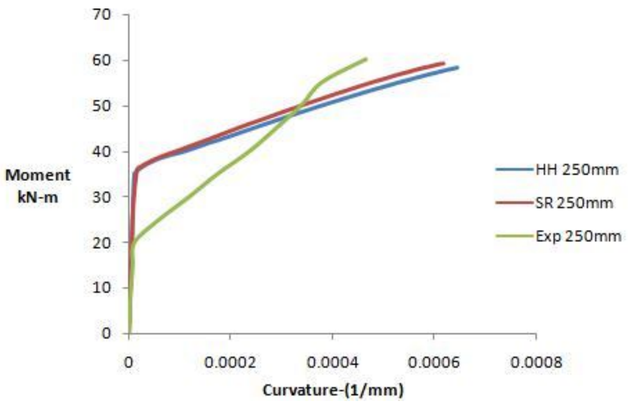
G. Beam-6 (Three legged stirrups at 100mm c/c spacing):

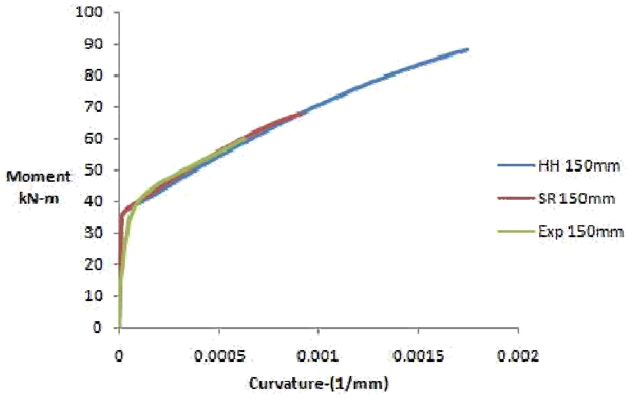
First Crack was bserved at 75kN and beam has failed in flexure at 185kN. Multiple cracks in flexure zone were observed



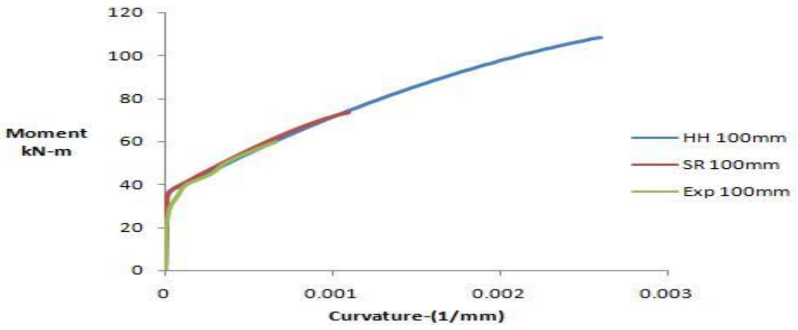


Graph 5.3 Comparison of experimental and analytical results for 2-legged 150mm c/c
Graph 5.4 Comparison of experimental and analytical results for 2-legged 100mm c/c





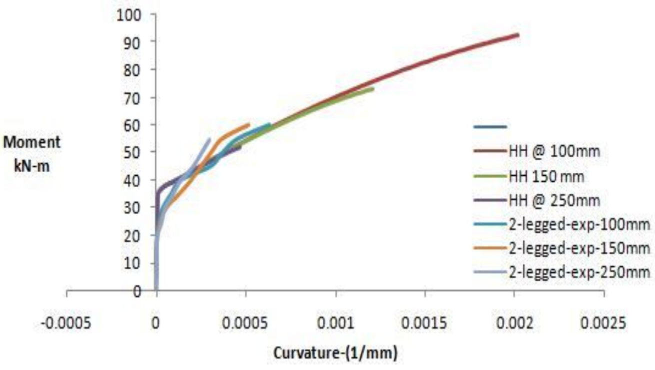
Graph 5.5 Comparison of experimental and analytical results for 3-legged 250mm c/c
Graph 5.6 Comparison of experimental and analytical results for 3-legged 150mm c/c

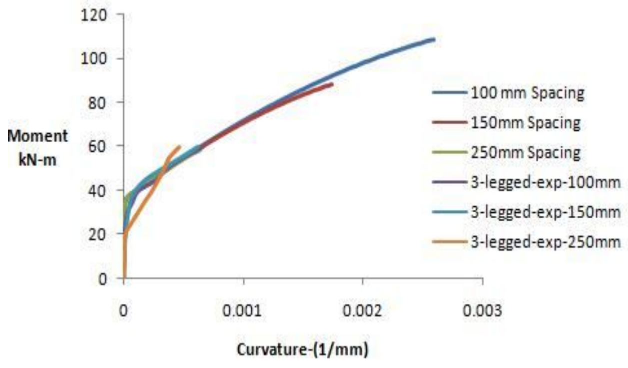


Graph 5.7 Comparison of experimental and analytical results for 3-legged 100mm c/c

The above graphs between Moment vs. Curvature is showing that curvature is increasing with decrease in spacing between the stirrups in the beam. At the same time there is a slight increase in curvature with increase in stirrup legs.
From the graph we can observe that there is a clear percentage increase in curvature for 2-legged beam is more than 3-legged beam. Percentage increase in curvature is maximum for 100mm and minimum for 250mm spacing.

