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PARAMETRIC STUDY OF HELICAL SPIRALS AGAINST COMPRESSIVE FORCE

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Abstract— In compression member when we apply compressive force both axial and lateral stresses were produced in member. As axial stresses are compressive in nature, they are carried by concrete easily but lateral stresses are tensile in nature. As Concrete is weak in tension, it causes failure of concrete member by bursting or bulging. Here confinement reinforcement comes into picture by taking lateral tensile stresses produced in the member. Mostly in circular member circular ties were used as confinement reinforcement despite of knowing that helical spirals provide better confinement. Also helical spirals provides stiffness to the member unlike conventional ties. This paper presents parametric study of helical spirals related to confinement and stiffness provided. Parameters to be studied are pitch, loop diameter, and spiral diameter of reinforcement. This study were done theoretically, analytically and experimentally. Theoretically by stiffness and confinement formula using thin shell theory concept of confinement. Analytically by using Ansys Workbench and experimentally by casting concrete cylinders with helical spirals and testing it under UTM for compressive load at 28th day. Total 20 cylinders were casted for experimental study with 3 variation of pitch, 2 in loop diameter and 2 in spiral diameter. This paper shows an optimal pitch, spiral diameter and loop diameter and their effect on stiffness and confinement.

Keywords: Helical Spiral, Stiffness model, Confinement model, Ansys Workbench, lateral stress.

I. INTRODUCTION

When any member subjected axial forces then along with longitudinal stress it also subjected to lateral stress. This lateral stress may became failure criteria for most of the member, as we know compression member like column fails due to buckling and bursting of external concrete, this both happens due to lateral stress. A confinement zone in a column is a region where we require stirrups with smaller for higher ductility. Concrete is a very brittle material and it can easily split in tension. During earthquake the demand on reinforced concrete members increases than the capacity. To carry this lateral stress, confining reinforcement is provided. It not only bind the longitudinal reinforcement but also carries hoop stresses. The main purpose confinement reinforcement is to provide support for longitudinal bar. Confinement reinforcement is also used in flexure member to carry shear stress. This confinement reinforcement is provided in the form rectangular or circular ties, but if we design this reinforcement correctly it can also increase load carrying capacity of member along with other advantages. Many researchers try to increase effectiveness of confinement reinforcement by using various types of confinements and it's proved that spiral reinforcement is better than rectangular or circular ties and there is increase in load carrying capacity of circular column by 5%.

Earlier observations of several investigators reveal that the effect of confinement holds good in the elastic stage only and it gets lost when spirals reach the yield point. Also spirals become fully effective after spalling off the concrete cover over the spirals due to excessive lateral stresses. Accordingly, the above two points should be considered in the design of such columns. The first point is regarding the enhanced load carrying capacity taken into account by the multiplying factor of 1.05. The second point is maintaining specified ratio of volume of helical reinforcement to the volume of core, as specified in cl.39.4.1 IS 456-2000. As the further increase in diameter of spiral reinforcement the load carrying capacity will further increase beyond 5%. And one stage will be reached where maximum load will be carried by the spiral reinforcement.

The helical spiral can be used to avoid or postpone the punching shear failure in flat slabs. The punching shear failure is the worst failure mechanism due to its catastrophic nature. The damage due to punching shear failure is high compared to other failure mechanisms. The spiral reinforcement can postpone the punching shear failure in flat slabs. The spiral can be easily made by steel wires. The fixing of spiral also not a difficult task, even with unskilled labors.

A post-tensioned system basically consists of a high strength tendon or strand running throughout the length of the prestressed structure. The strand is stressed using a hydraulic jack, the compressive force of the strand is transferred into the concrete after anchoring it at anchorage zone. The relatively large compressive forces generated from the strand were applied to the concrete over a small area. Hence lateral reinforcement known as anti-burst is used in the anchorage zone to control cracking caused by tensile forces as a result of the tensioning.

The purpose of this work is to see how spiral parameters contribute to confinement and stiffness in order to take advantage in actual design of compression member. The objective of the study,

1. To study effect of pitch of spirals on stiffness, confinement and load carrying capacity.
2. To study Loop diameter and spiral diameter of spiral for optimization with respect to stiffness, confinement and load carrying capacity.

II. PARAMETRIC STUDY

Various parameters of helical spirals were studies with respect to their effectiveness in load carrying capacity, stiffness and confinement effect under experimental, theoretical and analytical model.

Pitch Variation: In this we changes pitch of helical spirals by keeping other two parameters constant. In experimental model we take pitch variation of 25mm, 50mm and 75mm. In theoretical and analytical model pitch variation were 25, 35, 45, 55, 65, 75, 85, 95, and 105mm taken.

Spiral or Bar diameter variation: In this we changes spiral or bar diameter of helical spirals by keeping other two parameters constant. In experimental model we take bar diameter variation 3mm and 6mm. In analytical and analytical model bar diameter variation were 3, 4, 5, 6, 7, and 8mm taken.

