Study And Comparison of Structural Behaviour of Double Web Castellated Beam Using Time History Analysis

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Abstract*- This paper consist of an experimental and analytical study on structural behaviour of double web castellated beam with different openings. An experimental study was performed on a prototype model of steel beams with web openings. There are some Different specimens of hot rolled steel sections having different web opening such as circular hexagonal for ISMB 250 and were tested and analysis for failure mode and ultimate strength of double web castellated beams with web openings. The beams were simply supported at the ends and subjected to a concentrated load applied at the mid span. After performing experimental study, all the beams were analyzed by the elasto–plastic finite element method by using general finite element analysis software ANSYS and the results were compared with those obtained. The test results indicate that the load-carrying capacity decreases with the increase in the openings area as well as position of the openings. The finite element outcome for deformation and ultimate strength shows good agreement with the corresponding values observed in the experiments. The parametric study was carried out by using finite element method to study the capacity of double web castellated beams with web openings. The result of parametric study shows that, web openings reduce the beam ductility till 68%*

Keywords*-* Steel Beam With Web Openings (SBWO), Experimental Study, Beam Ductility, ANSYS, Finite Element Method.

I. INTRODUCTION

Now a day high-rise buildings of steel structure are of huge attention due to their many advantages, such as, ductility, fast construction etc. Since the construction cost of high-rise building steel structures is generally more than that of a concrete one, decrease of the construction cost of high-rise steel structures is of great importance for designers as well as builders. Many attempts have been made by engineers to decrease the cost of steel in buildings.

Sections having webs penetrated by large closely spaced openings over almost the full span are now common. Utilization of steel as auxiliary part in structure is quickly picking up intrigue now a days. In steel structures, the concept of pre-engineered building (PEB) is most popular because of ease and simplicity in construction. Such pre-design structures have vast traverses yet similarly subjected to less stacking. So by and large, steel areas are sheltered in quality necessity, be that as it may, segments don't fulfill functionality prerequisites. So it ends up basic to utilize bars with more profundities in order to fulfill this prerequisite. Utilization of punctured web or open web pillars is the best arrangement keeping in mind the end goal to conquer this trouble

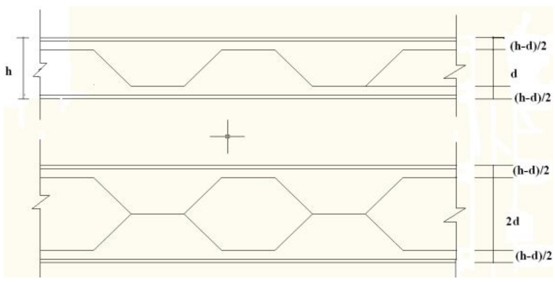


Figure 1. Mathematical Formation of Castellated Beam

The conduct of steel minute opposing casings (MR) is enormously influenced by the properties of the pillar to-section associations, particularly in seismic zones. According to experimental tests, there were 8 possible failure modes in steel beams with web openings (Kerdal and Nethercot, 1984; Mohebkhah, 2004; Zirakian and Showkati, 2006).These failure modes are caused by bar geometry, web slimness, sort of stacking Under connected load conditions, disappointment is probably going to happen due to the accompanying modes

1. Formation of a Vierendeel mechanism;
2. Lateral torsional buckling of the entire span;
3. Lateral torsional buckling of the web post;
4. Rupture of the welded joint

Thinking about the high utilization of steel pillars with web openings, especially in tall structures, investigation of their conduct is basic. Many investigations have been conducted regarding the behavior of these beams..1.2 Using finite element analysis software ANSYS. When compared with a solid web solution where services are provided beneath beam, the use of castellated beams could lead to savings in the cladding costs. Moreover, because of its lightweight the castellated beam is more convenient in transportation and installation than the normal I-beam. The web openings in the castellated beam, however, may reduce the shear resistance of the beam.

The essential favorable position of double web castellated beams is the enhanced quality because of the expanded profundity of the segment with no extra weight as contrast with single web beam. Anyway one outcome of the expanded profundity of the segment is the improvement of strength issues amid erection. Static testing of the bars, including disappointment tests, has been directed keeping in mind the end goal to decide such pillar properties as twisting modulus, shear firmness, disappointment mode, and extreme limit.

Figure 2.Double Web Beam With Stiffeners

A. Terminology

Throughout this study various terms will be used to discuss about double web castellated beam components and testing results. This section introduces the reader to the definition of these terms and Figure illustrates the terms

- Web Post: The cross-section of the castellated beam where the sections assumed to be a solid cross-section.
- Castellation: The area of the castellated beam where the web has been expanded (hole).

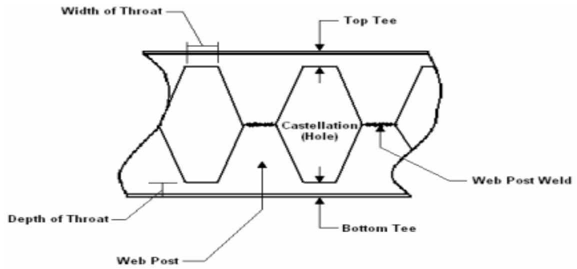


Figure 3.Components of a Castellated Beam

II. OBJECTIVE OF STUDY

- To Study Structural Behaviour of Double web Castellated Beam under Various Loading
- To study the behaviour of double web castellated beam under the influence of flexure load.
- To check influence of duct/voids on the structural response of double web castellated beam under flexure loading.
- To check effectiveness of vertical & horizontal stiffeners to improve the performance of double web castellated beam under nonlinear loading

III. METHODOLOGY

A. Material modelling

Other relevant data for RCC building like total height of The definition of the proposed numerical model was made by using finite elements available in the ANSYS code default library. SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behavior. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions.

This SOLID186 3-D 20-node homogenous/layered structural solid were adopted to discretize the concrete slab, which are also able to simulate cracking behavior of the concrete under tension (in three orthogonal directions) and crushing in compression, include bending stresses as shown in fig 2.5. CONTA174 is used to represent contact and sliding between 3-D "target" surfaces (TARGE170) and a deformable surface, defined by this element. The element is applicable to 3-D structural and coupled field contact analyses.

The geometrical representation of CONTA174 is shown Contact pairs couple general ax symmetric elements with standard 3-D elements. A node-to-surface contact element represents contact between two surfaces by specifying one surface as a group of nodes. The geometrical representation of is show in TARGET 170

The TARGET 170 and C0NTA 174 elements were used to represent the contact slab-beam interface. These elements are able to simulate the existence of pressure between them when there is contact, and separation between them when there is not. The two material contacts also take into account friction and cohesion between the parties.

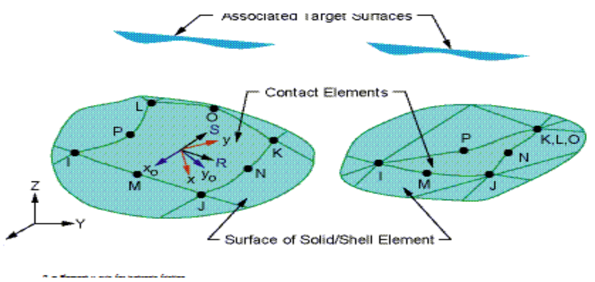


Figure 4. CONTA 174

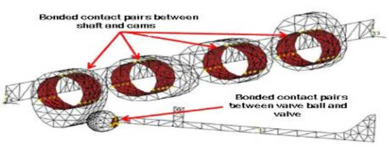


Figure 5.TARGET 170

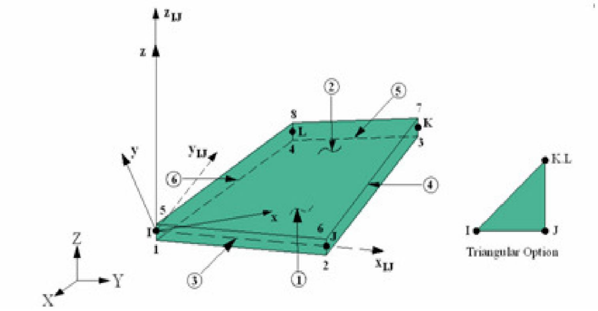


Figure 6.SHELL 43

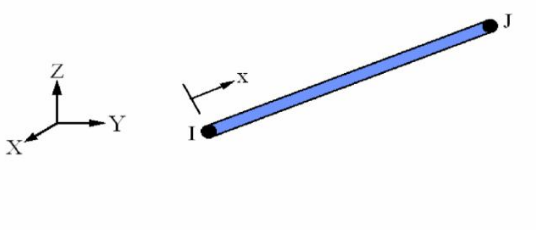
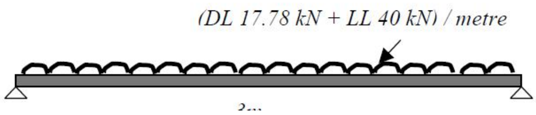


Figure 7.BEAM 189

B. Problem statement

Design a single web castellated beam without any opening Design a suitable 'I' beam for a simply supported span of 3 m and carrying a dead or permanent load of 17.78 kN/m and an imposed load of 40 kN/m. Assume full lateral restraint and stiff support bearing of 100 mm.



Design load calculation:

in this example the following load factors are chosen.
LDγ and LLγ
are taken as 1.50 and 1.50 respectively.
γ_{LD}– partial safety factor for dead or permanent loads
γ_{LL}– partial safety factor for live or imposed loads Total factored load = 1.50× 17.78 + 1.50 × 40.0 = 86.67 kN / m
Factored bending moment = 86.67 × 1.8^2 /8 = 97.504 kN – m
Z—value required for f_y=250 MPa ;γ_m=1.10
Z_{reqd}= 429.02 cm^3
Try ISMB 250
D = 250 mm B = 125 mm t = 6.9 mm T = 12.5 mm
I_{zz}= 5131.6 cm^4 I_{yy}= 334.5 cm^4
Section classification:
Flange criterion = B/2T = 5.0 Web criterion = (D – 2T)/t = 32.61 Since B/2T <9.4 ε & (D-2T)/t < 83.9 ε
The section is classified as ' PLASTIC
Moment of resistance of the cross section:
Since the section considered is 'PLASTIC'
M_d= mypfZγ×
Where $Z_p$is the plastic modulus
'Z_p' for ISMB 250 = 459.76 cm^3 M_d= 459.76 × 1000 × 250 /1.10 = 104.49 kN-m > 97.504 kN-m
Hence ISMB-250 is adequate in flexure.
Shear resistance of the cross section:
This check needs to be considered more importantly in beams where the maximum bending moment and maximum shear force may occur at the same section simultaneously,

Shear capacity $$V_c = \frac{0.6 f_y A_v}{\gamma_m}$$

A_v =250 × 6.9 = 1725 mm^2
V_c= 0.6 × 250 × 1725 /1.10 =235.3kN
V = factored max shear = 86.67 × 3 / 2 =130.0 kN
V /V_c=130/235.3 = 0.55 < 0.6
Hence the effect of shear need not be considered in the moment capacity calculation.

Check for Web Buckling:

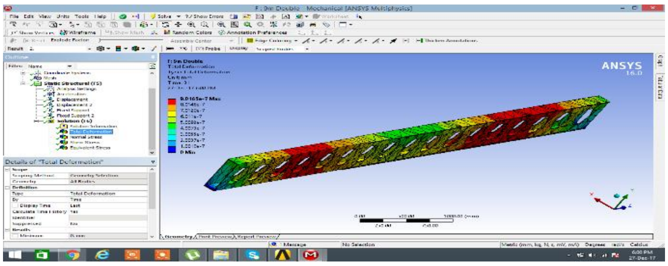
The slenderness ratio of the web = L_E/r_y= 2.5 d/t =2.5 × 194.1/6.9 =70.33
The corresponding design compressive stress f_c is found to be f_c= 203 MPa (Design stress for web as fixed ended column)
Stiff bearing length = 100 mm 45^0dispersion length n_1 = 125.0 mm
P_w = (100 + 125.0) × 6.9 × 203.0 = 315.16 kN
315.16 > 126 Hence web is safe against shear buckling
using code IS 1893-2002.The plinth beam designed for RCC frame is provided in PEB frame too.
Check for web crippling at support
Root radius of ISMB 250 = 13 mm
Thickness of flange + root radius = 25.5 mm
Dispersion length (1:2.5) n_2 = 2.5 x 25.5 = 63.75 mm
P_{crip}= (100+63.75) × 6.9 × 250 / 1.15 = 245.63 kN> 126kN
Hence ISMB 250 has adequate web crippling resistance
Check for serviceability – Deflection:
design load = 57.78 kN/m. =5.3mm< L/200

IV. RESULTS AND DISCUSSIONS

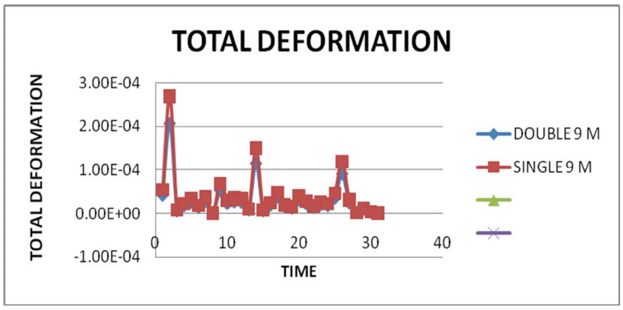
The following models are proposed for time history analysis of castellated beam

MODEL NO.1	ISMB 250 SINGLE WEB 6M SPAN
MODEL NO.2	ISMB 250 DOUBLE WEB 6M SPAN
MODEL NO.3	ISMB 250 SINGLE WEB 9M SPAN
MODEL NO.4	ISMB 250 DOUBLE WEB 9M SPAN
MODEL NO.5	ISMB 250 SINGLE WEB 12M SPAN
MODEL NO.6	ISMB 250 DOUBLE WEB 12M SPAN
MODEL NO.7	ISMB 250 SINGLE WEB 16M SPAN
MODEL NO.8	ISMB 250 DOUBLE WEB16M SPAN

