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# Analytical Study of Effect on Reinforcement on Strength of Web Opening In Steel-Concrete Composite Beam

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***Abstract:*** Steel I-beams combined to concrete slabs make up composite beams, which are frequently used in construction worldwide. For ducts and pipes to pass through, the steel web of the composite beam is frequently perforated, saving space underneath the beam and maintaining clear spaces in buildings. The composite beam's load-bearing capacity and flexural performance, however, can be compromised as a result. Only a little amount of research has been done on the flexural behaviour of composite beams having reinforced web holes. The purpose of this study was to determine the effect of the kind and cross-sectional area of stiffeners on the flexural performance of full-scale composite beams with reinforced web apertures. A similar composite beam was created without the web opening for comparison's sake, and a composite beam with the web opening was built without reinforcement. The web holes strengthened with longitudinal stiffeners significantly increased the ultimate bearing capacity of the composite beams, as shown by the experimental results. The ultimate bearing capacity of the composite beam with reinforced web opening was comparable to that of the regular composite beam lacking web opening once the cross-sectional area of the double-sided longitudinal stiffeners reached the weakened area of the steel web opening. The final bearing capacity of the composite beam was not appreciably increased by the web holes strengthened with transverse stiffeners. The ultimate bearing capacity of the composite beams with reinforced web holes was also predicted using analytical methods by ABAQUS software

***Index Terms* – Steel I- beam, composite beam, web opening, ABAQUS software**

## I. INTRODUCTION

Steel–concrete composite beams have been extensively used in building and bridge construction. Composite action in a composite beam is achieved by means of mechanical shear connectors. Headed stud shear connectors are usually welded to the top flange of a steel beam to resist longitudinal slip and vertical separation between the concrete slab and the steel beam. Concrete slabs can be either solid slabs or composite slabs incorporating profiled steel sheeting. Composite beams under applied loads are often subjected to combined actions of bending and vertical shear. Despite experimental evidences, the contributions from the concrete slab and composite action to the vertical shear strength of a simply supported composite beam is not considered in current design codes, which result in conservative designs. In order to design composite beams consistently and economically, it is necessary to develop new design models for shear strength including contributions from the concrete slab and composite action and for moment shear interactions.

## II. PROBLEM STSTEMENT

The composite beams with web openings are widely used in buildings to accommodate ducts and pipes. However, the presence of the web opening could weaken the flexural performance and the load bearing capacity of the composite beam. The purpose of this study was to investigate the influences of the type and cross-sectional area of stiffeners which were used to reinforce the web opening. For the purpose of comparison, a similar composite beam was designed without the web opening and a composite beam with the web opening was constructed without the reinforcement. Additionally, the analytical model for predicting the ultimate bearing capacity of the composite beam with reinforced web opening was proposed.

## III. LITERATURE REVIEW

1 **Therese Sheehan, Xianghe Dai, et. al., 2016.** This paper describes a sequence of experiments on a long-span asymmetric composite cellular beam. This type of beam has become very popular, combining the composite action between the steel and concrete with the increased section depth, compared with more commonly used solid-web I sections. Openings in the steel web also reduce the self-weight and can accommodate the passage of service ducts. Eurocode 4 recommends a high degree of shear connection for asymmetric composite beams despite the practical difficulties in achieving this. Recent research suggests that the required degree of shear connection could be reduced, particularly for beams that are unpropped during construction. However, little test data exists to verify the behaviour of unpropped composite cellular beams. Therefore two series of tests were conducted on a 15.26 m long asymmetric composite cellular beam with regular circular openings and an elongated opening at the mid-span. The degree of shear connection was 36%, less than half of that recommended in Eurocode 4, and the beam was unpropped during construction.

