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STUDY ON BEHAVIOUR OF SECONDARY STRESSES IN TRUSSES DUE TO CONNECTION ECCENTRICITIES

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ABSTRACT

Secondary stresses occur in steel truss members due to fixity at the nodes, which are considered, pinned in primary analysis. It may also occur in the members due to member imperfections or due to temperature variations. When a truss is fabricated with web members directly welded to chord members, secondary stresses may be induced due to eccentricity of member at the node and weld length imbalance at a joint. If loads are applied over a member, flexural stresses are superimposed over axial stresses, thus the member will be a beam – column. This paper aims at studying the secondary stresses occurring in the following problems, pitched roof truss with directly welded connections with loads at nodes, pitched roof truss with concentric connections (with gusset plates), Parallel chord lattice trusses with directly welded connections with loads at nodes, Parallel chord lattice trusses with directly welded connections with loads on chords. Based on the analysis, Elimination of gusset plates will result a considerable economy in the total cost of the roof truss (i.e)5 to 10% of the cost of truss can be omitted, High secondary stresses exist only in some of the members and then only in the extreme fibers at the ends of the members.

Keywords *- Secondary stresses, Finite element method, Connection eccentricities, Gusset plate.*

I. INTRODUCTION

For light and normal building roof loads, beams can span up to certain dimensions; beyond that they will be deeper and heavier. Also, for large column free spaces for operational purposes, they are unsuitable. The logical choice for relatively light loads and large spans is the trusses. Trusses are generally symmetrical in shape since the loads coming on the trusses, except wind, are symmetrical about the center line. The important principles in the design of a truss, considered as a plane frame are A perfect truss is composed of straight members between node points, assumed to be frictionless joints, and arranged in such a manner that only axial forces occur in the straight members. The warren truss has relatively High secondary stresses, Pratt truss is considered more effective in order to reduce secondary stresses, the economic height-to-span ratio of trusses is about one-sixth to one-ninth, varying with the type of truss, loadings, span length, etc. It can be further shown that the optimum inclination of the diagonals is About 45^0. Slight variation from these proportions will not noticeably affect the over-all weight but excessive deviations may result in appreciable additional material for the truss. For subdivided trusses and warren truss with verticals, certain members may have secondary stresses as high as 40 to 100% of the primary stresses (Saidani 1998, Shankar nair 2013. Although the magnitude of secondary stresses can be high, their significance is not necessarily comparable to that of primary stresses.

II. REVIEW OF LITERATURE: Boris et al., (1968) have inferred that secondary stresses may be produced in members of a truss by the following Conditions, a). Eccentricities in the member connections - when the centroids of the sections at a joint do not intersect at one point, moments will be produced. Trusses are generally detailed so that such eccentricities will be avoided or minimized. b). Torsional moments – introduced by members not lying in the plane of the truss, such as floor beams in bridges. For usual designs, such stresses are neglected. c). Transverse loads on a member, such as the weight of the member Itself. Geethu et al., (2014) have studied the effect of connection eccentricity in the behaviour of steel tension members and concluded that, Lateral bracing is generally designed using single angles, double angles or T sections connected with high strength bolts, The shear lag reduces the effectiveness of the component plates of a tension member that are not conected directly to a gusset plate because the entire section is not fully effective at critical section location., Ideally, in these situations placement of the connectors should be along the centroidal axis of the member.

Shankar (2013) has put recommendations on secondary stresses in steel trusses as, (a). If the truss members are designed for the axial forces that would occur if the members were pin-connected, then the flexural stresses indicated by a more refined analysis may be defined as secondary stresses and may be neglected, within reasonable limits.

(b). In summary, the key to proper treatment of secondary stresses in steel trusses is to be consistent between analysis and design. If member forces for design are determined from an analysis that neglects certain stiffness components (such as flexural stiffness of some or all members), stresses corresponding to those stiffness components may be regarded as secondary stresses and may be neglected in design. This approach is consistent with *plastic* and *ultimate* design concepts.