H. Vs. Hong K N and Han S H Model (2005):

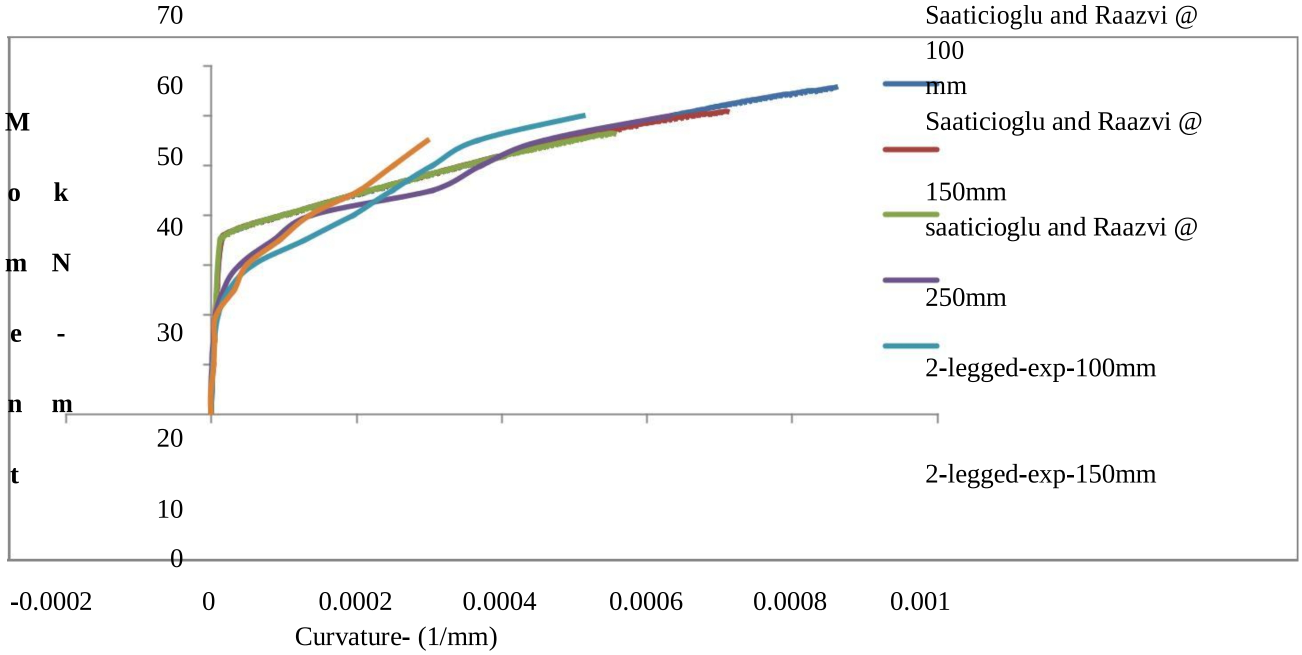




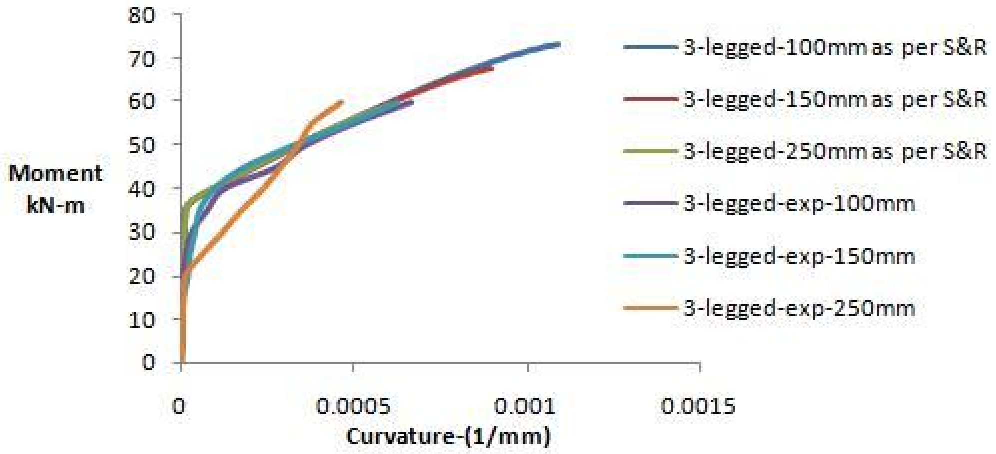
Graph 5.2 Comparison of Moment vs. Curvature (2-legged)
Graph 5.3 Comparison of Moment vs. Curvature (3-legged)

Analytical results are found to be 3-5 times more than the experimentally obtained values. In both cases curvature is increasing with decrease in spacing of stirrups.