2 **M.A. Basher, N.E. Shanmugam, A.R. Khalim, 2009.** The paper is concerned with the effects of circular or square web openings on the ultimate strength of horizontally curved composite plate girders. Finite element analysis using the computer package LUSAS has been employed to investigate the behavior and ultimate strength capacity of the girders with web openings of different proportions. The opening sizes and their locations within the web panels have been studied in detail, and the results are presented in the form of load–deflection and load–opening size plots. An approximate method to determine the ultimate strength capacity of horizontally curved composite plate girders accounting for the presence of web openings and composite action between the steel girder and concrete slab is presented. The accuracy of the method is established by comparing the predicted strength with the corresponding values predicted by the finite element method.

3 **A.J. Wang, K.F. Chung, 2008.** The authors have engaged in a thorough research and development programme to create cutting-edge analysis and design tools for the practical design of long span composite beams in structures. To explore the whole spectrum of structural behaviour of composite beams, two- and three-dimensional finite element models using solid and shell elements with material, geometrical, and interfacial non-linearity were constructed. In order to examine the structural behaviour of perforated composite beams, two-dimensional finite element models using plane stress elements are established in this paper. Shear connectors with non-linear deformation characteristics are incorporated into the models through the use of both vertical and horizontal springs. It is shown that the finite element models can accurately forecast the load carrying capacity of composite beams with large rectangular web holes against the "Vierendeel" mechanism after thorough calibration against test data. Additionally, after data analysis, a number of significant structural values are determined, including local axial and shear forces as well as local bending moments operating on the composite and steel tee sections at failure. Together with the load carrying capacities, these quantities compare favourably with the values obtained from a design method the authors had previously proposed; as a result, the suggested design method is quantitatively justified. Additionally, the finite element models include comprehensive details on the structural behaviour of shear connectors along the length of the beam, including longitudinal shear forces, pull-out forces, and slippage of the shear connectors. Several recommendations are made regarding the design and construction of perforated composite beams based on the results of the finite element modelling.

4 **F.D. Queiroz, P.C.G.S. Vellasco, D.A. Nethercot, 2007** The current work employs the commercial finite element (FE) programme ANSYS to evaluate full and partial shear connections in composite beams. The suggested three-dimensional FE model has the ability to mimic the general flexural behaviour of simply supported composite beams subjected to either concentrated or uniformly distributed loads. This includes the distribution of stud shear force, load deflection behaviour, longitudinal slide at the steel-concrete contact, and failure scenarios. Comparisons with experiments and alternative numerical calculations show how reliable the model is. The calibrated FE model is then used in a thorough parametric study that follows. In-depth discussions of several numerical modelling difficulties, including potential convergence challenges, loading tactics, and computer efficiency are also included in the article.

## IV. CASTELLATED BEAM

The adoption of perforated beams in steel constructions is growing quickly because of their many beneficial qualities, such as their light weight, simplicity of construction, advanced load deflection characteristics, increased strength, and stiffness, as well as the attractive appearance they provide. Pre-engineered buildings are typically secure when strength parameters are taken into account. However, these portions do not meet the serviceability standard, which is to check for deflection. These requirements can be met by a beam with greater depth. Therefore, the beam can be constructed so that its depth grows rather than selecting a part with a greater depth. As the desired depth is reached in the same material, this can lower the cost. When the offered apertures are hexagonal in shape, perforated webbed beams are often referred to as castellated beams. Due of their attractive qualities, cellular beams, or beams with circular apertures, are very widely used. Additionally, some producers recently created additional openings like hexagonal Castellated beams are classified according to the openings provided in the web portion. Following are some castellated beams provided with different openings.

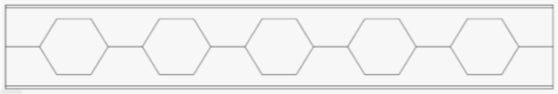

**Figure 1 Castellated Beam With Hexagonal Opening**

Castellated beams are manufactured by cutting the web portion of the parent I-section in zigzag pattern and again reuniting them those two halves in such a way that the depth of the beam is increased.