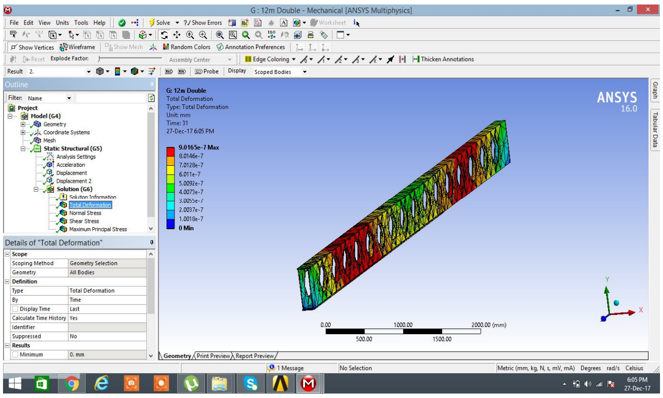
Total Deformation**:**



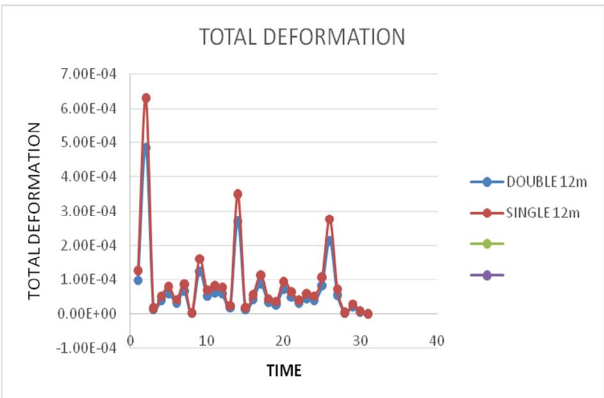
N	TOTAL DEFORMATIONORMAL STRES	
TIME	DOUBLE 9 m	SINGLE 9m
1	4.20E-05	5.46E-05
2	2.08E-04	2.70E-04
3	5.86E-06	7.61E-06
4	1.73E-05	2.25E-05
5	2.64E-05	3.43E-05
6	1.38E-05	1.80E-05
7	2.87E-05	3.73E-05
8	1.06E-06	1.37E-06
9	5.30E-05	6.89E-05
10	2.30E-05	2.99E-05
11	2.71E-05	3.52E-05
12	2.57E-05	3.34E-05
13	7.98E-06	1.04E-05
14	1.16E-04	1.50E-04
15	5.93E-06	7.71E-06
16	1.85E-05	2.40E-05
17	3.76E-05	4.89E-05
18	1.48E-05	1.93E-05
19	1.20E-05	1.56E-05
20	3.14E-05	4.08E-05
21	2.15E-05	2.79E-05
22	1.34E-05	1.74E-05
23	1.96E-05	2.54E-05
24	1.73E-05	2.25E-05
25	3.57E-05	4.64E-05
26	9.15E-05	1.19E-04
27	2.39E-05	3.11E-05
28	1.34E-06	1.75E-06
29	9.38E-06	1.22E-05
30	2.80E-06	3.63E-06
31	3.87E-07	5.04E-07



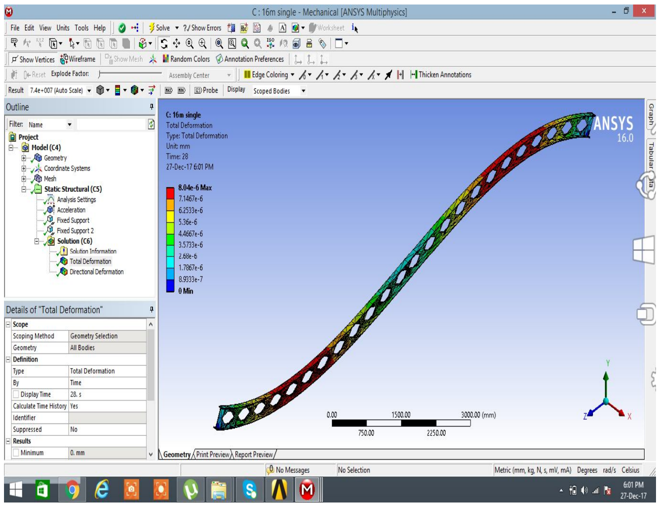
Graph no 1 Total deformation v/s time is compared for 9m span and it is observed that double flange Total deformation reduce by 10%



N	TOTAL DEFORMATIONORMAL	
TIME	DOUBLE 12m	SINGLE 12m
1	9.77E-05	1.27E-04
2	4.84E-04	6.29E-04
3	1.36E-05	1.77E-05
4	4.03E-05	5.24E-05
5	6.14E-05	7.98E-05
6	3.22E-05	4.18E-05
7	6.68E-05	8.68E-05
8	2.46E-06	3.19E-06
9	1.23E-04	1.60E-04
10	5.35E-05	6.95E-05
11	6.30E-05	8.19E-05
12	5.97E-05	7.76E-05
13	1.86E-05	2.42E-05
14	2.69E-04	3.50E-04
15	1.38E-05	1.80E-05
16	4.29E-05	5.58E-05
17	8.75E-05	1.14E-04
18	3.45E-05	4.49E-05
19	2.79E-05	3.62E-05
20	7.31E-05	9.50E-05
21	4.99E-05	6.49E-05
22	3.12E-05	4.06E-05
23	4.55E-05	5.92E-05
24	4.03E-05	5.24E-05
25	8.30E-05	1.08E-04
26	2.13E-04	2.77E-04
27	5.57E-05	7.24E-05
28	3.13E-06	4.07E-06
29	2.18E-05	2.84E-05
30	6.51E-06	8.46E-06
31	9.02E-07	1.17E-06

