STATIC PERFORMANCE OF STEEL STRENGTHENED AND CONCRETE IN-FILLED CASTELLATED BEAM

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Abstract – Castellated beams are used where the stiffness of the steel need to be increased without increasing the weight of the steel required. This paper examines the static performance of steel strengthened and concrete in filled castellated beam. Firstly the performance of effect of various shapes in double webbed I section using two point loading test. Secondly the web and hole section is strengthened using diaphragms. Then the performance of concrete in filled castellated beam is analyzed by flexural testing to find out the deflection, stiffness, ductility, strength over conventional I beams .Result showed that steel strengthened and concrete in-filled castellated beam have better performance than other beams.

Key Words: Concrete in-filled concrete, Diaphragms, Finite element analysis, ANSYS, Doubly webbed castellated I beam

1. INTRODUCTION

Castellated beams are beams with increased depth of section and regular openings in web. A single rolled I section undergoes flame cutting in a definite pattern and then rejoining the segments after offsetting one portion to form a section openings in its web. These beam also have increase in vertical bending stiffness, high strength to weight ratio, lower maintenance and painting cost. These type of beams are well suited for power plants, industrial buildings and multi store buildings.

In castellated beam stress concentration occur near perforation and at load application points. Most of the failure of castellated beam is due to buckling. There are studies concentrating on effect of different shapes on castellated beams. Only a limited number of studies evaluate method to reduce the buckling in which buckling could be avoided using steel encasement method, where steel in encased partially or fully within the concrete. Most of the studies were focused on singly webbed I section where the concrete may break away easily as steel is encased in concrete.In doubly webbed I section, concrete infill method can be used where the concrete is in-filled with steel.

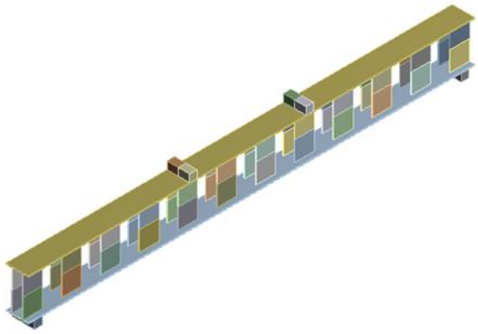
Steel–concrete composite section is a new idea, for beams comprising hollow steel elements with an infill of concrete. The concrete used for in-filled method is of grade M25 RCC. Concrete filled hollow steel sections for beams will allow easy casting of in-fill concrete. These sections do not require temporary formwork to infill concrete as the steel acts as formwork in the construction stage and as reinforcement in the service stage. They are simple to fabricate and construct compared to conventional reinforced concrete, where skilled workers are needed to cut and bend complex forms of reinforcement. . Doubly webbed I section are made as built up sections. Two plates are cut and placed above each other and to which flanges are welded.

In this study, static performance of steel strengthened and concrete in filled castellated beam is done. The investigation is conducted using the FEM software ANSYS 16.1.

2. STRUCTURAL MODELLING AND ANALYSIS

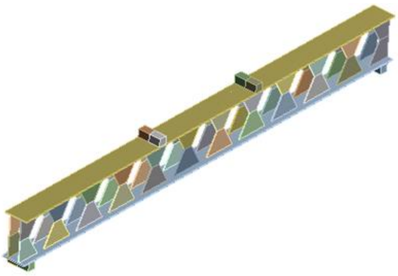
2.1Doubly webbed castellated I beam

Using ANSYS 16.1 software a non- linear static analysis is done on the beams. Full height castellated beam were developed with three different shapes. The length of beam is 2860mm.The height of the section from which castellation is made is 150mm ,width of flange is 75mm,flange thickness is 7mm,web thickness 5mm and yield strength 278MPa.Height of rectangular hole is 264mm and breadth is 130mm.Yield stress is 278 Pa. Young's modulus is 200 MPa. Poisson's ratio is 0.3.Two point loading was used for analysis with hinged support at one end and roller at other end. Hexagonal and elliptical shapes are also considered with same geometry and material property as of rectangular castellated beam for analysis. Height of the beam remain same and breadth varies for the different shapes.



a) Doubly webbed rectangular castellated I beam

b) Doubly webbed elliptical castellated I beam

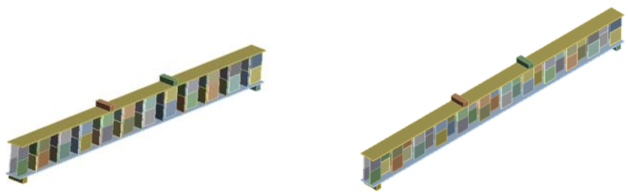


c) Doubly webbed hexagonal castellated I beam

Fig.1Model of doubly webbed castellated I beam

2.2 Strengthening of beams using Diaphragms

The flange and hole of castellated beam is strengthened using diaphragms which are placed perpendicular and parallel to the web for analysis.

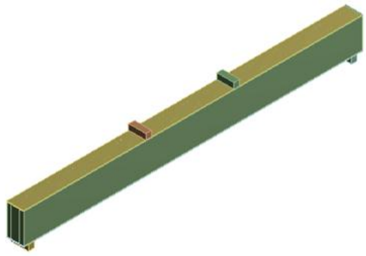


a) b)

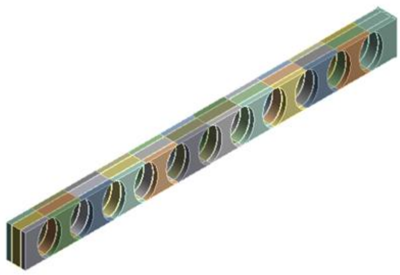
Fig.2 Model of steel strengthened castellated beam by diaphragm placed a)perpendicular b)parallel

2.3 Concrete in-filled castellated beam

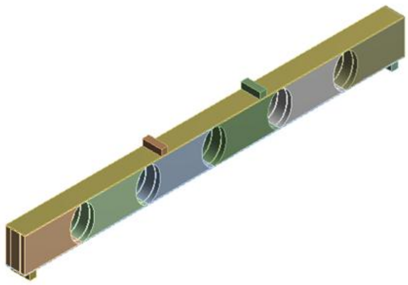
Concrete in-filled castellated beams were made using M25 grade RCC without holes, with holes and with alternate holes and are analyzed.



a) Concrete filled castellated beam without holes



b) Concrete filled castellated beam with holes

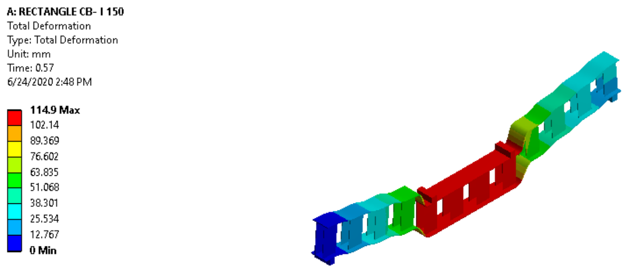


c) Concrete filled castellated beam with alternate holes

Fig.3. Model of various concrete in- filled beam

3. ANALYTICAL RESULTS AND DISCUSSIONS

Total deformation of beams are shown below:

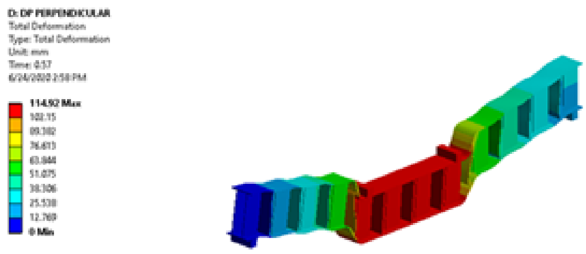


a) Rectangular castellated beam

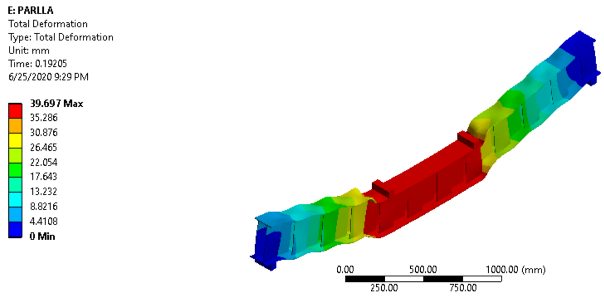
b) Elliptical castellated beam

c) Hexagonal castellated beam

Fig.4 Total deformation of doubly webbed castellated beams

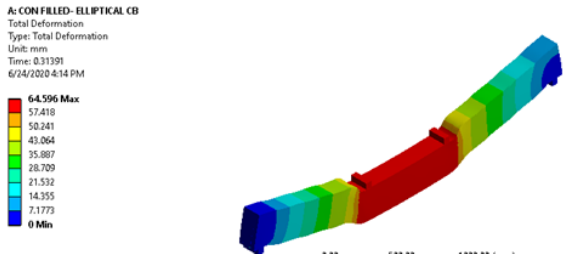


a)diaphragm placed perpendicular to web

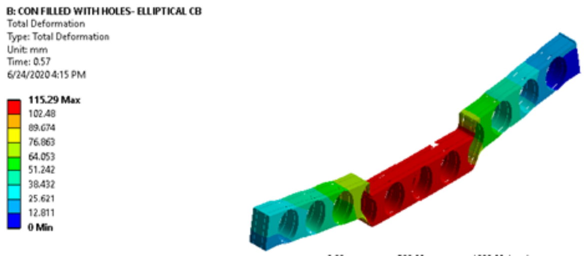


b) Diaphragm placed parallel to web

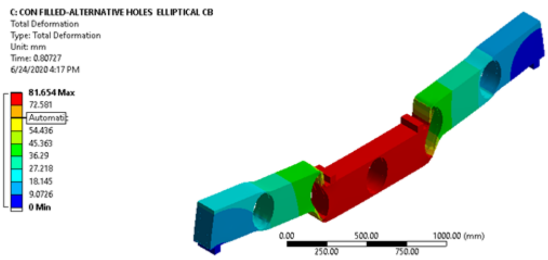
Fig.5 Total deformation of diaphragms placed in different ways



a)Concrete in-filled beam without holes



b)Concrete in-filled beam with holes



c) Concrete in-filled beam with alternative holes

Fig. 6 Total deformation of various concrete in-filled beam

TABLE1.Comparison of ultimate load for beams without stiffeners, with stiffeners and with concrete in-filled form.

Model	*Shape of hole*	*Ultimate load (kN)*
Doubly webbed I beam	Elliptical	74.266
	Hexagonal	71.99
	Rectangle	46.132
Steel strengthened beam by diaphragm placed perpendicular	Elliptical	54.108
Steel strengthened beam by diaphragm placed parallel	Elliptical	132.9
Concrete in-filled castellated beam without holes	Elliptical	200.38
Concrete in-filled castellated beam with holes	Elliptical	81.397
Concrete in-filled castellated beam with alternate holes	Elliptical	107.52

The interpretation of the analytical results of beam failures their strengthening method and concrete in-filled are done. Their behavior throughout analysis is studied from the recorded data obtained using ANSYS. Result showed both the strengthening method and concrete in-filled method improves the ultimate load carrying capacity of castellated beam.