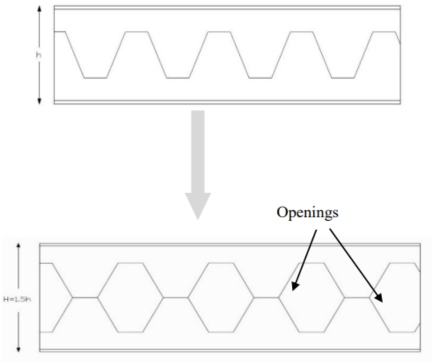

**Figure 2 Castellation Process Of Castellated Beam With Hexagonal Opening**

## V. FINITE ELEMENT ANALYSIS

Due to complex geometry of castellated beams the finite element analysis (FEA) is the best available software to analyze the beam. FEA is done by the simulation software of version "ABAQUS/CAE 6.13". Below given is basic stepwise description of modelling a castellated beam in ABAQUS. For preparing a model of castellated beam in ABAQUS we have to choose shape of the part as solid and of extrusion type. The pictorial view of part model of castellated beam along with loading and boundary conditions. After creating part model, in the next property module create a material by putting elastic property such as Young's modulus (2 x 105 N/mm2) and Poisson's ratio (0.3) of steel. Then give plastic properties of steel in terms of yield stress and plastic strain.

In load module concentrated load by selecting point of loading and apply boundary conditions by selecting proper edges. Simply supported condition is taken in consideration. As we are modeling in the space ad no specification are given in software we need to restrain al the three displacement module. In case of castellated beam select the Quad-dominated structured element. Which is S4R doubly curved shell element, which will give accurate results in case of castellated beam with circular perforations.

After meshing has been done, now model is ready for analysis. This is done in job module by creating job and submitting it.

