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# Study on reinforced concrete beams with helical transverse reinforcement

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**Abstract.** In a Reinforced Concrete (R.C) structure, major reinforcement is used for taking up tensile stresses acting on the structure due to applied loading. The present paper reports the behavior of reinforced concrete beams with helical reinforcement (transverse reinforcement) subjected to monotonous loading by 3-point flexure test. The results were compared with identically similar reinforced concrete beams with rectangular stirrups. During the test crack evolution, load carrying capacity and deflection of the beams were monitored, analyzed and compared. Test results indicate that the use of helical reinforcement provides enhanced load carrying capacity and a lower deflection proving to be more ductile, clearly indicating the advantage in carrying horizontal loads. An analysis was also carried out using ANSYS software in order to compare the test results of both the beams.

## 1. Introduction

The progress of construction sector has been mainly supported by the development in construction materials where high strength reinforced concrete beams are mainly predominant. Recently, the use of helical reinforcement has been extended in RC elements with rectangular cross-sections. The extension in usage of these reinforcements with rectangular cross-sections is a recent promising technology which can enhance the performance of these RC members. The increase in ductility as well as the compressive strength in beams can be achieved by using helical reinforcement because of their ability to counter the lateral expansion due to Poisson's effect upon loading. Moreover, ductility in beams could allow redistribution of moments to take place which can stop the buildings from quick collapse during earthquake attack or accidental impact.

In this paper, experimental results of testing six beams with respect to deflection and load bearing capacity by using normal and normal with helical reinforcements are done by comparing with each other to show the significant enhancement in load bearing capacity and ductility of the normal with helical reinforced concrete beams.

Ahmed M. Ali et.al [1] described about the effect of installing different configurations of confinement in the compression zone of over-reinforced concrete beams where significant increase in flexural capacity, ductility and energy absorption was observed when the confining zone had square and circular spiral confinement. Dr. Sawsan Akram Hassan et.al [2] stated about the improvement in strength and ductility of the beams by compression zone strengthening where the increase in the amount of compression reinforcement produced better results. J.C.M Ho et.al [3] described about the importance of flexural ductility in reinforced concrete beams by using the method of nonlinear moment-curvature analysis, taking into account the stress-path dependence of steel reinforcement where a formula was developed to enable rapid evaluation of ductility in beams that correlates the curvature ductility factors to the other major factors. Luke Pinkerton et.al [4] described about the helical reinforcement in concrete stating the important properties of an helix which are mainly responsible for increasing the tensile strength, ductility and modulus of rupture in a concrete where the special property is that it does this without moving or stretching enough for a crack to form and at the most, it only leads to the formation of microscopic fissures in the concrete thereby allowing for thousands of load re-distributions to occur as loads increase, thereby increasing the load bearing capacity when more and more fissures form as more and more load is transferred into the helix. Elbasha N [5] stated about the improvement in ductility of over-reinforced helically confined concrete beam by throwing light on the fact that the advantage of high strength concrete and high strength steel when used together helps in increasing the beam's load carrying capacity thereby reducing its cross-section. Muhammad N. S Hadi et.al [6] stated about the increase in strength and ductility of high strength concrete beams by the usage of helical reinforcement in which the level of increase was mainly controlled by the pitch of helix and the behavior of helically confined beams was influenced by spalling off phenomenon where the spalling off load was dependent upon the helical pitch. Elbasha N et.al [7] described about the significance of helical reinforcement which helps in enhancing the ductility and compressive strength of concrete beam under compression as the lateral expansion due to Poisson's effect upon loading is prevented by its usage. Muhammad N.S. Hadi et.al [8] and Elbasha N [9] stated about the effect of helical pitch and tensile reinforcement ratio on the concrete cover spalling off and displacement ductility for over reinforced HSC helically confined beam by the usage of steel helixes in the compression zone of concrete which helped in improving the strength and ductility of the beams. But the increase in longitudinal reinforcement ratio also lead to the decrease in load at spalling off concrete covers and increases in ultimate deflection and displacement ductility index. M.N.S Hadi et.al [10] described about the increase in ductility of high strength concrete beams through the use of different shapes of confinement reinforcement where helical confinement was considered to be the most effective in increasing the strength and ductility of the concrete because of the application of uniform radial stress along the concrete member when compared to the rectangular ties which tends to confine the concrete only at the corners.M.M.Ahmedet.al [11] and Anant Parghi et.al [12] described about the effect of ductility with respect to the post-peak load-deflection response where ductility was directly proportional to the volume of steel helix but the effect of same helix decreased when main reinforcement was increased and the increase in toughness was also evident in the beams with helical confining in the compression zone. Muhammad N.S. Hadi et.al [13] stated about the important effect of helical pitch on the displacement ductility of helically confined beams where the reduction in helical pitch lead to the increase in displacement ductility index and yield deflection was the same for all the beams but ultimate deflection was different which proved the effectiveness of helical confinement as there was an increase in the concrete compressive strength which also meant that the failure changed from brittle to ductile. Apart from this method many researchers reported that FRP wrapping improve the properties of RC structures [14], [15].

In this paper, experimental results of testing six beams with respect to deflection and load bearing capacity by using normal and normal with helical reinforcements are done by comparing with each other to show the significant enhancement in load bearing capacity and ductility of the normal with helical reinforced concrete beams.

## 2. Experimental work

The main concept of this study is to test the performance of concrete by providing normal and normal with helical reinforcements. The helical reinforcement will enhance the properties like flexural strength, ductility and will prevent brittle failure when compared to normal confinement in a more efficient way.

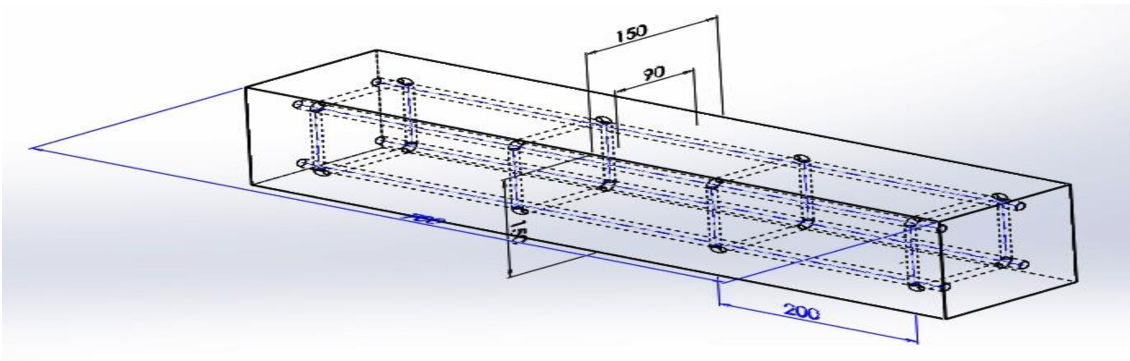
### *2.1 Materials*

For concrete preparation, Ordinary Portland Cement of grade 43 was used. River sand, locally available and confirming to Zone II specification with respect to IS 383-1970 [16] was taken as fine aggregate and crushed stones of 20 mm nominal size were taken as coarse aggregate. For the experimental work, a number of specimens were casted. M20 grade of concrete was chosen. The properties of the materials used were listed in Table 1.

**Table 1**. Physical Properties of cement, fine aggregate and coarse aggregate

| Property | Cement | Fine aggregate | Coarse aggregate |
|---|---|---|---|
| Specific Gravity | 3.15 | 2.61 | 2.68 |
| Water Absorption | - | 3.7% | 0.5% |
| Initial Setting time | 30 min | - | - |
| Final Setting time | 600 min | - | - |

In the present work, six reinforced concrete beams of size of 70x15x15cm were casted and tested. Three beams were reinforced with 10 mm main bars and rectangular stirrups of size 6 mm and the other three beams were reinforced with 10 mm main bars, rectangular stirrups of size 6 mm along with steel helix of size 5 mm. The isotropic and cross-sectional views of both the type of beams are shown in Figure1 and Figure 2.

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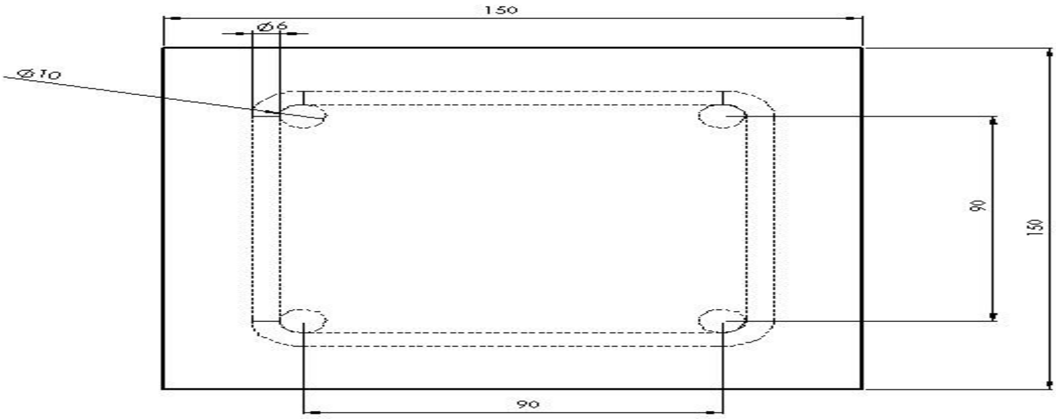


**(b)**

**Figure 1.** (a) Isotropic view of normally reinforced beam (b) Cross-sectional view of normally reinforced beam

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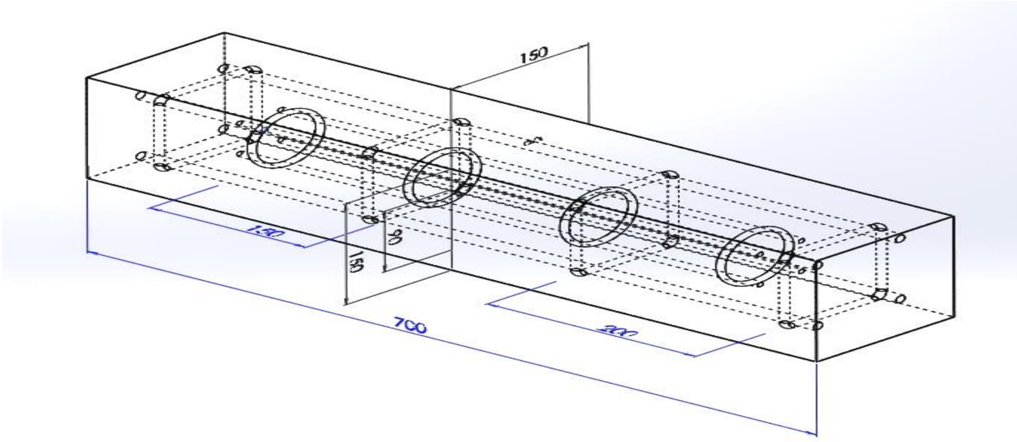


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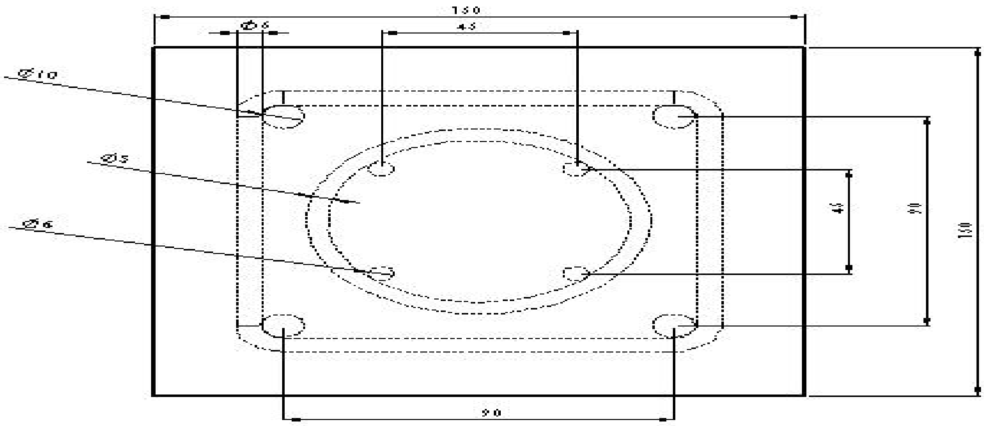



**(b)**

**Figure 2.** (a) Isotropic view of normal with helically reinforced beam (b) Cross-sectional view of normal with helically reinforced beam

*2.2 Preparation of test specimen and test procedure*

Concrete of grade M20 was batched and mixed using a concrete mixer. The deflection test was performed on beams after 28 days from the day of casting. The test was done in accordance with IS: 516-1959 [17] using 400 kN universal testing machine by three-point loading. The loading was applied in increments of 5 kN and the crack pattern, cracking load, mid-span deflection and failure load were measured and recorded.

## 3. Results and discussion

All the six beams were tested under three point loading and the results were plotted. The following observations were made from the test results.