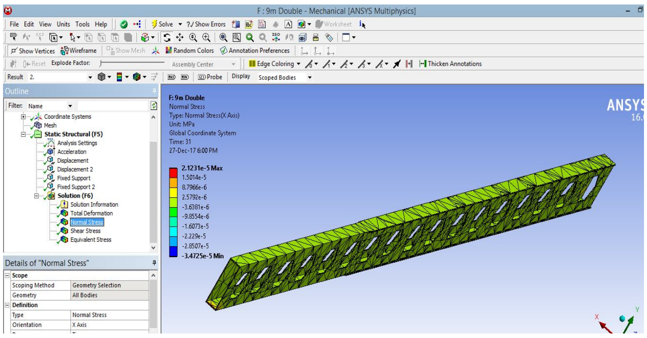


Graph no 2 Total Deformation v/s time is compared for 12m span and it is observed that double Total Deformation reduce by 10%

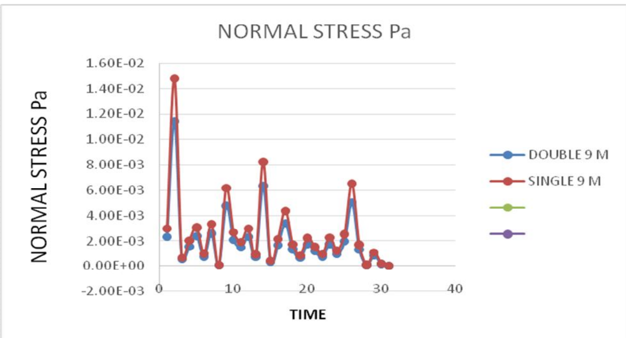


TOTAL DEFORMATION t		
TIME	DOUBLE 16m	SINGLE 16m
1	3.73E-04	4.85E-04
2	1.85E-03	2.40E-03
3	5.21E-05	6.77E-05
4	1.54E-04	2.00E-04
5	2.35E-04	3.05E-04
6	1.23E-04	1.60E-04
7	2.55E-04	3.32E-04
8	9.39E-06	1.22E-05
9	4.72E-04	6.13E-04
10	2.04E-04	2.66E-04
11	2.41E-04	3.13E-04
12	2.28E-04	2.97E-04
13	7.10E-05	9.23E-05
14	1.03E-03	1.34E-03
15	5.28E-05	6.86E-05
16	1.64E-04	2.13E-04
17	3.34E-04	4.35E-04
18	1.32E-04	1.72E-04
19	1.06E-04	1.38E-04
20	2.79E-04	3.63E-04
21	1.91E-04	2.48E-04
22	1.19E-04	1.55E-04
23	1.74E-04	2.26E-04
24	1.54E-04	2.00E-04
25	3.17E-04	4.13E-04
26	8.14E-04	1.06E-03
27	2.13E-04	2.77E-04
28	1.20E-05	1.55E-05
29	8.34E-05	1.08E-04
30	2.49E-05	3.23E-05
31	3.45E-06	4.48E-06

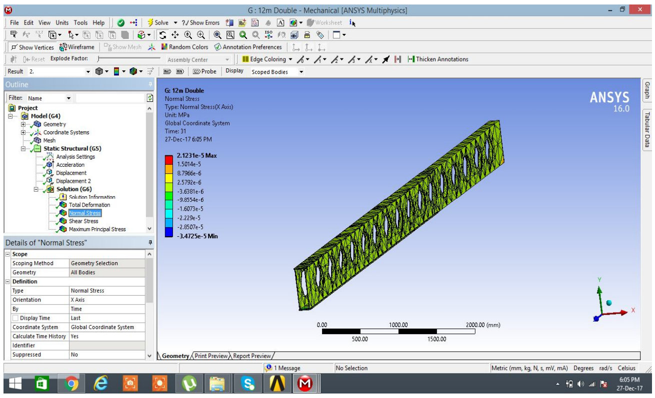
NORMAL STRESS:

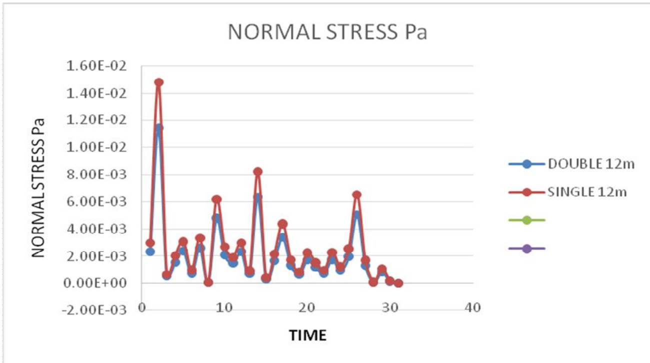


N	NORMAL STRESSORMAL STRES	
TIME	DOUBLE 9 M	SINGLE 9 M
1	2.30E-03	2.99E-03
2	1.14E-02	1.48E-02
3	5.25E-04	6.82E-04
4	1.55E-03	2.02E-03
5	2.36E-03	3.07E-03
6	7.57E-04	9.84E-04
7	2.57E-03	3.34E-03
8	5.79E-05	7.52E-05
9	4.75E-03	6.18E-03
10	2.06E-03	2.68E-03
11	1.48E-03	1.93E-03
12	2.30E-03	2.99E-03
13	7.16E-04	9.30E-04
14	6.34E-03	8.24E-03
15	3.25E-04	4.23E-04
16	1.65E-03	2.15E-03
17	3.37E-03	4.38E-03
18	1.33E-03	1.73E-03
19	6.56E-04	8.53E-04
20	1.72E-03	2.24E-03
21	1.18E-03	1.53E-03
22	7.35E-04	9.55E-04
23	1.75E-03	2.28E-03
24	9.50E-04	1.23E-03
25	1.95E-03	2.54E-03
26	5.02E-03	6.52E-03
27	1.31E-03	1.71E-03
28	7.37E-05	9.58E-05
29	8.40E-04	1.09E-03
30	1.53E-04	1.99E-04
31	2.12E-05	2.76E-05

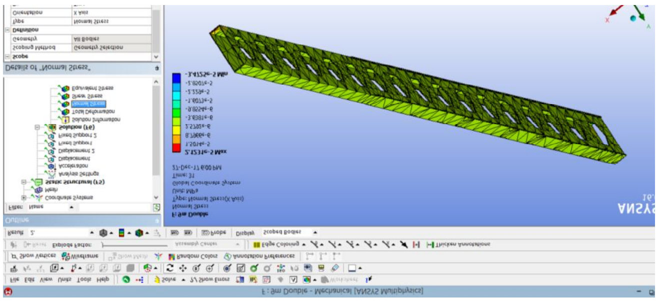


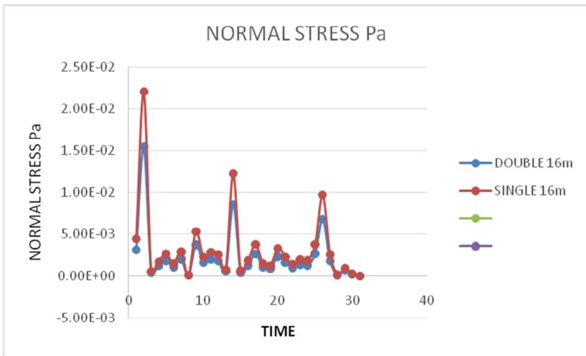
Graph no 3 Normal stress v/s time is compared for 9m span and it is observed that double flange Normal stress reduce by 10%





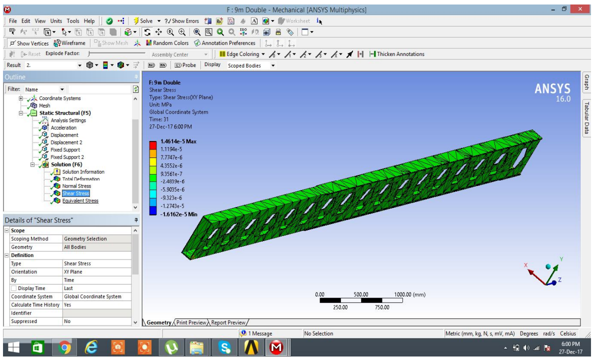
Graph no 4 Normal Stress v/s time is compared for 12m span and it is observed that double Normal Stress reduce by15%



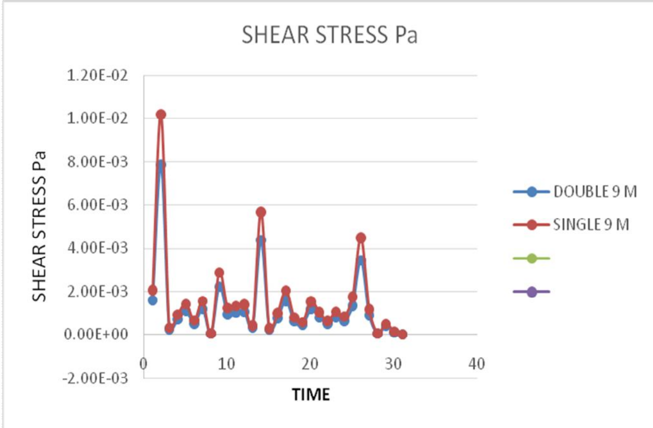


Graph no 5 Normal Stress v/s time is compared for 16m span and it is observed that double Normal Stress reduce by15%