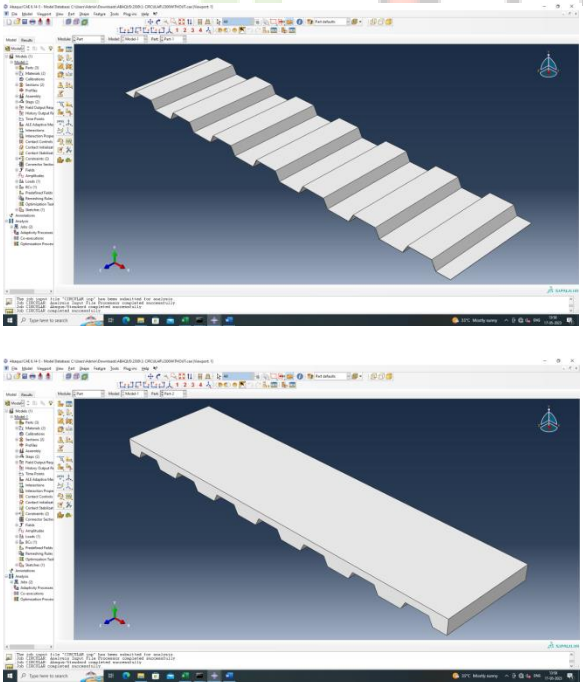

**Figure 3 Part Model Of Concrete Slab**

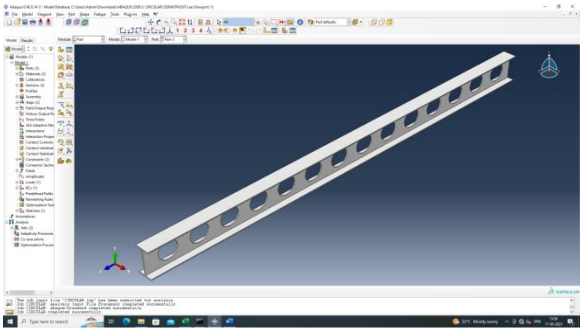

Figure 4 Part Model Of Castellated Beam

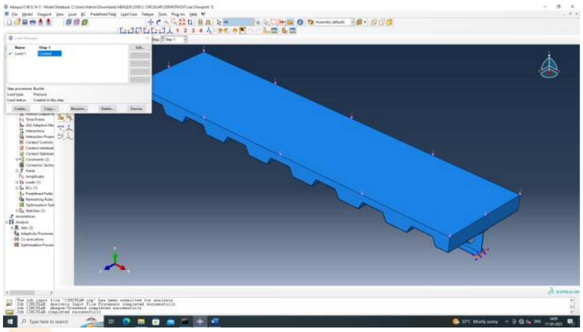

Figure 5 Loading and Boundary Condition of Model

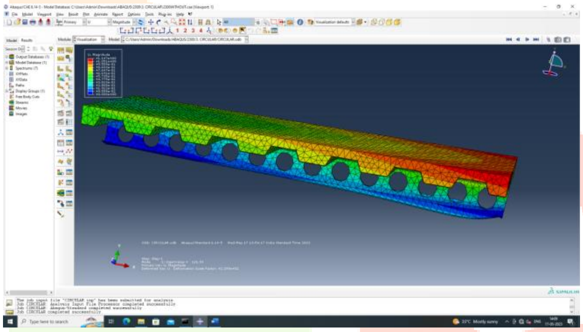

Figure 6 Sample Results of Eigen Value of Model.

## VI. RESULT AND DISCUSSION

### 5.1 Load Carrying Capacity Of Composite Beam

Table No 1: Load Carrying Capacity Of Composite Beam

| Sr. No | Depth of Section | ISMB 150 Section | | | | | Shape of Opening | Concrete Slab | | | | ABAQUS Load Carrying Capacity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bf | tf | tw | hw | L | | Length | Width | Thickness | Beff | |
| | h | mm | mm | mm | mm | mm | | mm | mm | mm | | KN |
| 1 | 150 | 75 | 5 | 5 | 140 | 1000 | Without Opening | 1000 | 1000 | 150 | 250 | 396.81 |
| | | | | | | | Hexagonal | | | | | 249.1 |
| | | | | | | | Circular | | | | | 223.17 |
| | | | | | | | Rectangular | | | | | 172.13 |
| 2 | | | | | | 1325 | Without Opening | 1325 | | | 331.25 | 336.71 |
| | | | | | | | Hexagonal | | | | | 204.57 |
| | | | | | | | Circular | | | | | 183.92 |
| | | | | | | | Rectangular | | | | | 149.69 |
| 3 | | | | | | 1650 | Without Opening | 1650 | | | 412.5 | 285.16 |
| | | | | | | | Hexagonal | | | | | 175.92 |
| | | | | | | | Circular | | | | | 158.61 |
| | | | | | | | Rectangular | | | | | 131.99 |
| 4 | | | | | | 1975 | Without Opening | 1975 | | | 493.75 | 247.57 |
| | | | | | | | Hexagonal | | | | | 153.08 |
| | | | | | | | Circular | | | | | 138.6 |
| | | | | | | | Rectangular | | | | | 113.93 |
| 5 | | | | | | 2300 | Without Opening | 2300 | | | 575 | 208.7 |
| | | | | | | | Hexagonal | | | | | 131.51 |
| | | | | | | | Circular | | | | | 121.93 |
| | | | | | | | Rectangular | | | | | 101.02 |