I. Saatcioglu and Razvi Model (1992)



Experimental results are found to be nearer to the analytically obtained value. In this model also it is observe that there is an increment in curvature as the stirrup spacing decreases.



Graph 5.4 Comparison of Moment vs. Curvature (2-legged)

As per this model there is no considerable increase in curvature if the stirrup legs are increased. But experiment exhibited that there is a considerable increase in curvature as the legs are increasing.

VIII. CONCLUSIONS

A. Stresses in concrete increase because of confinement and the corresponding strains are increases because of confinement.

B. Hong K N and Han S H (2005) model is giving higher stresses and strains compared to the Saatcioglu and Razvi (1992) Model.

C. Curvature ductility increases as the stirrup spacing decreases following both the confinement models.

D. There is no significant increase in Curvature ductility if the stirrup's vertical legs increase.

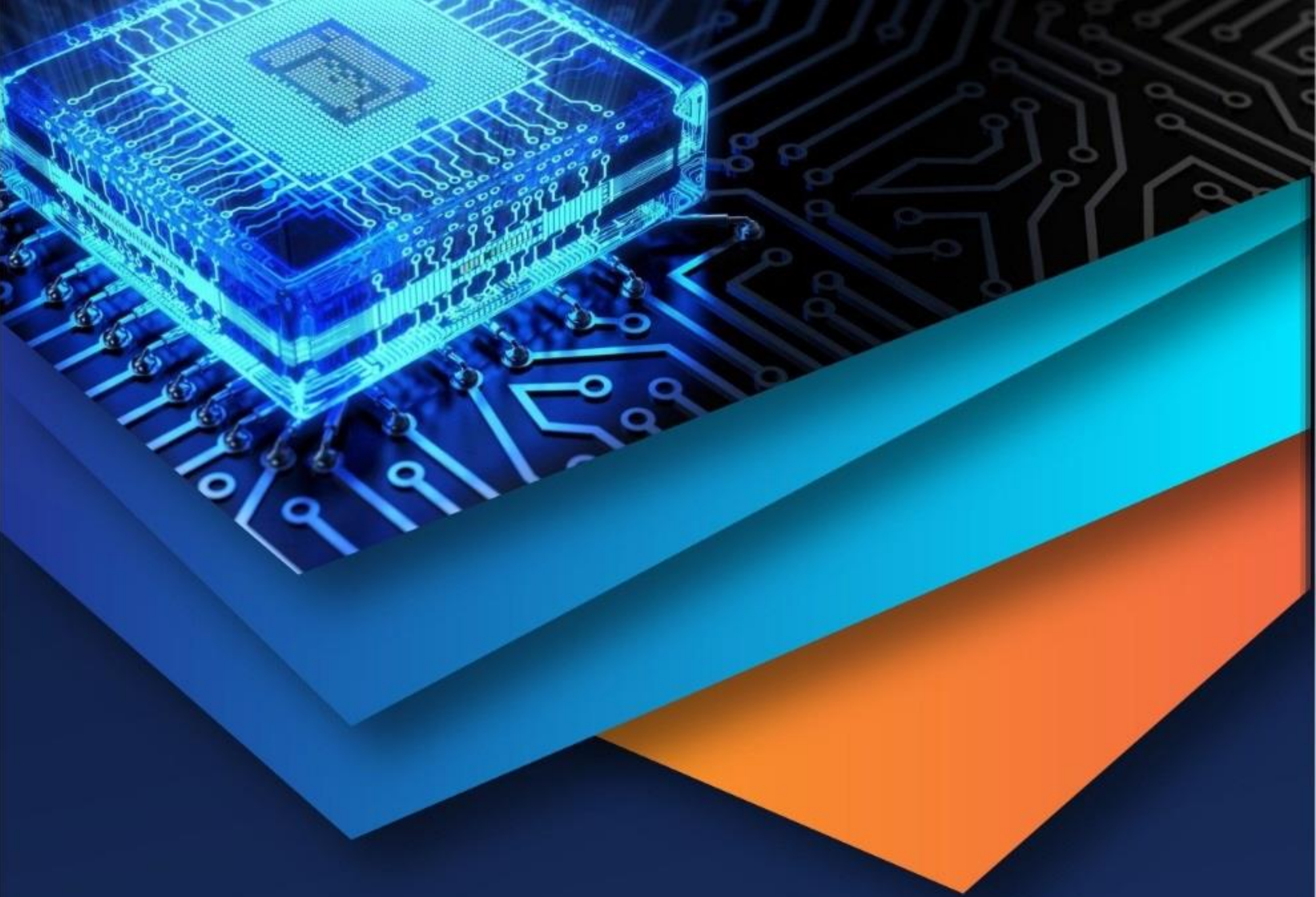
E. Experimental results are showing that the Curvature ductility increases as the stirrup spacing decreases.

F. Hong K N and Han S H model is giving higher Curvature ductility values than the experimental findings.

G. 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 confined concrete.'' 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 normal strength 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 by Ultra-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, Parthasarathi Mandal. "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.



10.22214/IJRASET

INDEX COPERNICUS
45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL
IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY