# Effect of Confinement on Curvature Ductility of Reinforced Concrete 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 deformab ility 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 Model 1 and Saaticioglu and Razvi Model 2 and compared with experimental results. Six rectangular RCC beams having same cross section and main reinforcements are analyzed 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 Model are found to be in well agreement with the experimental results.*

*Keywords –RCC building, IDR, PCF, OPENSEES*

## 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.

## II. PREVIOUS WORK

**Ko et al. [2020]** In this context, ductility can be defined as the ability to support large plastic deformations before failure without significant resistance loss. The main reasons to consider ductility as a mandatory characteristic in the modern structural design are: ductility prevents brittle ruptures, which is a failure mode that must always be avoided elements with ductile behavior have higher plastic rotation capacities when compared to brittle elements and contribute to large deformations/displacements before a physic rupture ductility of cross sections are essential to provide bending moment redistribution along the beam as longitudinal reinforcement steel yields ensuring the redundant behavior of hyperstatic structures.

**Kara and Ashour [2018]** Another important application in which the ductility is essential to guarantee safe behaviors of RC structural systems is related to dynamic loads generated by seismic tremors. In such cases, the ductility of the structural elements must be predicted and quantified in a detailed way to avoid severe damage and brittle failures of the buildings.

**Lopes et. al [2018]** However, the prediction and the assessment of ductility as a single value to describe how ductile or brittle is an element or some cross section is not an easy task. There are several parameters interacting each other that influence the ductility at ultimate limit states. Moreover, it is impossible to dissociates ductility from rigidity of a RC element because they are function of almost the same parameters as: longitudinal reinforcement ratio, concrete strength, concrete softening branch in compression, crack pattern development, tension stiffening, bond-slip relationship.

**Oehlers et al. [2017]** The curvature depends on the material strain levels and their limits. On the other hand, these strain values are function of the neutral axis position, which influences the effective depth and longitudinal reinforcement ratio. In order to at least guarantee a ductile behavior for RC structural elements, the design codes x) on the cross section determinations. EUROCODE 2 (2004) and ABNT NBR 6118 (2014) recommend for ensure ductility in RCβimpose some restrictions to the relative neutral axis position.

**Demir et al. [2016]** Although this form to solve the problem of ductility is simple and intuitive, it does not quantify the ductility of the designed RC cross sections. Moreover, several important mechanisms that interfere on the overall behavior of the RC beams are not take into account, such as the evolution of damage along time as the loading conditions change; confinement effect of the compressed concrete provided by stirrups and tension stiffening.

## III. PROBLEM IDENTIFICATION

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

## IV. RESEARCH OBJECTIVES

The objective of the present work is to study the effect of different level of confinements on curvature ductility of an RCC beams.

- The study is further followed by experimental investigation. Six rectangular RCC beams having same cross section and main reinforcements are analyzed 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.
- The experimental investigation consists of six RCC beams 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. The analytical results are compared with experimental results.

## V. METHODOLOGY

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.

1. *fpc*Concrete compressive strength at 28 days
2. *epsc*Concrete Strain at maximum strength: *epsc0*
3. *fpcu*Concrete crushing strength
4. *epsU*Concrete strain at crushing strength

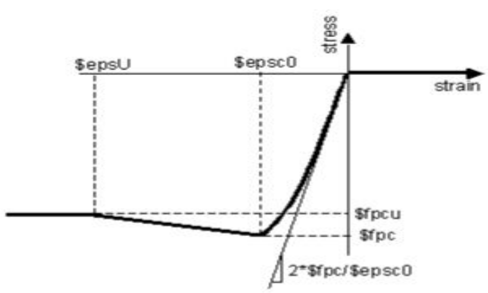



Figure 1: Parameters for *OPENSEES*

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

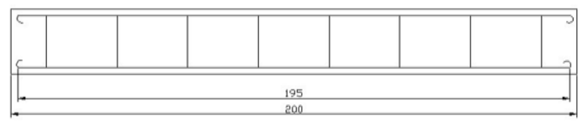
2. Young's Modulus.

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.