III. METHODOLOGY

- Study on connection designs and details of a normal trusses and its comparison of results
- Literature collections and study
- Modeling of a truss with eccentric connection using FEA software ANSYS
- Analysis of truss with different connection
- Comparisons and validation of results

IV. ANALYTICAL WORK

A. Pitched roof truss with connection eccentricity

Truss joints are modeled as pin jointed and the members are analyzed in the conventional system. But in practice the assumed pin joint is not possible to achieve. When modeling the load is applied exactly over the nodal points. It is also not achieved in the field, because the load is transferred through the cleats which are placed eccentric to the main chords. Here the truss is modelled such that one end is pined, and the other end is roller, all the inner joints are free, and the load is applied over the nodes. The members are designed for the axial compression or tension corresponding to the loads. Allowable stresses are calculated by considering the cross-sectional area of the member and its slenderness effects without considering the effect of eccentricity.

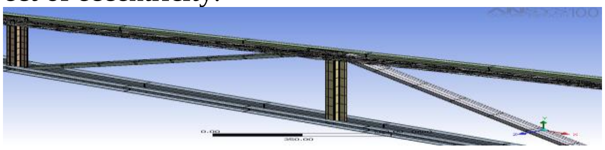

Figure 1: Pitched roof truss with connection eccentricity

B. Pitched roof truss with concentric connection (with gusset plates)

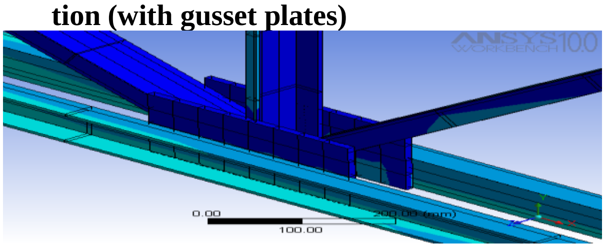

Figure 2: Pitched roof truss with concentric connection (with gusset plates)

The truss is modelled with 2nos of ISMC 75 Back to back with 99mm inner spacing and the inner web chords as ISMC 75. Channel flanges are turned outside to provide greater lateral rigi- dity and this is the common arrangement for compression members. Gusset plates of 12mm thickness are provided inside the main chords and the web chords are inserted and welded to the plates. such that centroidal axes of all the members meet concentrically. Nodal loads are applied through the cleat plate of size 200x50 which is placed on one of the top chords. Size of the gusset plates are arbitrarily arrived.

V. RESULTS AND DISCUSSION

A. TRUSS WITH ECCENTRIC CONNECTION: When a web member is directly welded to chord members, the central lines of chord members and web members will not meet concentric with a result eccentric connection exists, eventually the gusset plates could have been avoided and due to its expense. However, in the absence of gusset plate the eccentricity will result in a moment, the web member is subjected to three types of stresses namely Major axial stress, bending tension and Warping tension due to bending of the directly connected flange. The resulting stresses are combined, and equivalent vanishes (failure) stresses. When main chord and web member sizes are equal, and they are inclined greater than 300, all joint stresses are less than the failure stress. However, the resulting stress 30-40% higher than the allowable stress (165mpa), but less than the yield stress of 250mpa.