## 5.2 Comparison of Load Carrying Capacity in Same Length of Beam

**Table No 2: Load Carrying Capacity in Same Length of Beam**

| Sr. No | ISMB 150 Section | Shape of Opening | Concrete Slab | | | | Load Carrying Capacity | Variation in Load Capacity |
|---|---|---|---|---|---|---|---|---|
| | Length | | Length | Width | Thickness | Beff | | |
| | mm | | mm | mm | mm | | KN | KN |
| 1 | 1000 | Without Opening | 1000 | 1000 | 150 | 250 | 396.81 | - |
| | | Hexagonal | | | | | 249.1 | 147.71 |
| | | Circular | | | | | 223.17 | 173.64 |
| | | Rectangular | | | | | 172.13 | 224.68 |
| 2 | 1325 | Without Opening | 1325 | | | 331.25 | 336.71 | - |
| | | Hexagonal | | | | | 204.57 | 132.14 |
| | | Circular | | | | | 183.92 | 152.79 |
| | | Rectangular | | | | | 149.69 | 187.02 |
| 3 | 1650 | Without Opening | 1650 | | | 412.5 | 285.16 | - |
| | | Hexagonal | | | | | 175.92 | 109.24 |
| | | Circular | | | | | 158.61 | 126.55 |
| | | Rectangular | | | | | 131.99 | 153.17 |
| 4 | 1975 | Without Opening | 1975 | | | 493.75 | 247.57 | - |
| | | Hexagonal | | | | | 153.08 | 94.49 |
| | | Circular | | | | | 138.6 | 108.97 |
| | | Rectangular | | | | | 113.93 | 133.64 |
| 5 | 2300 | Without Opening | 2300 | | | 575 | 208.7 | - |
| | | Hexagonal | | | | | 131.51 | 77.19 |
| | | Circular | | | | | 121.93 | 86.77 |
| | | Rectangular | | | | | 101.02 | 107.68 |