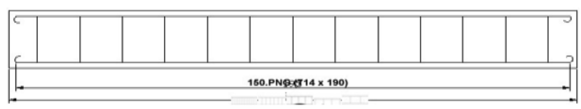
**CASE (I)**

*Beam with stirrup spacing @ 250mm* c/c



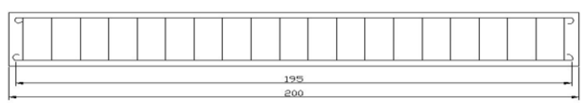

**CASE (II)**

*Beam with stirrup spacing @ 150mm* c/c



**CASE (III)**

*Beam with stirrup spacing @ 100mm* c/c

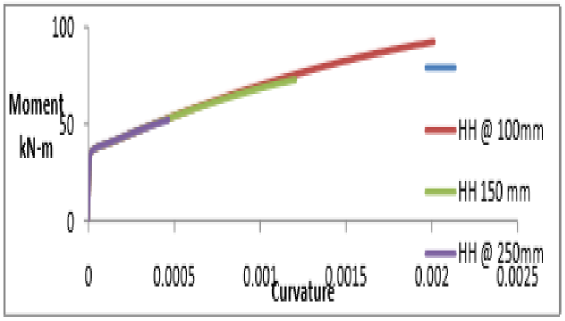



The Beam cross section for analysis is 230mm x 300 mm with 10 mm diameter hook bars in compression side and three 12 mm diameter main bars in tension side with a clear cover of 25 mm on all sides.

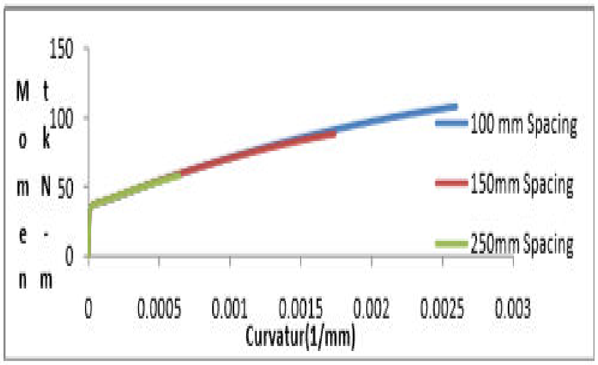
## VI. RESULTS

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

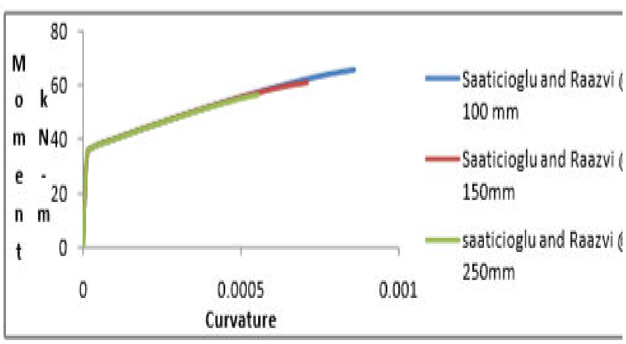
1. 2-legged Beams




2. 3-legged Beams




3. 2-legged Beams




4. 3-legged beams

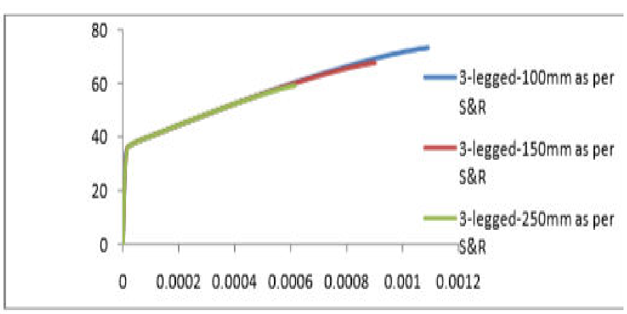



Table 1: Comparison Of Analytical Models

| S.No | Beam Description and Spacing | MODEL 1 | MODEL 2 |
|---|---|---|---|
| 1 | 2-Legged-250mm | 33.69 | 32.27 |
| 2 | 2-legged-150mm | 86.83 | 41.30 |
| 3 | 2-legged-100mm | 144.82 | 50 |
| 4 | 3-legged-250mm | 41.34 | 34.23 |
| 5 | 3-legged-150mm | 111.54 | 49.67 |
| 6 | 3-legged-100mm | 166.67 | 61.12 |

## VII. CONCLUSIONS

Stresses in concrete increase because of confinement and the corresponding strains are increases because of confinement. Model is giving higher stresses and strains. Curvature ductility increases as the stirrup spacing decreases following both the 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. The model-2 is giving higher Curvature ductility values than the experimental findings.

This chapter does not mark the end of our venture; rather we can say that it is the beginning of a major endeavor that has been initiated. Naturally, there are lots of activities left behind. In spite of these studies, there are several possible issues considered for future research work. Some recommendations of these includes

- 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. The impending demand of high strength materials to be used in the construction of beam members currently cannot be fully utilized, as both materials suffer from limited ductility. This deficiency in ductility reduces the ability to take full advantage of the increase in strength of both materials.

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