*3.1 Load-Deflection graphs*

Figure 3 shows the load deflection curve corresponding to beams with normal reinforcement and Figure 4 shows the load deflection curve for normal with helical reinforcement. The results show that reinforcing the concrete with steel helix lead to an increase in load bearing capacity of the beams. The effect of helical reinforcement in beams is more attributed at higher load levels only when the ultimate load capacity of the beams is taken into consideration. The cracks were first observed in the mid-lower region and as the load increased, new cracks were found along the beam towards the point of application of load. The mode of failure also changed from brittle to ductile for the normal with helically reinforced beams when compared to the normally reinforced beams.

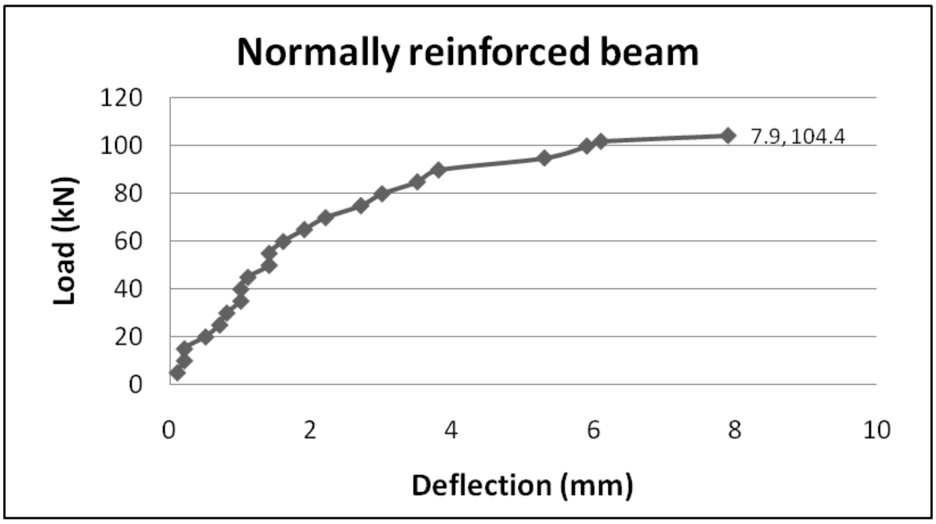



**Figure 3.** Load-Deflection curve for normally reinforced beam

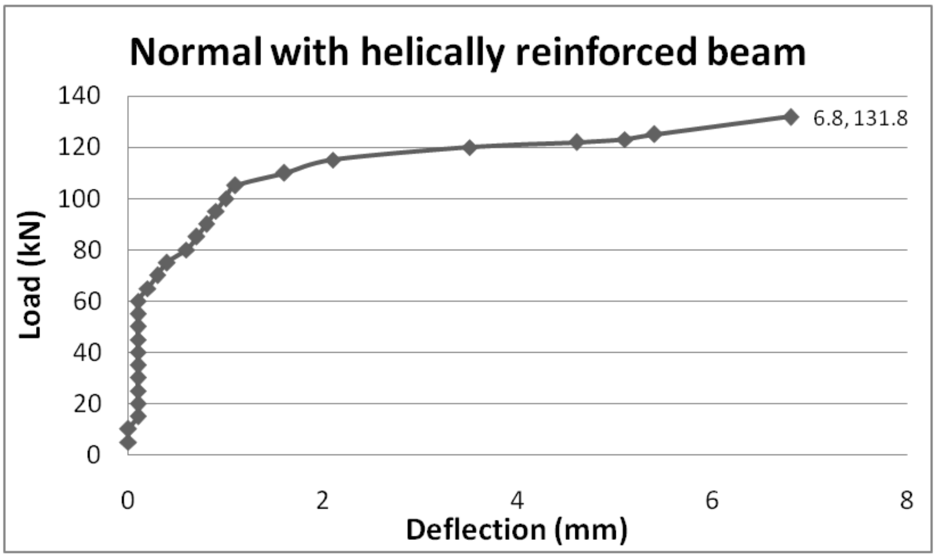


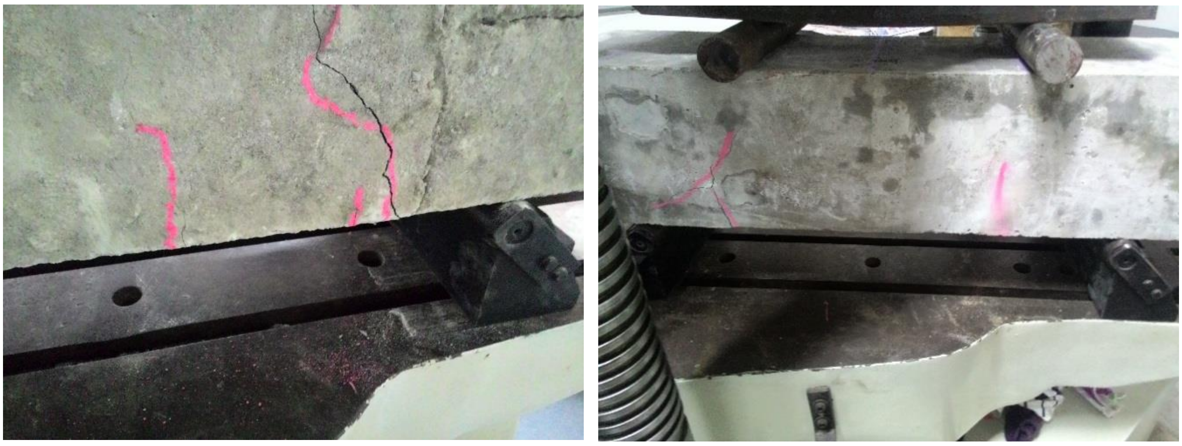

**Figure 4.** Load-Deflection curve for normal with helically reinforced beam

*3.2 Ductility*

The ductility of the beam can be assessed with respect to the deflection during loading. From Figure 3 and Figure 4, it can be seen that the normal with helically reinforced beams showed an increase in the ductility of the beams when compared to the normally reinforced beams. The effectiveness of helix in increasing the ductility can be related to the ability of the helices to apply uniform radial stress in all directions.

*3.3 Cracking pattern and Ultimate load*

The formation of cracks upon loading was found to be identical in both cases in the initial stage since the first crack occurred at a relatively low load. But the effect of helical reinforcement was seen significantly in the ultimate load when compared to the normal reinforcement. Figure 5a shows the crack pattern in normally reinforced beam and Figure 5b shows the crack pattern in normal with helically reinforced beam corresponding to a load of 80 kN.



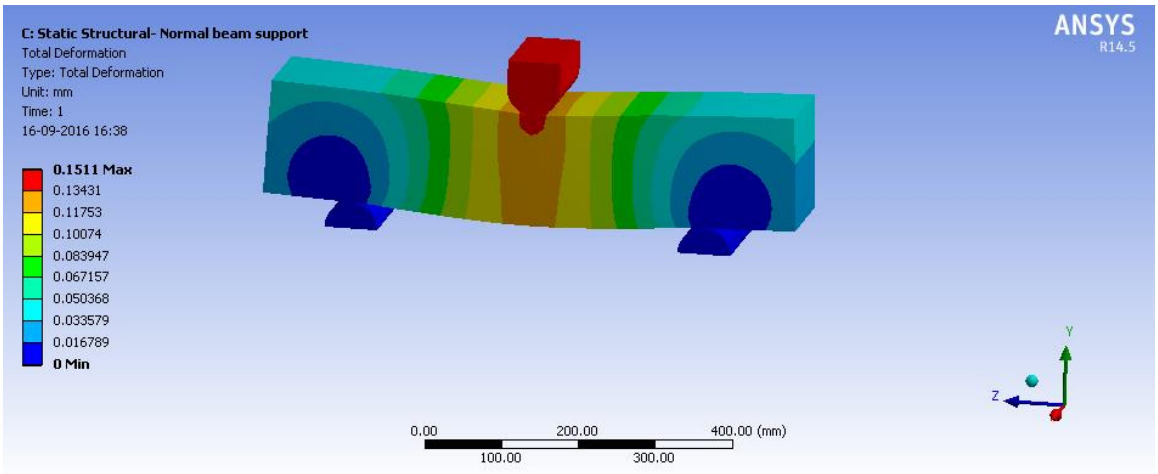
**(a)** **(b)**

**Figure 5.** Crack pattern in (a) Normally reinforced beam (b) Normal with helically reinforced beam corresponding to a load of 80 kN

*3.4 Finite Element analysis*

To compare the results obtained from the experimental investigation, a finite element analysis was also carried out using ANSYS. The following deflection profiles were obtained using ANSYS software for the different loading cases for both the normal as well as normal with helically reinforced beams.

The deflection profile of normally reinforced concrete beam at loads of 2kN, 85kN, 102kN, 104.4kN were shown in Figure 6a, 6b, 6c and 6d respectively.

