Analytical And Experimental Behavior of Continous Rc Beam With Sprial Tranverse Reinforcement Under Pure Torsion

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Abstract- *The use of continuous rectangular spiral shear reinforcement as transverse reinforcement is analytically investigated under pure torsion. In this paper, four inclination angle of stirrups (80º, 75º, and 45º) and traditional(90º) kind of stirrups are adopted. The behavior of the torsion in beams is studied through monitoring the load–deflection curves, ultimate load values, vertical deflections measurements and crack propagation during static tests. The analytical torsional capacity of the beams is compared with Numerical values from the design for torsion formulas by using ACI and Macgregor Method. Test results clearly indicate that using rectangular spiral shear reinforcement improved the Torsion capacity of beams compared with traditional individual closed stirrup beams. Using rectangular spiral shear reinforcement is recommended because it improves the stiffness in beams and can reduce the total cost due to labor costs.*

Keywords- Continuous Spiral Reinforcement, Reinforced Concrete, Torsional Strength, Ductility.

I. INTRODUCTION

Apart from the flexure and shear resistance of Reinforced Concrete (RC) structural elements, torsion resistance is also a crucial factor that must be considered for peripheral beams in multistorey buildings. Torsional moments can be developed in RC members significantly such as bridge elements, horizontal curved members, eccentrically loaded beams, spandrel beams etc., So the torsional capacity of these members needs to be maximized due to several factors, including structural damage, deterioration and increased loading. In the case of reinforced concrete structural systems torsion has been generally considered as secondary in importance, but modern structural configurations do require the study of torsional behavior. The brittle catastrophic nature of failure of concrete under shear stress developed due to torsion is of importance under present day context of seismic analysis and design. The Fig. 1 represents the rebar arrangement of beam with the continuous spiral reinforcement. In monolithic construction of reinforced concrete structure tends to introduce torsional moments into the members which, in general, cannot be ignored in design. Torsional strength of sections made with homogeneous materials can be estimated quite accurately using the theory of elasticity.

Fig. 1. Beam with continuous spiral reinforcement

However, it is very difficult to assess the torsional strength of heterogeneous reinforced concrete sections. The problem becomes even more acute because such members are seldom under pure torsion; rather they are subject to bending, shear and torsion. Torsion has always been an interesting and important aspect of structural behavior. Axial loads, flexure, shear and torsion are the basic loading situations for which independent theories have been developed for conventional concrete, and the more complicated interactive loading situations have been well established with as combinations of these basic effects. A common example of torsional loading is that of a ring beam provided at the bottom of an elevated circular water tank. Such a ring beam is subjected to bending moment, shear force and torsional moment. The beams supporting cantilevered canopy slabs are also subjected to significant torsional loading. Other prominent examples of loadings are edge beams of concrete shell roofs, and helicoidal staircase This research focus on torsional behavior of single span beam with inclined shear reinforcement with different configuration of angle to understand the failure mechanism of the beam under pure torsion. The use continuous spiral reinforcement will result in better ductile performance than the conventional one.

II. PREVIOUS WORKS IN TORSIONAL BEAM

The use of optimum angle of reinforcement better resistant against torsion. [1]. AbdeldayemHadhooda et. al., made a research in Torsion in concrete beams reinforced with GFRP spirals. [2]. Jeyashree T.M. and M Nethaji made an Experimental investigation on flexural behavior of reinforced concrete curved beams with different types of shear reinforcement. [3]. Ammar N. Hanoon and Haider A. Abdulhameed made an Research in Energy Absorption Evaluation of CFRP-Strengthened Two-Spans Reinforced Concrete Beams under Pure Torsion. [4]. Tuan-Anh Nguyen, et. al., made an study for Enhanced finite element model for reinforced concrete members under torsion with consistent material parameters. [5]. Mohammed Sirage et. al., made a research in effect of concrete cover on the pure torsional behavior of reinforced concrete beams. [6]. Nasim Shatarat et. al., studied the shear capacity in concrete beams reinforced by stirrups with two different inclinations. [7]. MohammadaminAzimi et. al., studied the seismic performance of R.C beam-column connections with continuous rectangular spiral transverse reinforcements for low ductility classes. [8]. Piero Colajanni et. al., Made an investigation Shear capacity in concrete beams reinforced by stirrups with two different inclinations. [9]. K.Gunasekaran et. al., made an Experimental evaluation of high strength concrete beams are subjected to pure torsion.