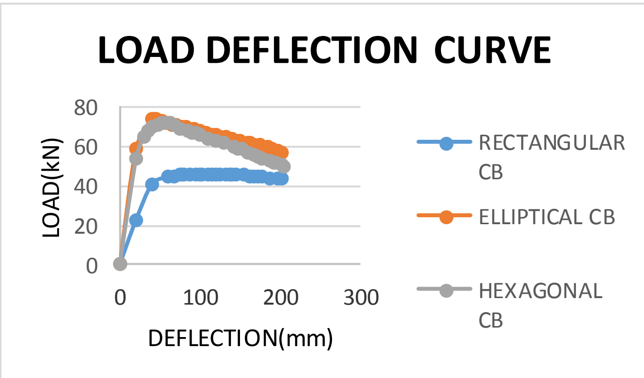


Fig .7 Load Deflection curve comparing three types of opening in doubly webbed castellated beam

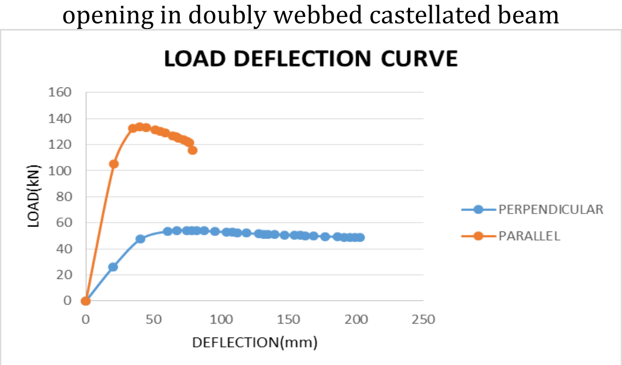


Fig .8 Load Deflection curve of diaphragms

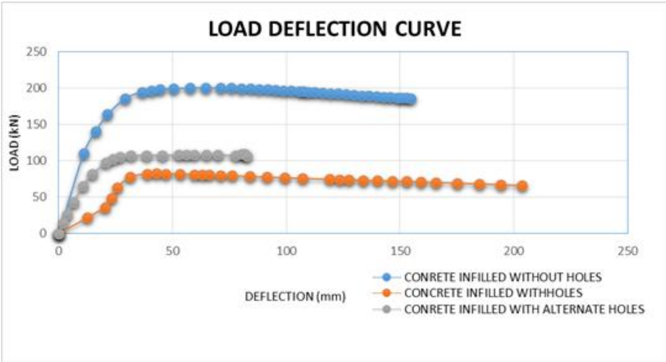


Fig. 9 Load Deflection curve of concrete in-filled beam

TABLE 2.Comparison of deflection, ultimate load, yield displacement and ductility in various shapes of doubly webbed castellated beam

Shape of hole in Castellated beam	*Deflection(mm)*	*Load(kN)*	*Yield disp(mm)*	*Ductility*
Rectangular	104.14	46.132	20.211	5.153
Elliptical	40.793	74.266	20.626	2
Hexagonal	56.254	71.99	20.569	2.7

TABLE 3. Comparison of deflection, ultimate load, yield displacement and ductility in strengthening

Diaphragms placed	*Deflection(mm)*	*Load(kN)*	*Yield disp(mm)*	*Ductility*
Perpendicular	82	54.108	20.2	4.04
Parallel	44.45	132.9	21	2.1

TABLE 4. Comparison of deflection, ultimate load, yield displacement and ductility in concrete in-filled beam

Concrete infilled castellated beam	*Deflection(mm)*	*Load(kN)*	*Yield disp(mm)*	*Ductility*
Without holes	76	200.4	11.6	6.94
With holes	59.5	81.4	12	4.71
With alternate holes	77.8	107.52	1.8	41.7

4. CONCLUSIONS

From the study the followings things can be concluded:-

1) This paper examines the performance of doubly webbed castellated beam with 3 different type of web opening out of which elliptical shape of web opening is suitable for castellation's.

2) Strengthening techniques and concrete in-filled method increases the overall load carrying capacity of castellated beam.

3) Concrete in-filled castellated beam without holes have better performance than beams with holes.

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