Loop diameter variation: In this we changes loop diameter of helical spirals by keeping other two parameters constant. In experimental model we take loop variation of 50mm and 100 mm. In theoretical and analytical model loop variation of 40, 50, 60, 70, 80, 90, and 100 mm were taken.

III. DESCRIPTION OF EXPERIMENTAL, THEORETICAL AND ANALYTICAL MODEL

Experimental model:

In this we cast concrete cylinders with helical reinforcement in it by using M30 grade concrete. Diameter of cylinder was 150mm and Height 600mm. Clear cover to spiral was maintained at 25mm. This cylinders were tested for failure load under CTM after 28 days of curing. Sample data of all samples were as follows:

TABLE I
EXPERIMENTAL SAMPLE DATA

Sample No.	Bar Dia.(mm)	Height(mm)	Loop Dia.(mm)	Pitch(mm)
1	*	600	*	*
2	6	600	100	25
3	6	600	100	50
4	6	600	100	75
5	6	600	50	25
6	6	600	50	50
7	6	600	50	75
8	3	600	100	25
9	3	600	100	50
10	3	600	100	75
11	*	450	*	*
12	6	450	100	25
13	6	450	100	50
14	6	450	100	75
15	6	450	50	25
16	6	450	50	50
17	6	450	50	75
18	3	450	100	25
19	3	450	100	50
20	3	450	100	75

***indicates sample without helical spiral**

Theoretical Model:

Stiffness model: when helical spiral subjected to any axial load both torsional and shear stress generated in it. By using castigliano's theorem for strain energy developed, we will following equation for stiffness of helical spiral:

$$k = \frac{F}{y} = \frac{G.d^4}{8D^3.N}$$

Here k is spring stiffness or spring rate, F=force applied in N, y=deflection in mm, G=modulus of rigidity, d=bar or spiral diameter, D=mean loop diameter and N=number of active coils of spirals.

Confinement Model: As per thin cylindrical pressure vessel theory for hoop stresses, the lateral stresses generated in confinement reinforcement is given by,

$$P.B.\sigma.\mu = fs.\pi.d^2/4$$

Here P=Pitch, B=Loop Diameter, σ=axial stress, μ= poison's ratio, fs=stress generated in steel and d=bar diameter of confinement reinforcement. Here fs represent the confinement effect. High fs means low confinement. Above Equation formed after equating lateral force produced and lateral force taken by confinement.

Analytical Model:

Axial stiffness model: This model was prepared by using Ansys Workbench software. In this springs with impactor at both ends were modelled. On one impactor load of 30 N was applied and another impactor was fixed. This model tested for deformation which shows stiffness of spiral and stresses due axial forces which shows its behaviour in axial action.

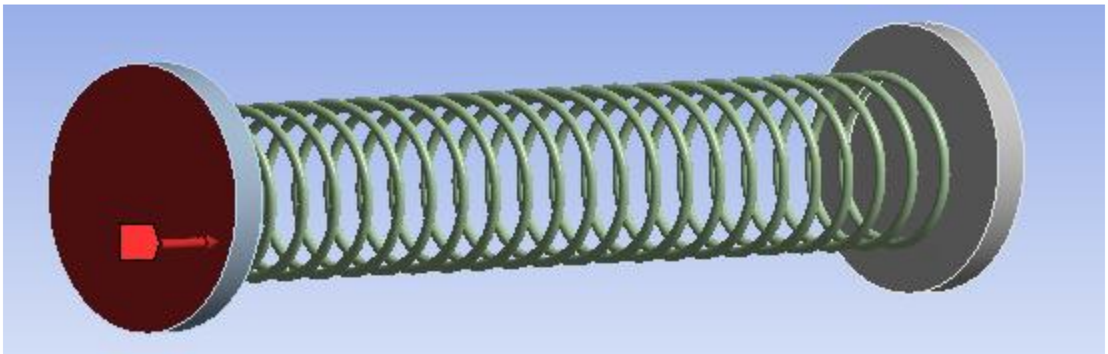


Fig. 1 Axial stiffness model

Confinement model: This model war prepared by confining hollow cylinder with 68mm and 88 mm inner and outer diameter respectively by helical spiral and again surrounding it with another hollow cylinder of 20 mm thick which is in contact with spiral. Here lateral pressure of 20 MPa was applied from inside on inner hollow cylinder. From this model we will get behaviour of spring under lateral stresses i.e. confinement effect.

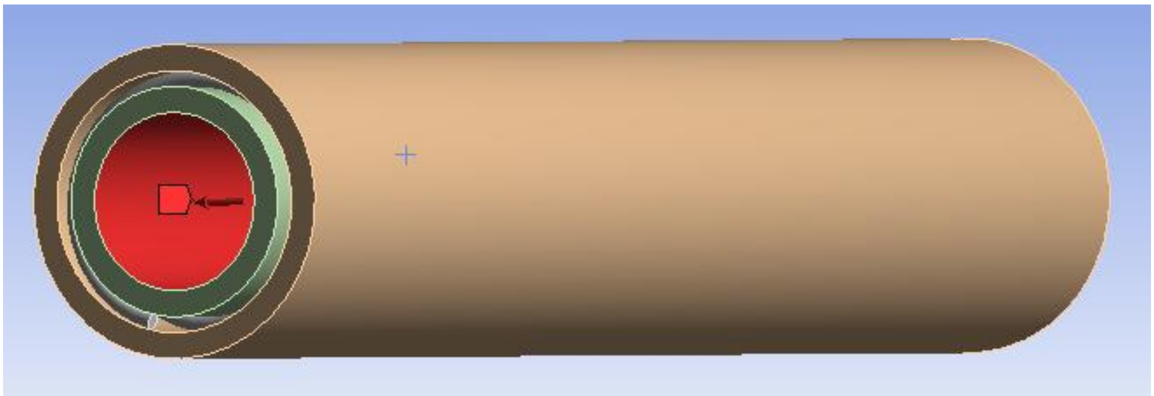


Fig. 2 Confinement model

IV. RESULTS

Results obtained for above models for various parameters discussed above were shown with the help of tables and graphs.

Experimental results:

Failure load for all sample data studied were as given below. As we tested samples with bar diameter variation 3mm and 6mm only we cannot draw graph for bar diameter variation and for loop diameter variation also.

TABLE II
EXPERIMENTAL RESULTS OF SAMPLES

Sample No.	Bar Dia.(mm)	Height(mm)	loop Dia.(mm)	pitch(mm)	Failure Load(KN)
1	*	600	*	*	398
2	6	600	100	25	421
3	6	600	100	50	437
4	6	600	100	75	430
5	6	600	50	25	430
6	6	600	50	50	427
7	6	600	50	75	415
8	3	600	100	25	401
9	3	600	100	50	412
10	3	600	100	75	408
11	*	450	*	*	440
12	6	450	100	25	477
13	6	450	100	50	481
14	6	450	100	75	483
15	6	450	50	25	470
16	6	450	50	50	485
17	6	450	50	75	479
18	3	450	100	25	453
19	3	450	100	50	467
20	3	450	100	75	472

***indicates sample without helical spiral.**

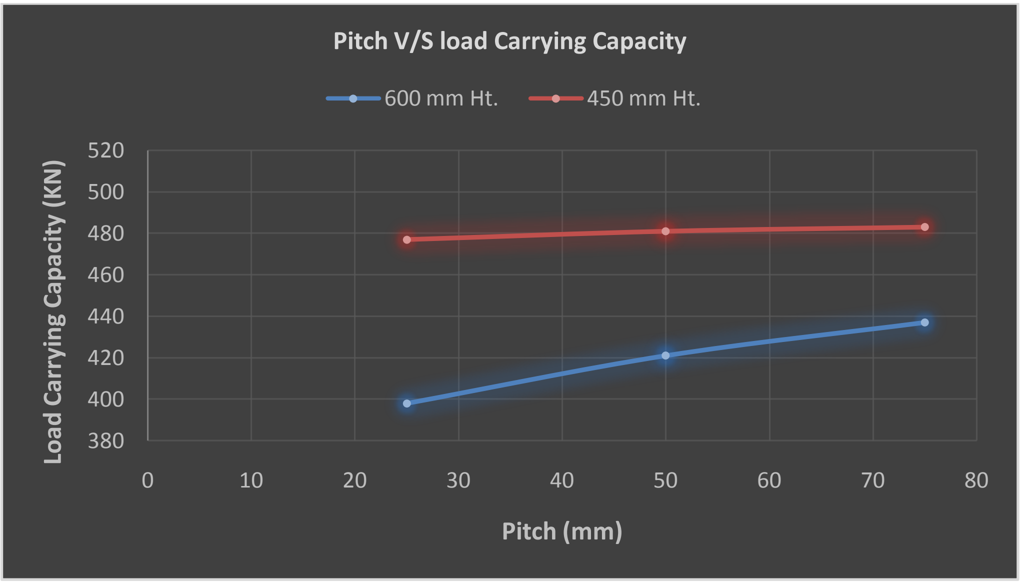
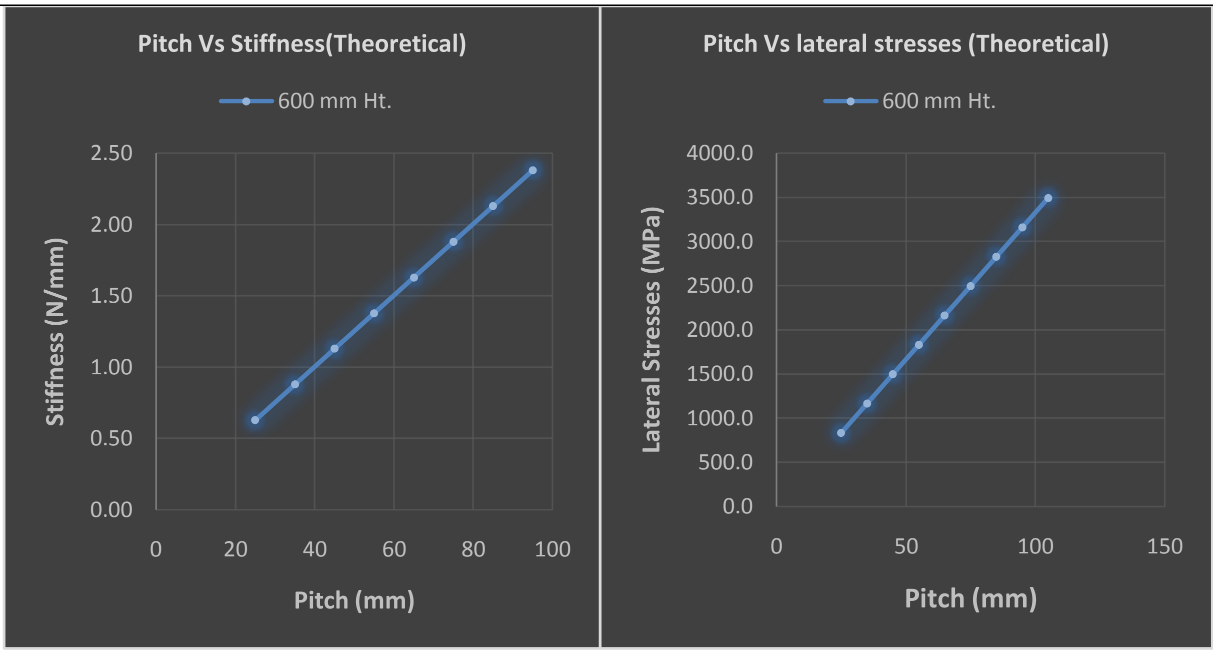