III. ANALYTICAL PROGRAM

3.1 Design Criteria

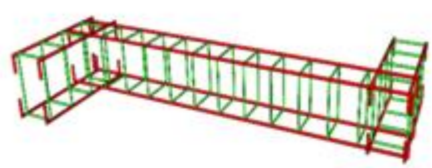
The Concrete structure must satisfy the following conditions: (1) The structure must be strong and safe. (2) For the analysis of structural member, ABAQUS has been chosen for the purpose of modeling and analyzing theconcrete beam with steel in this study due to its flexibility in creating geometry and material modeling. In the preprocessing work the general properties of element i.e., concrete grade M30 and Steel grade of Fe415 was feeded in ABAQUS along with that other non-linear properties also has been feeded in abacus FEA. Then the element was modelled and configuration reinforcement arrangement was placed into the element and the interaction was done to acts as a homogenous element and the element is finely meshed to obtain the accurate results.

3.2 Description of specimens

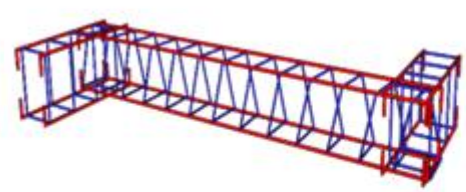
Four reinforced concrete beams of M30 grade used in this investigation program were it 230 mm wide,300 mm depth, and 2000 mm long. Fig.2 shows the different configuration of rebar arrangement. Beam (B1) is designed with 2 nos- 12 mmØ bars at top and bottom , 8 mmØ @150 mm c/c stirrup (Conventional type 90º) are provided, Beam (B2) is designed with 2 nos- 12 mmØ bars at top and bottom , 8 mmØ @150 stirrup (Inclined type 80º) are provided, Beam (B3) is designed with 2 nos- 12 mmØ bars at top and bottom , 8 mmØ @150 mm stirrup (Inclined type 75º) are provided, Beam (B4) is designed with 2 nos- 12 mmØ bars at top and bottom , 8 mmØ @150 mm stirrup (Inclined type 45º) are provided, these details are presented in below Table 1.

Beam ID	Cross Section	Longitudinal Reinforcement	Transverse Reinforcement	Type	Concrete and Steel Grade
B1	230 mm x 300 mm	2-12 mm Ø at top 2-12 mm Ø at Bottom	8 mm Ø at 150 mm c/c	Conventional (90º)	M30 & Fe 415
B2				Inclined (80º)	
B3				Inclined (75º)	
B4				Inclined (45º)	

Table 1. Reinforcement details of the members



a) B1 - Conventional type Stirrups (90º)



b) B2 - Inclined type Stirrups(80º)

c) B3 - Inclined type Stirrups(75º)

d) B4 - Inclined type Stirrups (45º)

Fig. 2: Rebar Arrangement

IV. RESULTS AND DISCUSSIONS

4.1 Load Vs Crack

The cracking pattern in the specimens can be obtained using the Crack/Crushing plot option in ABAQUS. Initial cracking is defined to be the loading at which the extreme tension fiber reaches the modulus of rupture. After cracking, concrete behaves as a nonlinear discontinuous medium forming a truss action in which reinforcement acts as a tensile link and concrete as compression diagonal. As the applied torque increases, the spiral cracks developed approximately at 45º and spread over the test region. The maximum crack was observed at specimen (B1) is 0.24 mm which is under the maximum allowable limit of 0.3mm. From Table 2 it is observed that the specimen (B1) & (B2) undergoes initial crack due to initial cracking torque of 16.91 kNm and (B3) & (B4) undergoes initial crack due to initial cracking torque of 22.40 kNm. The beam (B1, B2, B3 & B4) observed same ultimate cracking torque was obtained as 26.70 kNm.

Beam ID	Initial Crack load (kN)	Ultimate Crack load (kN)	Maximum Crack Width (mm)	Initial Cracking Torque (kNm)	Ultimate Cracking Torque (kNm)
B1	9.5	12	0.24	16.91	26.70
B2	9.5		0.24	16.91	
B3	11.5		0.19	22.40	
B4	11.5		0.19	22.40	

Table 2. Reinforcement details of the members

4.2 Load Vs Deflection

All 4 specimens were analyzed using FEM, and the results were compared for maximum deflection and ultimate load carrying capacity. Specimens were analyzed for pure torsion loading condition Fig. 3 shows the span vs deflection curve of beams. From Fig. 3, it is observed that specimen (B3 & B4) i.e., Specimenwith(45º & 75º) inclined continuous stirrups has an increase in load carrying capacity and a very less deflection of 0.0011 mmwhen compared to specimen with conventional type stirrup. Under flexural loading condition the maximum allowable deflection 6.6 mm for the span of 2m. here due to pure torsion condition the maximum deflection in specimens is 0.0013mm.