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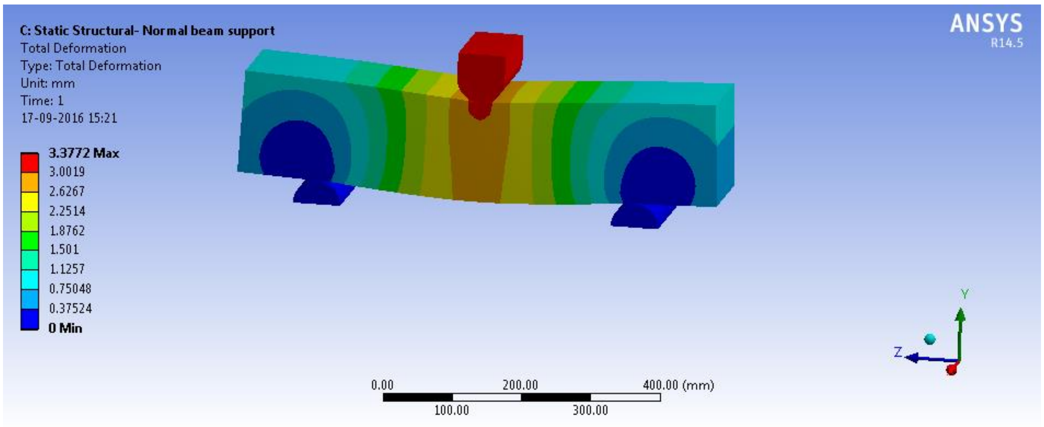


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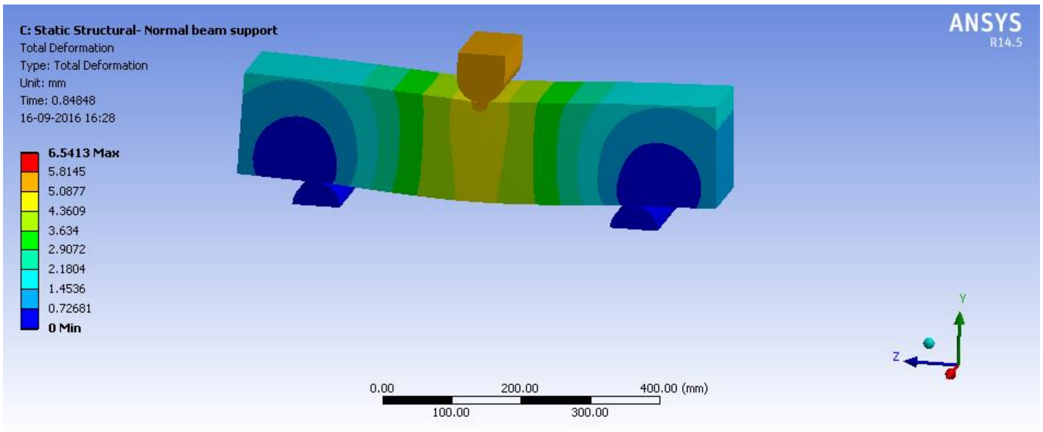


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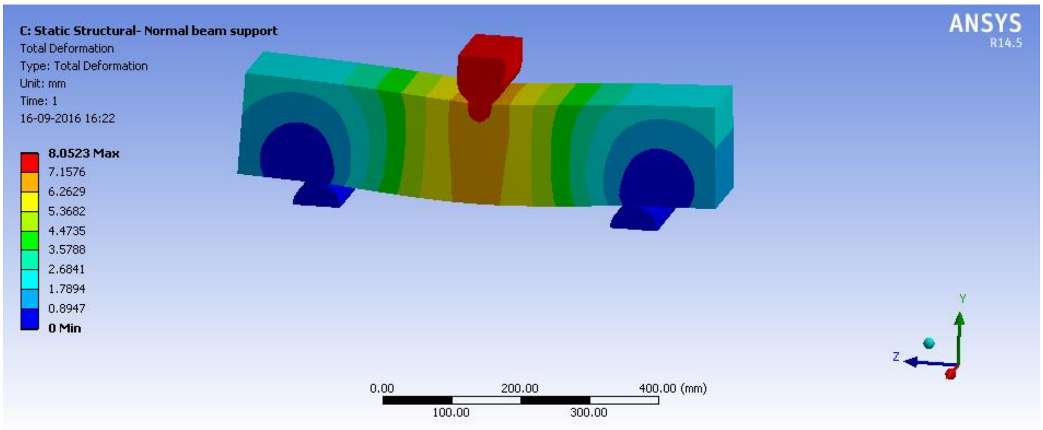
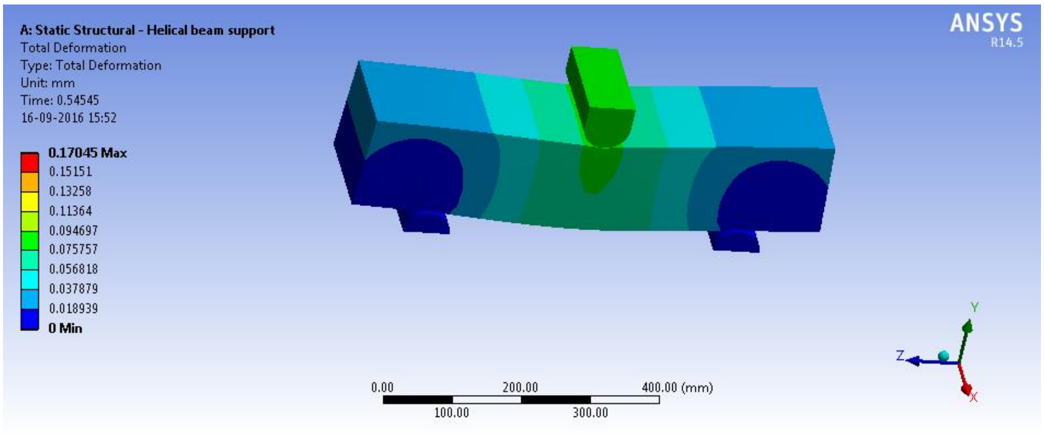