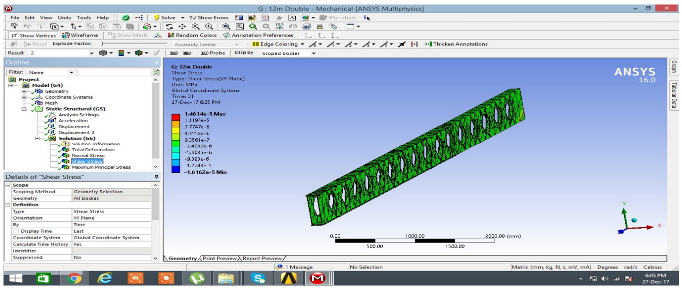
SHEAR STRESS

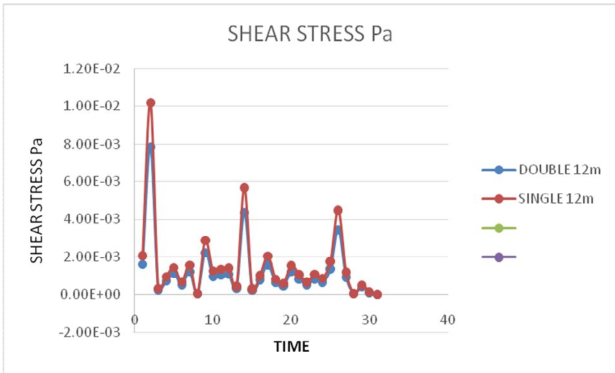


SH	SHEAR STRESSA STRESS Pa	
TIME	DOUBLE 9 M	SINGLE 9 M
1	1.58E-03	2.06E-03
2	7.84E-03	1.02E-02
3	2.44E-04	3.18E-04
4	7.23E-04	9.39E-04
5	1.10E-03	1.43E-03
6	5.21E-04	6.78E-04
7	1.20E-03	1.56E-03
8	3.98E-03	5.18E-03
9	2.21E-03	2.88E-03
10	9.58E-04	1.25E-03
11	1.02E-03	1.33E-03
12	1.07E-03	1.39E-03
13	3.33E-04	4.33E-04
14	4.36E-03	5.67E-03
15	2.24E-04	2.91E-04
16	7.70E-04	1.00E-03
17	1.57E-03	2.04E-03
18	6.19E-04	8.05E-04
19	4.52E-04	5.87E-04
20	1.18E-03	1.54E-03
21	8.09E-04	1.05E-03
22	5.06E-04	6.57E-04
23	8.16E-04	1.06E-03
24	6.54E-04	8.50E-04
25	1.35E-03	1.75E-03
26	3.45E-03	4.49E-03
27	9.03E-04	1.17E-03
28	5.07E-05	6.59E-05
29	3.91E-04	5.08E-04
30	1.05E-04	1.37E-04
31	1.46E-05	1.90E-05

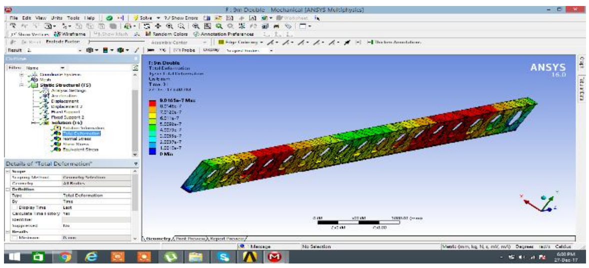


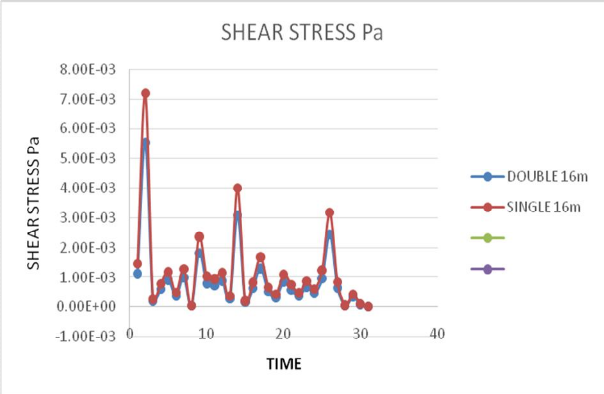
Graph no 6 Shear Stress v/s time is compared for 9 m span and it is observed that double Normal Stress reduce by15%





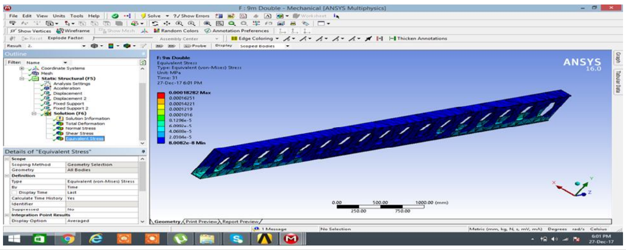
Graph no 7 Shear Stress v/s time is compared for 12m span and it is observed that double Shear Stress reduce by15%