Fig. 3 Pitch V/S load carrying capacity (Experimental)

Theoretical results:

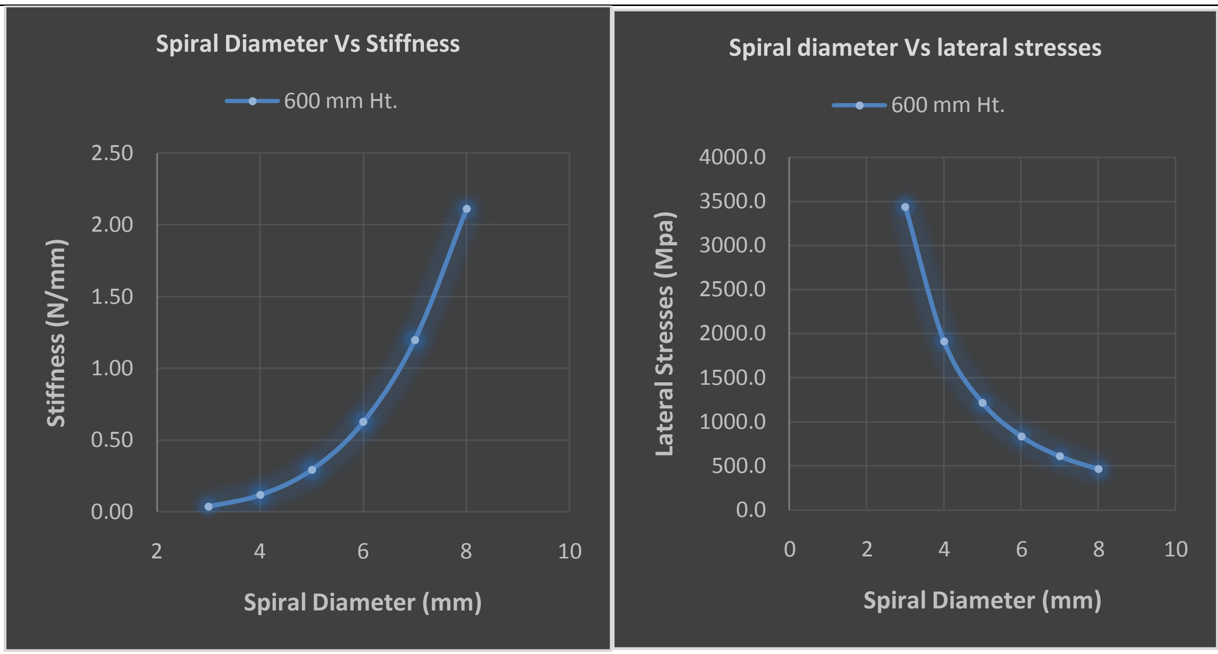
Pitch variation:



(a) Pitch V/S stiffness (b) Pitch V/S lateral stresses

Fig. 4 Pitch variation results (Theoretical)

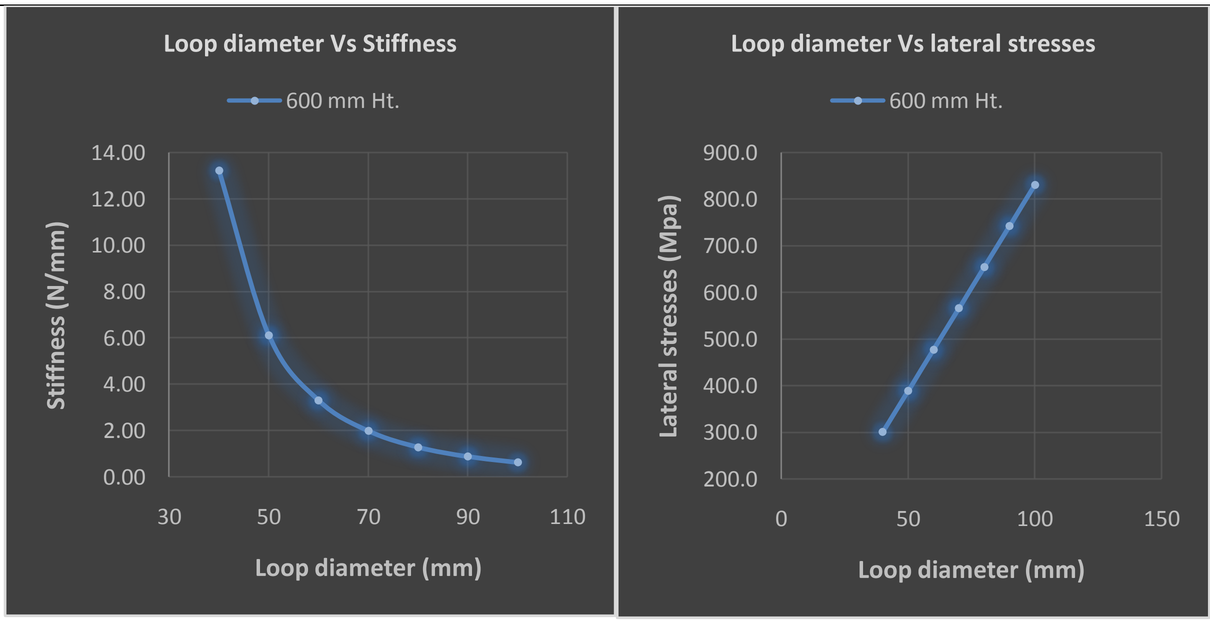
Bar or spiral diameter variation:



(a) Spiral diameter V/S stiffness (b) Spiral diameter V/S lateral stresses

Fig. 5 Spiral or bar diameter variation (Theoretical)

Loop diameter variation:

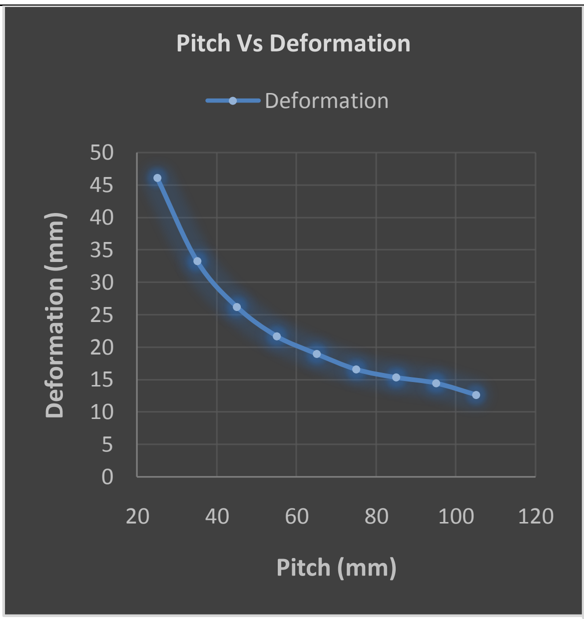


(a) Loop diameter V/S stiffness (b) Loop diameter V/S lateral stresses

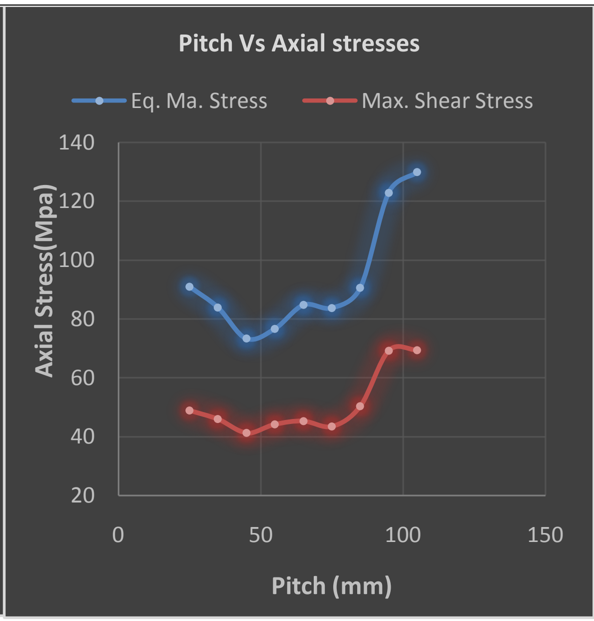
Fig. 6 Loop diameter variation results (Theoretical)