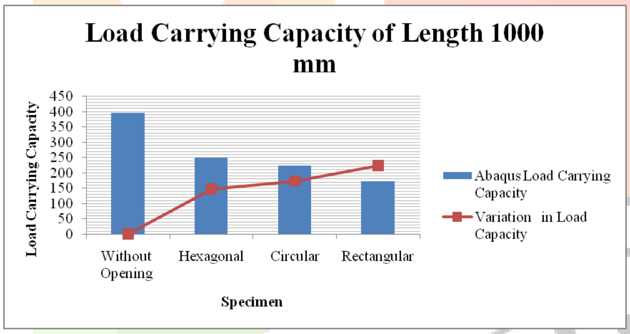

**Figure 7 Load Carrying Capacity of 1000 mm Length of Composite beam**

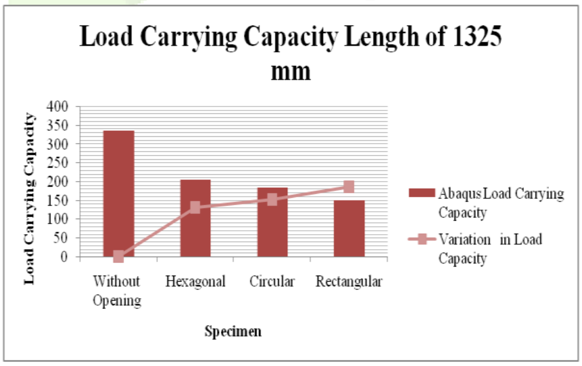

**Figure 8 Load Carrying Capacity of 1325 mm Length of Composite beam**

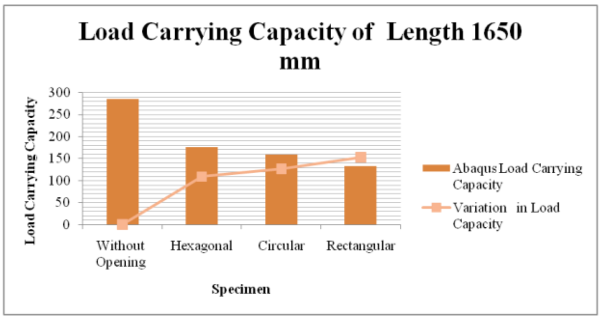

**Figure 9 Load Carrying Capacity of 1650 mm Length of Composite Beam**

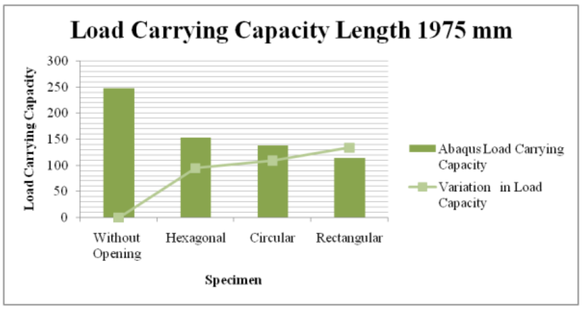

Figure 10 Load Carrying Capacity of 1975 mm Length of Composite Beam

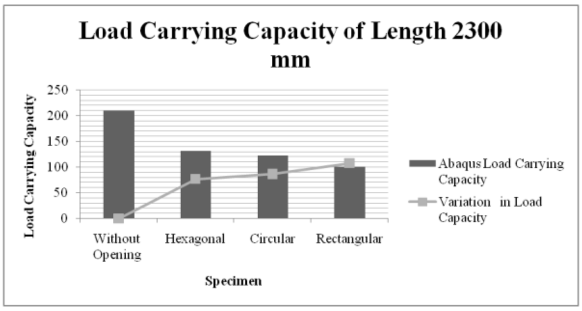

Figure 11 Load Carrying Capacity of 2300 mm Length of Composite beam

### 5.3 Comparison of Load Carrying Capacity in Same Shape of Opening

Table No 3: Load Carrying Capacity in Same Shape of Opening

| Sr. No | Length | Shape of Opening | Concrete Slab | | | | Abaqus Load Carrying Capacity | Variation in Load Capacity |
|---|---|---|---|---|---|---|---|---|
| | | | Length | Width | Thickness | Beff | | |
| | mm | | mm | mm | mm | | KN | KN |
| 1 | 1000 | Without opening | 1000 | 1000 | 150 | 250 | 396.81 | - |
| 2 | 1325 | Without opening | 1325 | | | 331.25 | 336.71 | 60.1 |
| 3 | 1650 | Without opening | 1650 | | | 412.5 | 285.16 | 111.65 |
| 4 | 1975 | Without opening | 1975 | | | 493.75 | 247.57 | 149.24 |
| 5 | 2300 | Without opening | 2300 | | | 575 | 208.7 | 188.11 |
| 6 | 1000 | Hexagonal | 1000 | | | 250 | 249.1 | - |
| 7 | 1325 | Hexagonal | 1325 | | | 331.25 | 204.57 | 44.53 |
| 8 | 1650 | Hexagonal | 1650 | | | 412.5 | 175.92 | 73.18 |
| 9 | 1975 | Hexagonal | 1975 | | | 493.75 | 153.08 | 96.02 |
| 10 | 2300 | Hexagonal | 2300 | | | 575 | 131.51 | 117.59 |
| 11 | 1000 | Circular | 1000 | | | 250 | 223.17 | - |
| 12 | 1325 | Circular | 1325 | | | 331.25 | 183.92 | 39.25 |
| 13 | 1650 | Circular | 1650 | | | 412.5 | 158.61 | 64.56 |
| 14 | 1975 | Circular | 1975 | | | 493.75 | 138.6 | 84.57 |
| 15 | 2300 | Circular | 2300 | | | 575 | 121.93 | 101.24 |
| 16 | 1000 | Rectangular | 1000 | | | 250 | 172.13 | - |
| 17 | 1325 | Rectangular | 1325 | | | 331.25 | 149.69 | 22.61 |
| 18 | 1650 | Rectangular | 1650 | | | 412.5 | 131.99 | 40.31 |
| 19 | 1975 | Rectangular | 1975 | | | 493.75 | 113.93 | 58.37 |
| 20 | 2300 | Rectangular | 2300 | | | 575 | 101.02 | 71.28 |