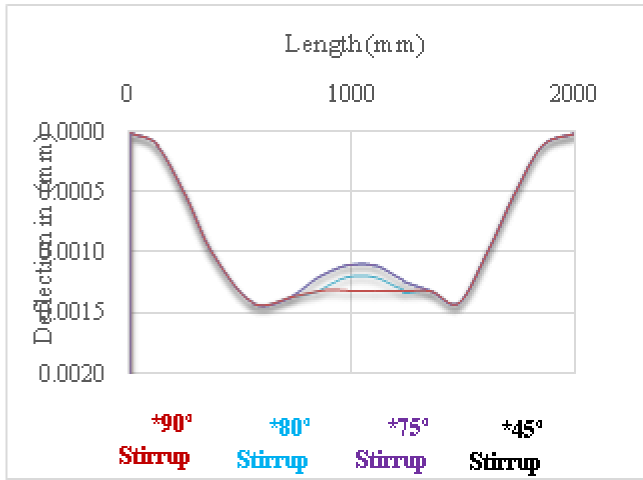


Fig. 3: Span Vs Central Deflection in "mm"

Therefore, all the specimens are safe under deflection.

4.3 Stiffness

The torsional stiffness of the torsional beam is calculated based on the torsional equation. From Fig. 4. Show the comparative torsional stiffness between different configuration of stirrups for the ultimate torque. When compared conventional type stirrup specimen (B1), specimen (B3) i.e., 75º inclined stirrups has 81% more stiffness.

4.4 Torque Vs Angle of Twist

The reinforcement arrangement of beams is in such a way that their failure is of torsional. After modeling and non-linear static analysis of samples, the accuracy of numerical model was confirmed based on the twist-twisting angle diagram and mode of torsional failure. The diagrams shown below under the Torque vs Twisting angle curve of mentioned beams in finite element method and with the help of ABAQUS software have been drawn. Many theories are proposed to find the torsional strength of RC rectangular beam here following methods are used for comparison of analytical torsion with theorical calculations

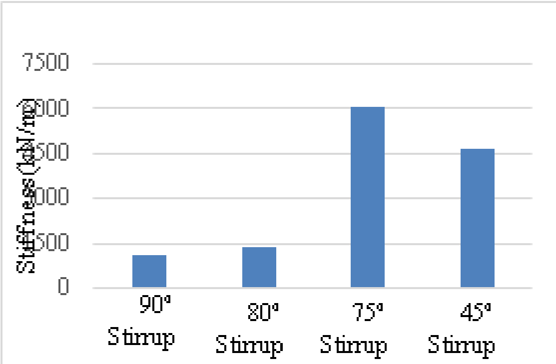


Fig 4. Comparative Stiffness between different configuration of stirrups

Based on ACI 318-99
Based on J.G Macgregor and M.G Ghonelm

In this present study the above two methods results are compared with analytical results. Based on analytical torque theoretical angle of twist was calculated. The ABAQUS FEM gives direct torque and angle twist. So, the applied torque is taken it depends on the iteration and amount to load applied on the beam. Based on that theoretical angle of twist is calculated.