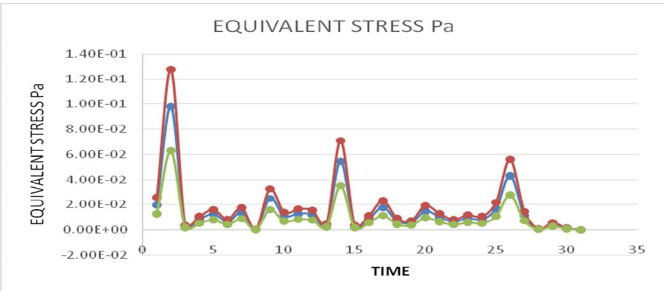




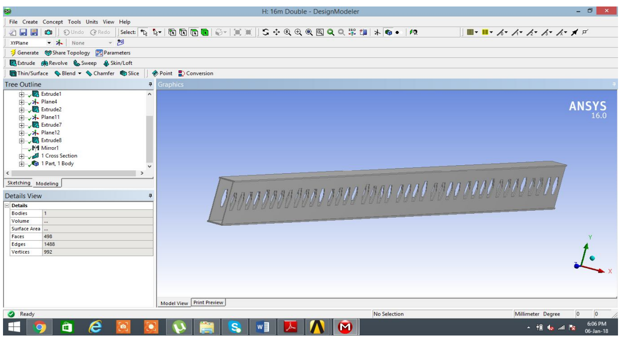
Graph no 8 Shear Stress v/s time is compared for 16m span and it is observed that double shear Stress reduce by 15%

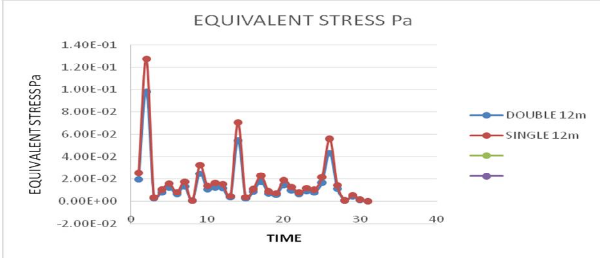
Equivalent stress**:**



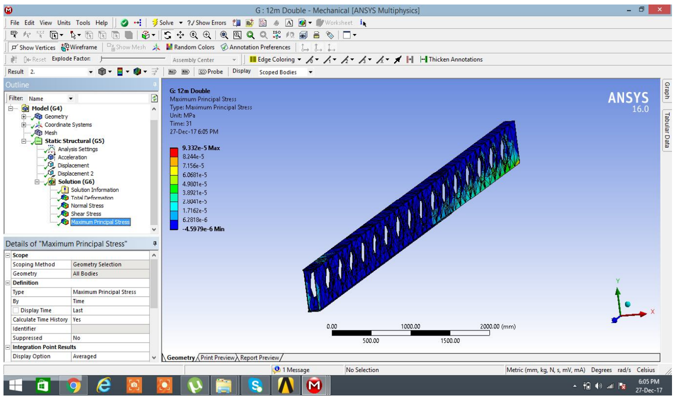


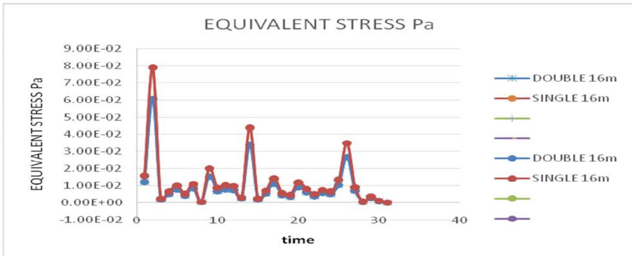
Graph no 9 Equivalent stress v/s time is compared for 9 m span and it is observed that double flange equivalent stress reduce by 15%





Graph no 10 Equivalent Stress v/s time is compared for 12m span and it is observed that double Equivalent stress reduce by 10%





Graph no 11 Equivalent Stress v/s time is compared for 16m span and it is observed that double Equivalent stress reduce by 15%

V. CONCLUSIONS

In this Paper single web and double web castellated beam are analyses for specified ground motion. The beam spans are selected as 6m, 9m, 12m, 16, respectively and for time history analysis the El Centro data is used after analysis by using ANSYS following conclusion are made

- The total deformation In double web castellated beam is observed 15 to 20 % less as compared to single web castellated beam
- Equivalent Stress In double web castellated beam is observed 5 to 10 % less as compared to single web castellated beam

- Shear Stress In double web castellated beam is observed 10 to 15 % less as compared to single web castellated beam
- For static result manual analysis done and both beam are observed safe in static analysis but it is observed that in time history analysis double web castellated beam is more suitable then single web castellated beam for larger span

Hence it is recommended that for larger span double web castellated beam should be used.

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