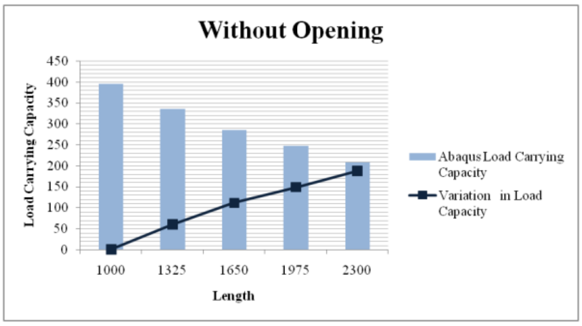

Figure 12 Load Carrying Capacity of Without Opening

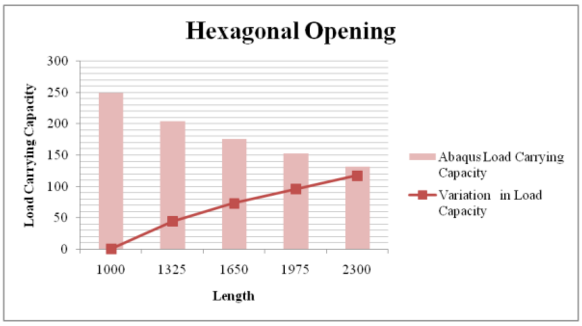

Figure 13 Load Carrying Capacity of Hexagonal Opening

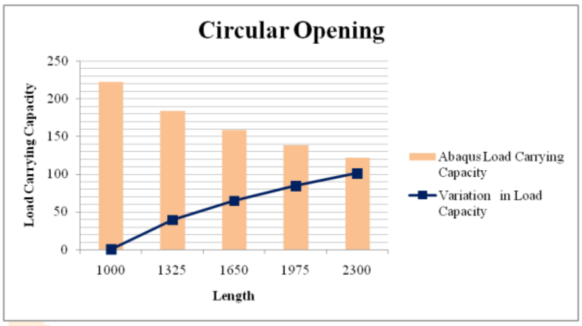

Figure 14 Load Carrying Capacity of Circular Opening

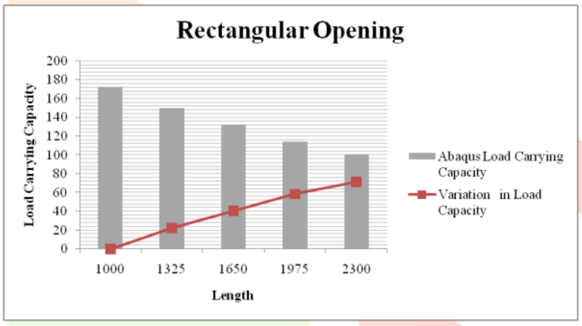

Figure 15 Load Carrying Capacity of Rectangular Opening

## VII. CONCLUSION

The analytical models were proposed for predicting the maximum bending capacity and shear capacity at reinforced web opening, respectively. The finite element analysis on the composite beams with reinforced web opening will be conducted to investigate the influences of the web opening size, web opening location concrete strength and steel beam strength.

The following conclusion are listed in finite element analysis

- In 1000 mm length of composite beam the hexagonal opening of maximum load capacity is 249.1KN. Minimum load carrying capacity of rectangular opening is 172.13KN
- In 1325 mm length of composite beam the hexagonal opening of maximum load capacity is 204.57KN. Minimum load carrying capacity of rectangular opening is 149.69KN
- In 1650 mm length of composite beam the hexagonal opening of maximum load capacity is 175.92KN. Minimum load carrying capacity of rectangular opening is 131.99KN
- In 1975 mm length of composite beam the hexagonal opening of maximum load capacity is 153.08KN. Minimum load carrying capacity of rectangular opening is 113.93KN
- In 2300 mm length of composite beam the hexagonal opening of maximum load capacity is 131.51KN. Minimum load carrying capacity of rectangular opening is 101.02KN
- Result finding hexagonal opening of castellated steel –concrete composite beam are carry more load as compare to circular and rectangular opening of composite beam

## VIII. FUTURE SCOPE

By developing watershed in proposed selected region, it will improve Socio-Economical condition of local farmers. Also at the appropriate location water and soil conservation structure suggested, which gives benefit to local farmer. Ground water level in various micro-watersheds can increase through proper management & by constructing various water and soil conservation structures. To understand the differential recharge condition in watershed, use of GIS and remote sensing gives higher accuracy in proposed region

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