Analytical results:

Pitch variation:



(a) Pitch V/S deformation



(b) Pitch V/S axial stresses

Fig. 7 pitch Variation results for axial stress model (Analytical)

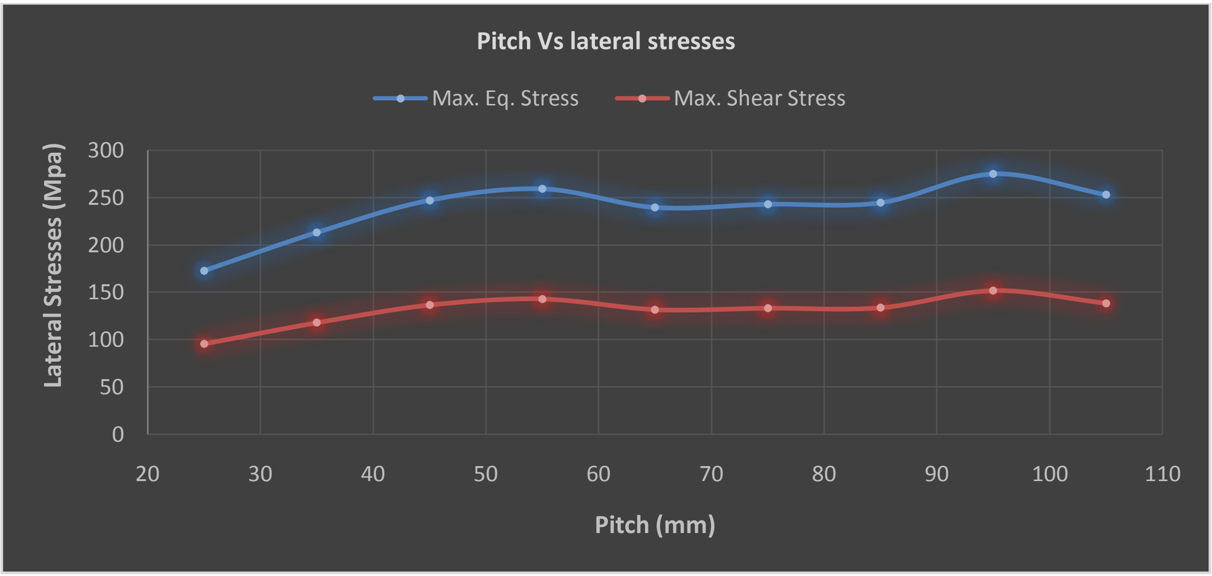
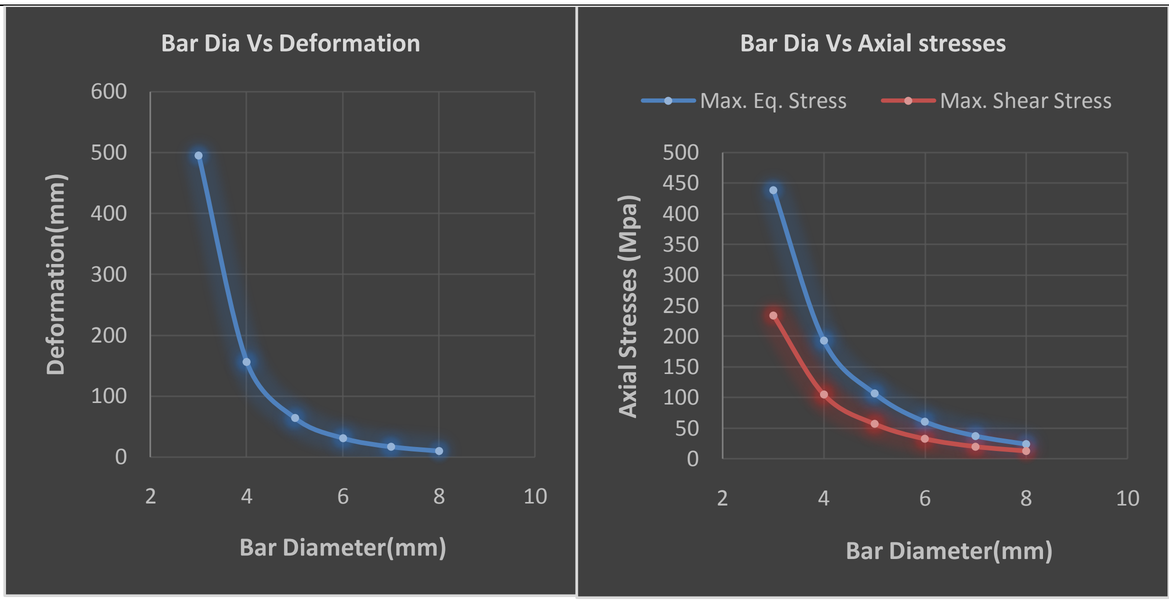


