Shear Lag in Tube Structures

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Abstract

In recent years, framed-tube and framed-tube-in-tube structures have been widely used as structural system for high-rise buildings. Framed-tube structure with multiple internal tube or tubes in tube structure, are widely used because of their high stiffness in resisting lateral load and the availability of internal tubes in supporting the vertical tubes. When subjected to lateral load such as wind load, the corner columns experience much higher axial load due to the well-known phenomenon of shear lag. Tubular structures or hollow structures undergo anomalous behavior when subjected to loads. The design of such buildings should take care of this shear lag effect. In this project it is proposed to study the understanding of shear lag phenomenon considering axial force under the action of lateral loading. The theses also include the study of non-dimensional structural parameters governing shear lag phenomenon.

Keywords – Flange Section, Web Section, Positive Shear Lag, Negative Shear Lag.

1. Introduction

A building framed tube structure is considered one of the most efficient lateral force resisting systems. The frame tube system in its simplest form consists of closely spaced exterior columns tied at each floor level with relatively deep spandrel beams, thereby creating the effect of a hollow concrete tube perforated by openings for the windows. Since the system is simulated to create a hollow tube effect using perimeter closely spaced frame elements, it is referred "framed tube". (Fig 1)
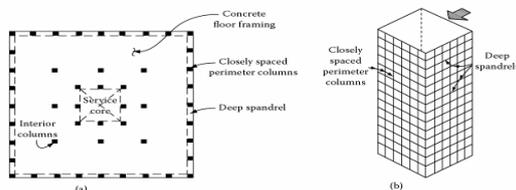

(a) Schematic Plan   (b) Isometric View
Fig. 1. Framed Tube Building.

The lateral force resistance of the framed-tube system is highly promoted with the help of tube action. The overall bending of a tubular frame building is similar to that of the box girder, though 'shear deformations' which are neglected in box girders, play a vital role in tubular framed buildings. In tubular framed buildings, flexibility of spandrel beams produces a "shear lag effect". The tube action is perceived as the behavior of a system that acts like a cantilever box beam when subjected to overturning moment induced by lateral loading, with a significant contribution from the flange elements.

As per the Euler-Bernoulli, elementary theory of bending states that a plane sections remains plane before and after bending. This assumption results in a linear distribution of bending stress in the cross section of the beam. The assumption can hold true in a box section only if the shear stiffness of the cross section is infinite or if there is no shear force in the box section. The panels displace longitudinally in the way that the middle portion of the flange and web lag behind that of the portion closer to the corner of the box section. This non-linear longitudinal displacement of the flange and web results in the non uniform "axial stress distribution", it is referred (Fig 2). This shear lag effect reduces the effectiveness of the box structure by increasing or decreasing the stress concentration at the web flange junctions, and reducing or increasing the axial stresses at the middle of the frame panels, which accumulates to increased lateral deflection of the web flange structure**.**
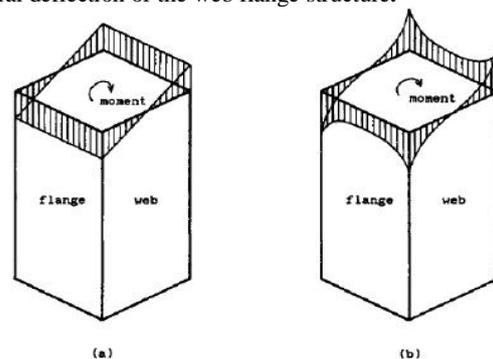
(a) Without Shear Lag   (b) With Shear Lag
Fig. 2. Axial Stress Distribution in Beam Structure.

2. Methodology

The approach and accuracy of the analytical results depends on the idealization of the geometry and loading of the structure. The exterior frame components or the exterior columns along the periphery of the structure are designed to

resist the lateral loads while the internal frame components or the internal columns are designed to carry the gravitational loads. Simple Analysis of Tube frame system for tall building will be carried out to determine the shear lag effect.