**(d)**

**Figure 6.** Deflection profile of normally reinforced concrete beam at loads of (a) 2kN, (b) 85kN, (c) 102kN, (d) 104.4kN

For normally reinforced beam, under 2kN load, deflection during experimental analysis was found to be 0.1mm and from ANSYS it was found to be 0.15mm. For 85kN load, deflection during experimental analysis was found to be 3.5mm and from ANSYS it was found to be 3.37mm. For 102kN load, deflection during experimental analysis was found to be 6.1mm and from ANSYS it was found to be 6.54mm. For 104.4kN load, deflection during experimental analysis was found to be 7.9mm and from ANSYS it was found to be 8.05mm.

The deflection profile of normal with helically reinforced concrete beam at loads of 20kN, 115kN, 118kN, 131.8kN were shown in Figure 7a, 7b, 7c and 7d respectively.

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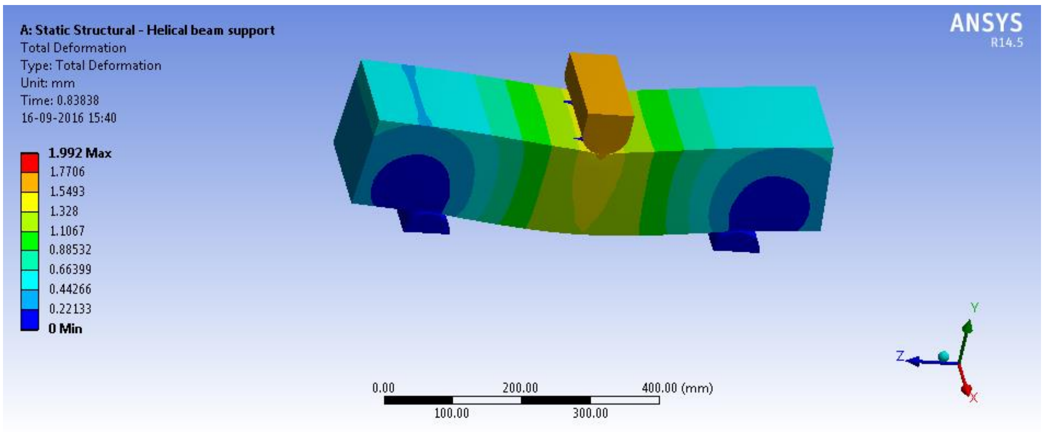


