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# Effect of Lateral Confinement on Strength of Concrete

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## Abstract

*In columns or compression members, lateral reinforcement in the form of hoops, cross-ties, or spirals play an important role in safeguarding the columns, especially when they are subjected to strong earthquakes or accidental lateral loads. They are required in any column-whether they are parts of a moment resistant frame or the gravity system in order for them to deform laterally and provide the required ductility. This paper deals with studies on the compressive strength of concrete specimens having confinement in various quantities. Studies on reinforced cement concrete specimens were used to understand the influence of the lateral confinement on the compressive strength of concrete. Cylindrical and square test specimens having height to diameter (or width) ratio as 2 were used for the study. The specimen was prepared with different spacing of hoops and having seismic and non-seismic hooks. This paper deals with the variation of peak strength with volumetric ratio of transverse steel to confined concrete core.*

**Keywords:** Concrete, confinement, reinforced concrete columns, hoops, confined concrete core.

## Introduction

It has long been recognized that the strength as well as deformability of concrete substantially increase wherever amount of confinement in the form of closed ties (hoops) is increased. The numerous experimental studies on the role of confinement Sheikh and Uzumeri[1], Saatcioglu and Razvi[2], Cusson and Paultre[3], Mander *et.al.*[4] have been done in the last four decades. Sheikh and Uzumer[5] proposed a stress-strain model reflecting the effect of confinement in columns. Mander *et.al*[6], Saatcioglu and Razvi[7] proposed stress-strain models for the study of confinement in concrete columns.

The main parameters involved in the confinement are the ratio of transverse reinforcement i.e. the ratio of volume of hoops to the volume of confined core of the member, the yield strength of transverse reinforcement, the compressive strength of concrete, the spacing of hoops, the longitudinal reinforcement, hoop pattern.

During earthquakes the failure in columns may occur due to poor or improper confinements see figure-1[8]. In India and some other countries it is a practice to tie the compression members with hoops having $90^o$ hooks but it has been recommended by seismic codes to provide $135^o$ hooks for proper confinement. The inferior performance was recorded in case of confinement with $90^o$ hooks with regard to strength and ductility.

In this paper the change in strength of specimens with $90^o$ hooks (non-seismic hooks) and $135^o$ hooks (seismic hooks) has been studied keeping other factors as constant.

## Material and Methods

Ordinary Portland cement (OPC) of 43 grade was used for the production of concrete. The locally available river sand and 20mm basalt aggregates were used. TMT bars of fe415 grade of diameter 5 mm, 6 mm and 8 mm were used. A nominal concrete mix of M20 grade (1:1.67:3.34) as specified in IS 456:2000 was used for this investigation. The constituents were batched by weight and mixed manually with water-cement ratio of 0.55 was used. Moulds of prism ratio of 2 *i.e.* 15cm diameter and 30 cm height and 15cmx15cmx30cm size were prepared.

The two different geometry for all columns were used. The columns had a square cross section 150×150 mm and length 300 mm and circular columns had a section of 150 mm diameter with 300 mm height. The longitudinal reinforcements, ribbed bars with a diameter of 8 mm- 4 nos. in square section and 6 mm- 6nos. in circular cross section were placed into the section. The transversal reinforcement was formed by closed stirrups with a diameter of 5 mm. The longitudinal distance between the stirrups at the middle part of the columns was 25, 50, 75, 100, 125 and 150 mm (these dimensions are used in the subsequent notation of the series, e.g. SS1 is a square normal strength (M20) concrete column with a 1" (25 mm stirrup distance at the mid height with seismic detailing), NS1 is a square normal strength (M20) concrete column with a 1" (25 mm stirrup distance at the mid height with non-seismic detailing) and C1 is a circular section normal strength (M20) concrete column with a 1" (25 mm stirrup distance at the mid height). The distance of the stirrups at the ends was denser to prevent damage in this region caused by introducing the load and by possible geometrical imperfections.

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**Figure-1**
**Failure due to poor confinement**

**Figure-2**
**Test specimens**

**Figure-3**
**Confinement in the form of hoops (ties)**

**Figure-4**
**Moulds for specimens**

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## Results and Discussion

The behavior of all series was very similar. Almost all specimens failed around the mid height. As an example, most specimens after collapse can be seen in figure-5. Column collapse was initiated by concrete softening at the mid height, accompanied by symmetric buckling of both reinforcing bars at the compressed side of the cross section. The bars always buckled between ties, as can be seen in figure-5. In most of the specimen the failure was localized at the middle part of the specimen in a wedge shape.

**Figure-5**
**Failure of Specimen**

The transverse confinement pressure exerted on the concrete core is directly related to the quantity of transverse reinforcing steels. Figure-7 shows the behavior of confined concrete. From the test results, it is found that the increase in volumetric ratio of the transverse steel can directly enhance the strength of the confined concrete and also simultaneously improve the ductility of the confined concrete. Moreover, it is seen that the effective configuration of the transverse steel can exert a greater effect in the concrete strength.

## Conclusion

The behavior of three series of reinforced concrete columns with a square and circular cross section was investigated. Normal strength (M20 grade) concrete was chosen and two different types of detailing were used (seismic and non-seismic). The columns were axially loaded. The results are summarized in table 1,2 and 3. From the test results following conclusions can be made:

By increasing the ratio of transverse reinforcement (ratio of volume of hoops to the volume of core) the peak strength of concrete substantially increases. The variation is shown in figure-6. The circular hoops are more effective than square hoops. The strength of cylindrical columns are more than square section columns. Giving the same volumetric ratio of transverse steel, a better confinement effect can be expected with the more effective configuration type of the transverse steel. Thus, it follows that a method to quantify the configuration of transverse steel as an important variable of confinement effect is in need. This study serves to illustrate that the degree of confinement provided by non-seismic details based on the use of $90^0$ hooks is less with comparison of seismic details. Columns with non-seismic detailing have limited confinement action, lesser strength enhancement and limited ductility.