3. Modeling method

Modeling method for frame panels is carried out as orthotropic equivalent members in a way that perimeter frame could be analyzed as a continuous structure. Perimeter frame structure shown in (Fig. 3) can be considered as two web panels which are parallel to lateral loads direction and two flange frames which are orthogonal to that in accordance with the following assumption the out of plane behavior with respect to stiffness of floors, are negligible in comparison with in-plane behaviors of frames; and it is also assumed that strain distributions in external web frame panel are identical, whereas those in external flange frame panels are equal but opposite.
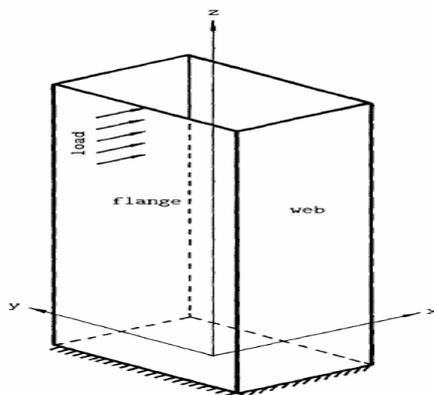

Fig. 3. Orthotropic Panels of Tube Structure

4. General Study of Shear Lag Phenomenon in Tubular Systems

The high-rise framed tube building system consists of closely spaced columns around the perimeter of the building. It is a very efficient structural system as it takes advantage of the perimeter configuration for the structure, therefore utilizing the whole width of the building to resist the overturning moment due to lateral load. A framed tube building behaves very much like box girder. The overturning moment due to lateral load is resisted by the axial stresses of the columns at the four sides of the building. Bending of the beams and columns of the web panels in the plane of of the load resist the shear force produced due to the lateral load.

With respect to box girder, a framed tube building is also affected by shear lag. As shown in Fig.4, columns at the edge flange panel of the building experience higher axial stresses than the middle columns. The columns at the edge of the web panel also have higher axial stresses than those stated as per the Euler-Bernoulli assumption. At the middle of the flange and web panels, the axial stresses in the columns are smaller than the axial stresses stated in Euler-Bernoulli assumption. In addition to reduced lateral stiffness, the nonlinear stress distribution of the axial stresses in framed tube building produces warping of floor slab and consequent deformation of the secondary structures.
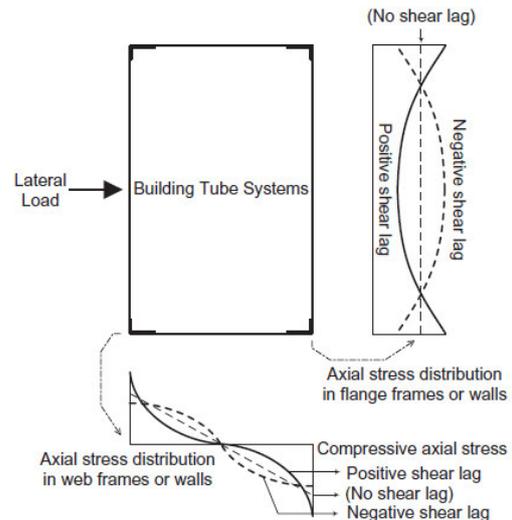

Fig. 4. Shear Lag in Framed Tube

5. Structural Parameters Governing Shear Lag Phenomena

The four non dimensional structural parameters governing the shear-lag behavior are:

(1) Stiffness factor Sf representing the ratio of the shear rigidity and the column bending stiffness, or

$$ S_f = \frac{12\,h}{A_c d^2} \frac{1}{\left(\dfrac{h}{I_c} + \dfrac{d}{I_b}\right)} $$

where Ic and Ib are, respectively, the second moments of area of the column and the beam; Ac is the sectional area of the column; h is the storey height; d is the bay width or span.

(2) Stiffness ratio Sr, the ratio of the bending stiffness of the column and that of the beam, or

$$ S_r = \frac{I_c d}{I_b h} $$

(3) Ratio g, i.e. the number of storey on the number of bays in the external flange frame Panel.

(4) Number of internal tubes, N.

6. The salient features of Shear Lag Effect

1. Positive shear lag occurs generally under both point loads and uniform loads.
2. Positive shear lag may lead to warping of floor slabs which in turn, causes the deformation of the interior partitions and other secondary components.
3. Negative shear lag occurs only under uniform loading.
4. Negative shear lag may lead to local buckling on the compression side and cracking on the tension side of the flange frame.
5. Ration of length/width affects the quantum of shear lag effect.

7. Expected Outcomes

Based on the literatures available it is concluded that several attempts have been made to explain the shear lag anomaly but the existing studies lack a more general and physical explanation on the origin of negative shear lag. Also not much studies have been attempted to describe the positive shear lag and variation of shear lag effect along a tubular (hollow) structure.

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