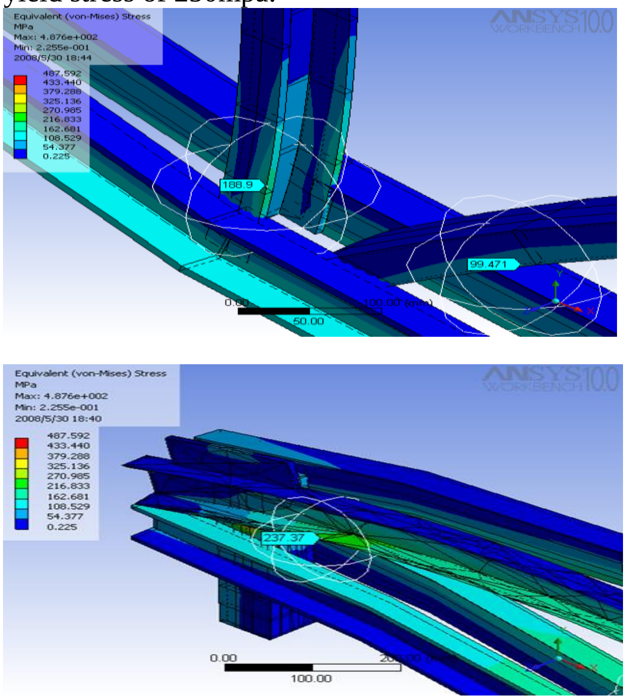

Figure 3: Trusses with Eccentric connection

B. IN PLANE DISTORTION EFFECTS IN THE WEB CHORDS

The distortion of joint also occurs in the same plane due to connection eccentricity. The member is relatively stiff in the other direction. Since the truss is laterally restrained by means of purlins, out plane bending is avoided. If the load is applied just away from the symmetrical line of the truss the web member experiences the out-plane bending stress. Generally truss members are analyzed by assuming the ends are pinned, the effective length is taken as 1.0 L for the design of members, but from this analysis the effective length factor may be taken as 0.5, this is due to the fixity at the ends by means of weld (IS 800-2007 recommends that in in plane direction the effective length taken as 0.7-1.0 L).

C. BUCKLING & CURVATURE EFFECTS

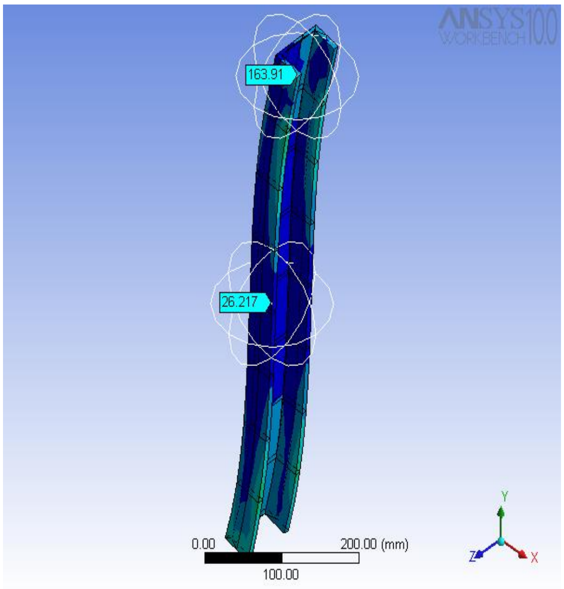

Figure 4: Distortion effects in web chords

In pin jointed concentric connection trusses, the web members are subjected to maximum stress at mid section of the length due to buckling in single curvature. Here stresses are increasing towards the mid section and minimum at the ends. The capacity is governed by single curvature buckling effect. But in the case of eccentrically connected directly welded truss connections, from the ANSYS finite element software analysis it is found to be most of the web members are influenced by double curvature buckling effect due to end fixity. Due to this behavior, slenderness ratio of member gets highly reduced which resulting the member subjected to comparatively less combined stresses at the mid section and higher value at the ends. This is found to be advantageous for taking higher panel loads relatively with lesser cross section.