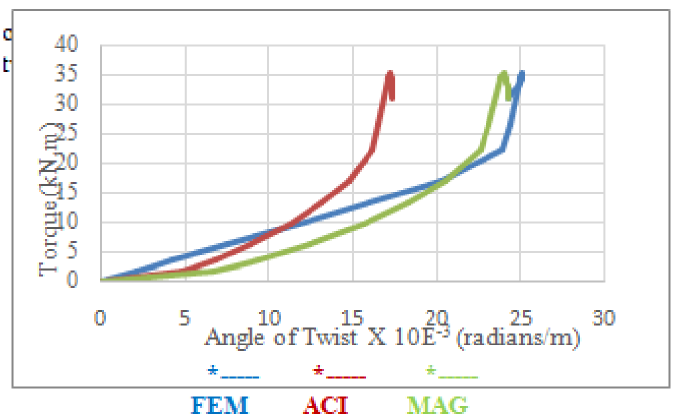


Fig 5. Comparative Results of Conventional 90⁰ stirrups

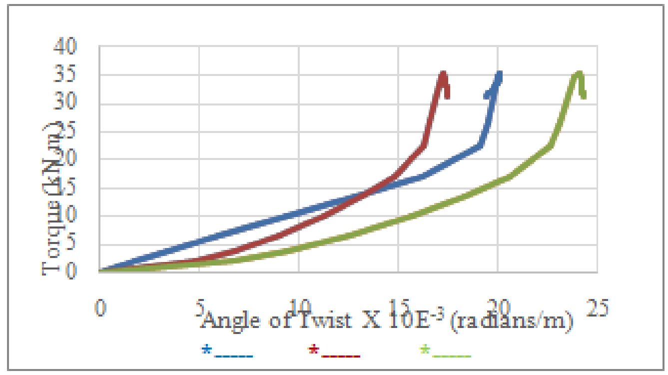


Fig 6. Comparative Results of inclined80⁰ stirrups

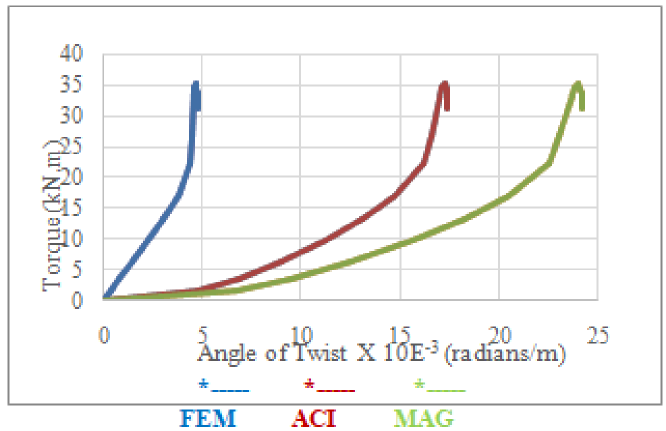


Fig 7. Comparative Results of inclined75⁰ stirrups

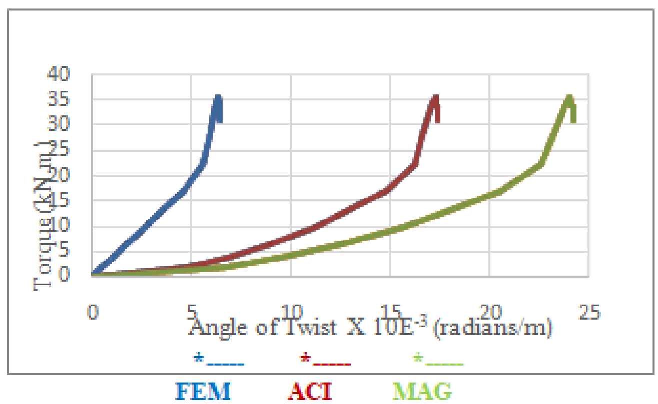


Fig 8. Comparative Results of inclined45⁰ stirrups

The above figures 5, 6, 7 & 8 are the graphical representation of comparative results of ABAQUS FEA, ACI and MacGregor method, the results obtained in ACI and Macgregor method are similar for all four specimens because of constant theoretical stiffness and applied torque. when compared to other specimens (B3) 75⁰ inclined stirrups performed well against the torsional force i.e., it has minimum angle of twist of 4.4 x 10-3 radians/m for the maximum applied torque of 26.70 kN.m. other specimens (B1, B2, & B4) carries the angle of twist of (24.3, 19.4, & 5.8) x 10-3 radians/m. Comparatively specimen (B3) resists nearly 81% of angle of twist for the applied torque when compared to specimen which has conventional type 90º stirrups (B1). As we know that if stiffness increases the angle of twist will reduces.

V. CONCLUSION

The main aim of the study is tounderstand the behavior of Torsion, Twist, and Deflection under varying inclined angles of stirrups. Based on the analytical study using ABAQUS FEA and theoretical calculation the following conclusions are arrived. So Finite Element Modelling technique can be used to better understand of Torsion Failure mechanism.

1. The element (B3 & B4) having inclined stirrups has very less deflection (0.0011 mm) than the allowable deflection (6.6 mm).
2. The element (B3) which has 75º inclined stirrups has minimum angle of twist of 4.4 x 10^{-3} radians /mother specimens (B1, B2, & B4) carries the angle of twist of (24.3, 19.4, & 5.8) x 10^{-3} radians/m. Comparatively specimen (B3) resists nearly 81% of angle of twist for the applied torque when compared to specimen which has conventional type 90º stirrups (B1).
3. The element (B3) which has 75º inclined stirrups has maximum stiffness of 6068.18 kN/m. other specimens (B1, B2, & B4) has the stiffness of (1098.76, 1376.28, 4684.21) x kN/m. Comparatively specimen (B3) resists nearly 81% of angle of twist for the applied torque when compared to specimen which has conventional type 90º stirrups (B1).

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