Fig. 8 Pitch variation results for confinement model (Analytical)

Bar or loop diameter variation:



(a) Spiral or bar diameter V/S deformation (b) Bar diameter V/S axial stresses

Fig. 9 Bar or spiral diameter variation for axial stress model (Analytical)

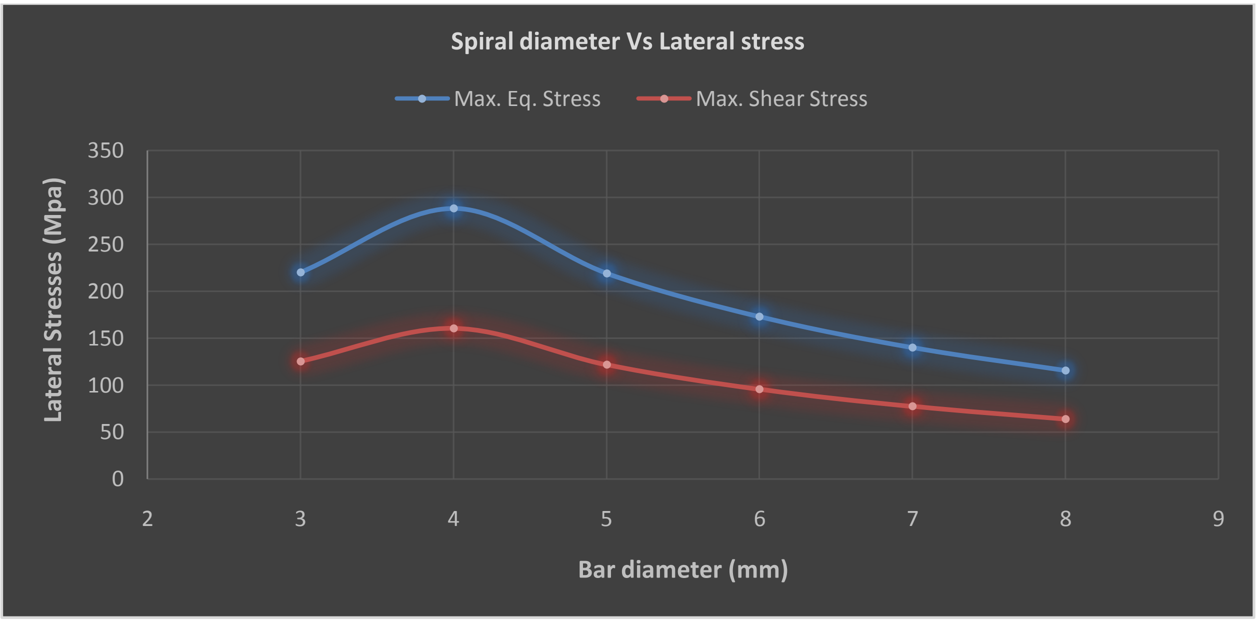
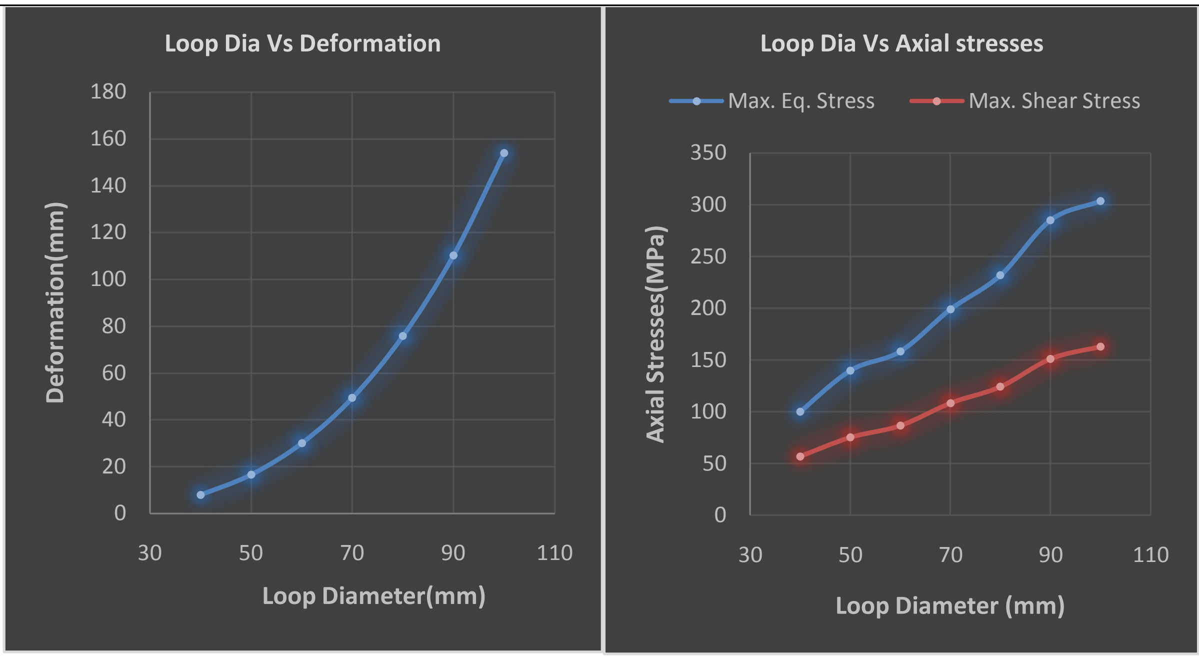