D. GUSSET PLATES

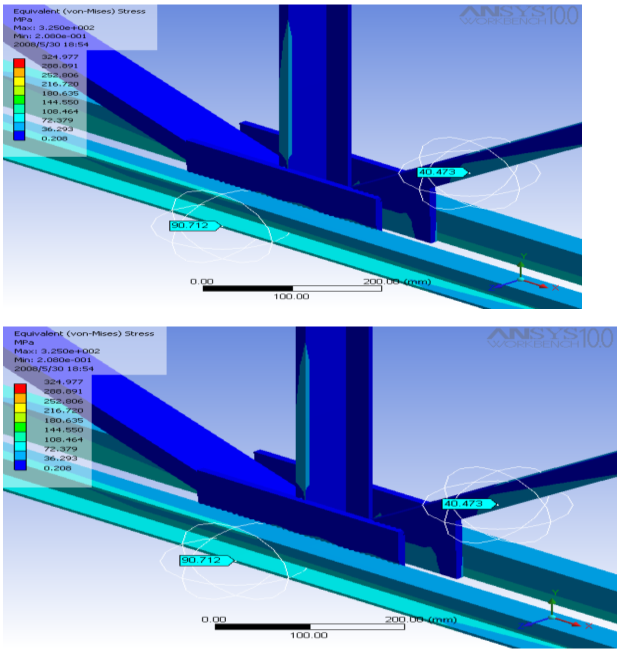

Figure 5: Connection with Gusset plates

Gusset plates in concentrically connected truss are subjected to highly complicated stresses. There is no standard methodology or method of analysis for finding the internal stresses of the gusset plates. The size and thickness are arrived arbitrarily, and it is still complicated for the analysis and design where number of members are meeting at a particular joint. From the past observations it is very clear that the failure has been occurred due to the failure of gusset plates. Gusset plates increases the cost of the truss by 5-10% and weld consumables twice.

E. BEAM ACTION OF TOP CHORDS

The vanishes (failure) stresses have been marked in the top & bottom chords. From the analysis it has been found that every panel point of the truss is act as a support and the top chord is act as a continuous beam over the panel points. due to the local eccentricity and joint distortion the combined stresses (axial & bending) are developed.

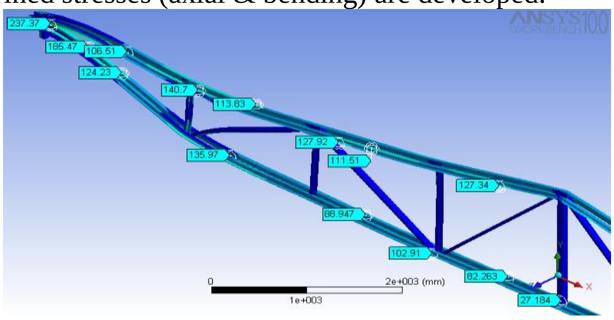

Figure 6: Top chord Stresses

From the truss configuration it has been found that the stress is minimum in the main chords at the centre due to larger depth and higher stress at the end due to minimum depth. Since the loads are applied even with a minimum eccentricity at the panel points and also due to connection eccentricity of the web members the effect of local buckling is minimum at the mid & end section of the members which resulting the combined axial and bending stresses are within the allowable limit.

F. BEHAVIOUR OF LATTICE: The lattice structure is behaving like a simply supported beam and hence the von mises stress variation is found to be maximum at the center chords of truss and gradually reduced to minimum at the end chords, the calculated depth of lattice is given such that the combined stress is within the allowable limit (150mpa). From ANSYS, Deflection of the lattice is found to be 58mm which marginally exceeds the allowable limit (span / 325 = 46mm). Due to this exceeded deflection at the centre of the truss no joint distortion has been found. Hence due to connection eccentricity no secondary stresses are formed in the members near the joints. The lattice depth may be increased to reduce the overall deflecttion. The deflection of the lattice can be reduced and the lattice members can be optimized if both ends of the lattice is pinned. But the lattice will behave a two pinned arch and it possesses a lateral thrust to the supporting member. And hence the supporting member whether reinforced concrete column or steel member should have sufficient stiffness to resist such lateral thrust. Application of nodal loads in between the panel points doesn't influences any increase in the secondary stresses, since the main and web chords integrally act as a beam. Hence the main chords should be designed as beam column.

CONCLUSION

Elimination of gusset plates will result a considerable economy in the total cost of the roof truss. i.e. 5 to 10% of the cost of truss can be omitted. If web member axis is inclined around 30 to 600, the secondary stresses due to bending of web member is only margined 25-30%, well within the yield strength of material. Even when yield takes place, the joint will rotate with very little increase in def-lection of the truss nodes. High secondary stresses exist only in some of the members and then only in the extreme fibers at the ends of the members. With the low value of basic allowable stresses used in design, such high localized stresses do not become a problem unless repeated often enough, in which case fatigue failure may occur. When it is desired to limit or to reduce the secondary stresses resulting from truss distortion, the width of the member in the plane of bending should be reduced relative to the length of the members. So that shear lag is reduced. Selection of configuration and truss type is important to minimize the secondary stresses. Pratt or Howe trusses may be avoided, instead sub divided fink truss is preferred. End vertical leg connecting the truss and base plate should be kept as slender member. Eccentricity of connection in trusses having better performance in resisting seismic forces.

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