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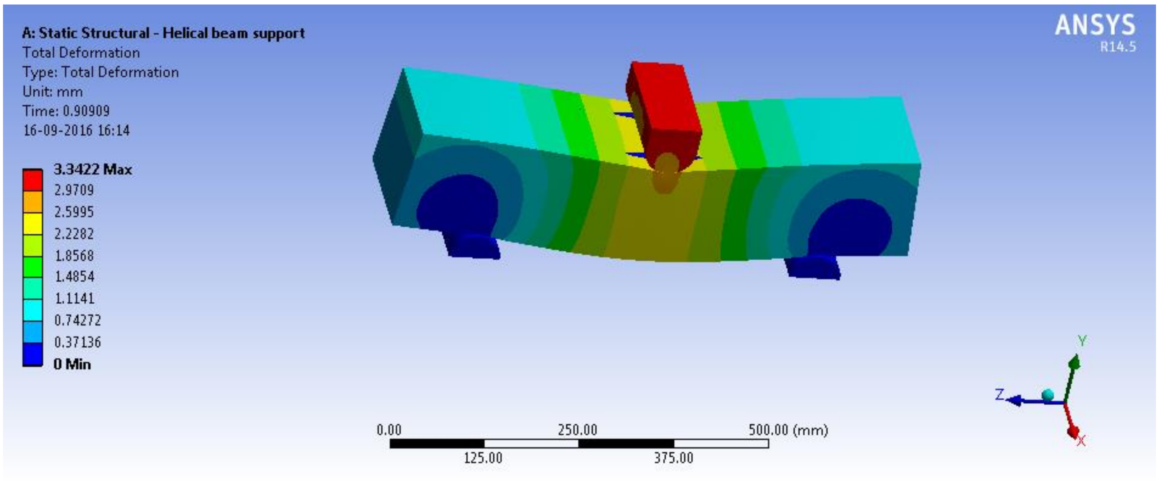


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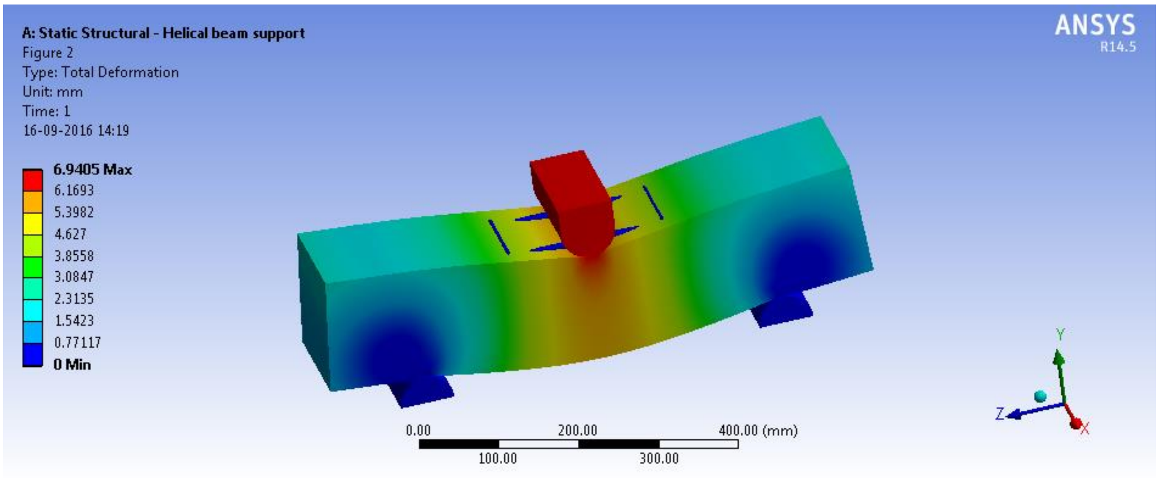


**(d)**

**Figure 7.** Deflection profile of normal with helically reinforced concrete beam at loads of (a) 20kN, (b) 115kN, (c) 118kN, (d) 131.8kN

For normal with helically reinforced beam, under 20kN load, deflection during experimental analysis was found to be 0.1mm and from ANSYS it was found to be 0.17mm. For 115kN load, deflection during experimental analysis was found to be 2.1mm and from ANSYS it was found to be 1.99mm. For 118kN load, deflection during experimental analysis was found to be 3.4mm and from ANSYS it was found to be 3.34mm. For 131.8kN load, deflection during experimental analysis was found to be 6.8mm and from ANSYS it was found to be 6.94mm.

## 4. Conclusions

The present work explores the compatibility of normal with helical reinforcement as a whole which can be looked upon as an efficient replacement for normal reinforcement because of its ability to reinforce in all directions. The effectiveness was assessed by performing tests on the beams with respect to the cracking pattern, ductility and load defection diagrams. The obtained results were compared using ANSYS software and the values were found to be nearly accurate and hence the advantage of using helical reinforcement can be observed significantly. Therefore, reinforced beam with helical reinforcement has higher ultimate load-bearing capacity than normally reinforced beam. Hence it can be used in places where horizontal loads have higher significance.

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