Fig. 10 Bar or spiral diameter variation for confinement model (Analytical)

Loop diameter variation:



(a) Loop diameter V/S deformation (b) Loop diameter V/S axial stresses

Fig. 11 Loop diameter variation for axial stress model (Analytical)

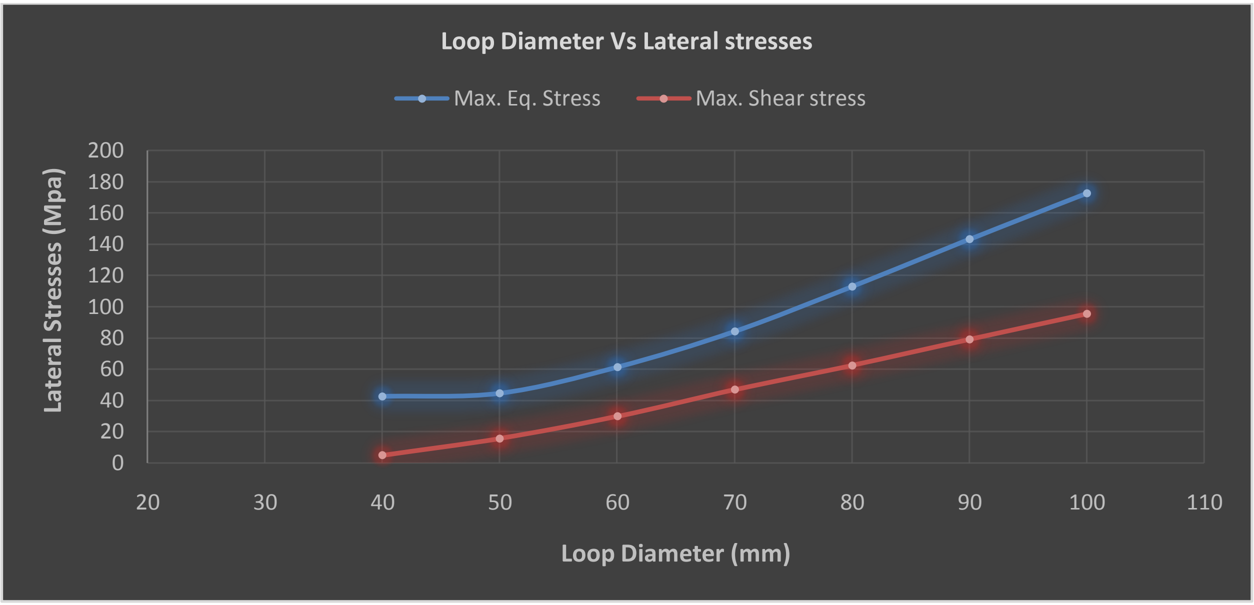


Fig. 12 Loop diameter variation for confinement model (Analytical)

V. CONCLUSION

Following conclusions were taken from results obtained as above:

- As pitch of helical spiral increases stiffness of spiral increases but confinement decreases.
- Between 25mm to 75mm pitch both confinement and stiffness increases at the same time, hence it is taken ideal to increase load carrying capacity by 5% in circular column with helical spirals.
- As pitch increases load carrying capacity increases as we taken pitch between 25mm to75mm.
- As bar diameter of spiral increases both stiffness and confinement increases at the same time.
- Load carrying capacity also increases with increase in bar diameter due to above reason.
- As loop diameter decreases stiffness of the spiral increases and confinement also increases but it is limited to the certain region whereas remaining outer concrete subjected to lateral stresses.
- If we able to increase both confinement and stiffness at the same time, we will get increased load carrying capacity in compression member.

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