Keeping other factors same, the column with seismic hooks ($135^o$) has higher peak strength than the column with non-seismic hooks ($90^o$). Compression failure (crushing) accompanied by concrete softening and steel buckling developed in the columns. In most of the cases failure of columns localized into the middle part, where a wedge-shape failure pattern developed in the concrete, together with buckling of the reinforcement between the stirrups. The damage zone had approximately the same dimensions for all tested series. The peak strength of the columns increases as the distance between stirrups becomes smaller. This was observed for both seismic and non-seismic detailing.

So the columns have to be properly designed, detailed and constructed such that they perform as desired during strong earthquakes. Properly designed and detailed confining transverse reinforcements prevent buckling of longitudinal bars, avoid shear failure and provide sufficient ductility.

**Table-1**
**Square specimens with seismic detailing**

| specimen | Peak load Ton | Peak strength Mpa | Confinement spacing mm | Volumetric ratio of transverse reinforcement steel to confined concrete core $\rho_s$ |
|---|---|---|---|---|
| SS1 | 70 | 43.95 | 25 | 0.025 |
| SS2 | 62 | 38.93 | 50 | 0.012 |
| SS3 | 53 | 33.28 | 75 | 0.008 |
| SS4 | 42 | 26.37 | 100 | 0.006 |
| SS5 | 38 | 21.15 | 125 | 0.005 |
| SS6 | 33 | 20.72 | 150 | 0.004 |
| S | 32 | 13.94 | No confinement | - |

**Table-2**
**Square specimens with non-seismic detailing**

| Specimen | Peak load Ton | Peak strength Mpa | Confinement spacing mm | Volumetric ratio of transverse reinforcement steel to confined concrete core $\rho_s$ |
|---|---|---|---|---|
| NS1 | 63 | 39.55 | 25 | 0.025 |
| NS2 | 54 | 33.90 | 50 | 0.012 |
| NS3 | 46 | 28.86 | 75 | 0.008 |
| NS4 | 40 | 25.11 | 100 | 0.006 |
| NS5 | 35 | 21.97 | 125 | 0.005 |
| NS6 | 30 | 18.84 | 150 | 0.004 |

**Table-3**
**Circular specimens**

| Specimen | Peak load Ton | Peak strength Mpa | Confinement spacing mm | Volumetric ratio of transverse reinforcement steel to confined concrete core $\rho_s$ |
|---|---|---|---|---|
| C1 | 71 | 56.76 | 25 | 0.025 |
| C2 | 60 | 47.96 | 50 | 0.012 |
| C3 | 51 | 40.77 | 75 | 0.008 |
| C4 | 39 | 31.18 | 100 | 0.006 |
| C5 | 33 | 26.38 | 125 | 0.005 |
| C6 | 27 | 21.58 | 150 | 0.004 |
| C | 26 | 14.42 | No confinement | - |

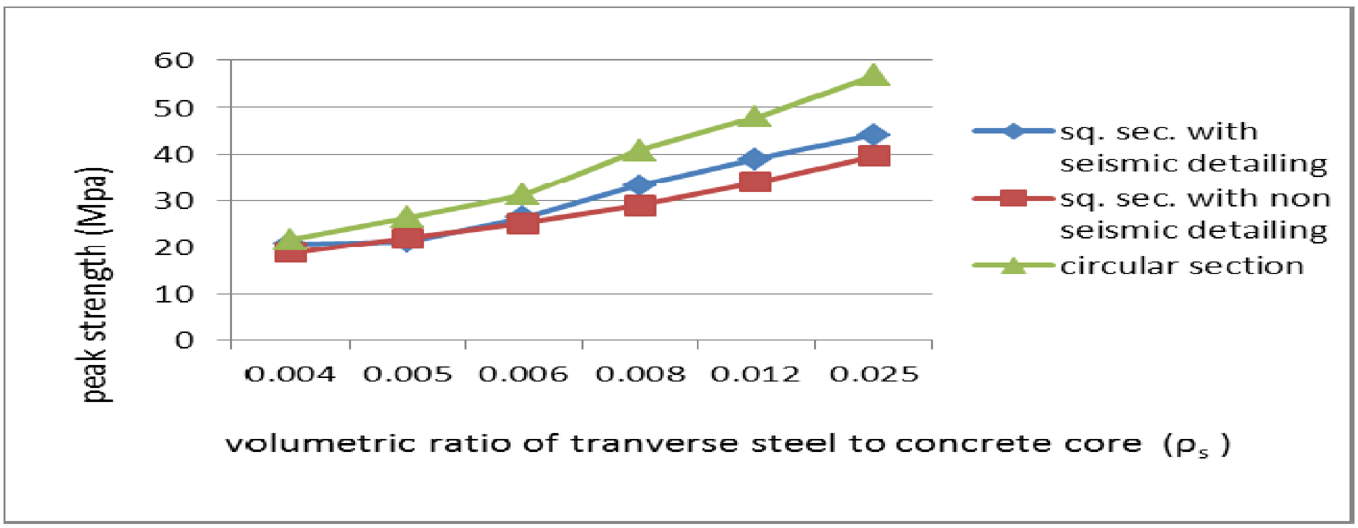


**Figure-6**
**Comparisons of three series**

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