CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Tubular structures are the most popular structural form used for construction of multi storey buildings. Construction of high-rise buildings used to be driven by the demand for vertically managed additional floor area in densely populated lands. Advancements in structural engineering and technology have greatly enhanced the height of the superstructures. Combined improvements in analysis and design, fabrications as well as construction techniques, made the skyscrapers more relevant and feasible. Major advancements in structural form for high-rise buildings enabled the height of building to rise. In recent years, framed-tube and framed-tube-in-tubular structures form have been applied as structural system for high-rise buildings. Framed-tube structure with multiple internal tube or tubes in tubular structure, are widely used because of their high stiffness in resisting lateral load and the availability of internal tubes in supporting the vertical tubes. The tube works as an effective lateral resisting system (Fig. A*.5). Framed-tube systems are advantageous than other structural forms as it is suitable for both concrete as well as steel. Although, these structural form gives rise to the shear lag phenomenon (SLP) subjected to the corner column having relatively large magnitude of axial forces at the base, a good aesthetic structure system can also be easily constructed by using this structural form. This system is considered to be the best choice for square as well as rectangular building.

The requirement of continuity of stiffness of the column in the structure as stipulated in IS 1983 part-4 (2002) through the height is essential to design criteria of the framed structures. However, the shear lag phenomenon distributed the stresses unsymmetrically in the column of the tubular structure along the height and width. In that case, it is not to analysis and caters for the desired continuity in the stiffness. It is also essential to investigate the behavior of the tubular structure under earthquake excitation.

1.2 SHEAR LAG PHENOMENON

As the height of the buildings increases, the wind load becomes governing design load. Under the excitation of lateral load, the distribution of the axial force in the flange columns is non-uniform. The high-rise tubular structure experiences non-uniform distribution of bending stresses subjected to the lateral load. Also, under the symmetrical flexure without torsion, the distribution of bending stresses across the flanges of the tube cross section is not uniform (Fig. A.4).

Shear lag phenomenon (SLP) mainly are of two types: (1) Positive SLP (2) Negative SLP (Fig. A.2).The stresses at the edge of the tube are much higher than the centre of flange. This phenomenon is termed as positive shear lag [Coull and Bose 1975, 1976; Coull and Ahmed 1978; Ha et al. 1978; Haji-Kazemi and Company 2002; Foutch and Chang 1982; Kwan 1994, 1996; Mahjoub et al 2011; Reissner 1945; Takabatake et al. 1993]. It is found that the axial force in corner column is much larger than the axial force in the center column of the flange, especially at the base level. This anomaly comes in the picture and well recognized by Reissner (1945) in analyzing a typical box beams. Shear lag effect is relevant to any laterally loaded tubular structure such as box girder bridges, high rise structures. This also includes the structural elements of buildings such as the core walls and the framed-tube system.

In the upper part of the tubular building, the normal stress in the corner column is much smaller than the central column. This phenomenon is known as negative shear lag [Haji–Kazemi and Company 2002; Luo and Li 2001; Kwan 1994, 1996; Mahjoub et al. 2011; Shushkewich 1991; Singh and Nagpal 1993]. Foutch and Chang (1982) firstly observed negative shear lag while analyzing a cantilever box beam subjected to uniformly distributed load. The negative shear lag primarily investigated in box the girder bridge by Chang and Zheng (1987) and explained in detail by Shushkewich (1991). In the above cases, simple bending theory is violated and uniform flexural stress variation along flange has not been actuated. As in the web panel, expected triangular variation of flexural stresses was not obtained, as observed in the simple bending theory of hollow beams. Shear lag phenomenon has also been analyzed in box girder bridges, tubular framed buildings and in axial members by various researchers [Chan et al 1974; Chang 1984; Chang and Zheng 1987; Chen et al. 2014; Fang et al. 2013; Lee et al 2000, 2001; Lin and Zhao 2011, 2012; Teh and Yazici 2013; Zhang and Lin 2014; Zhu et al. 2015]. An anomaly in shear lag was duly investigated and nature of the anomaly have been reported at different levels (i.e., at different distance from fixed support). The degree of negative shear lag illustrated in terms of the ratio of maximum stress at the centre of the flange to the minimum stress at the edge in box girders [Lee et al. 2002]. The SLP has been also explained by several authors in their respective publications on multi story buildings [Smith and Coull 1991].

1.3 OUTLINE OF THE THESIS

Chapter I sketches the wider context and growing relevance of the shear lag phenomenon (SLP) in tubular structures.

Chapter II deals with overviews of the relevant literature regarding mathematical as well as numerical formulations of the stresses in the tubular structures considering shear lag effect. In this chapter, various type of the structures are categorized along with the effect of shear lag. The effect of shear lag reported herein, ranges from the box beam to the axial tension members.

Chapter III includes the objectives and methodologies along with the validation of the methodology are presented in the research parameters and the objectives of the research are outlined. The aim listed in this chapter has been achieved by incorporating the methodology to each of the specific objects in the forthcoming chapters.

Chapter IV presents a more detailed investigation of various parameters that affect the shear lag phenomenon. The longitudinal displacement of the flange is assumed as a polynomial of higher order and the differential equations are solved through the principle of minimum potential energy. For the proper understanding of the effect of shear lag, a factor has been defined and illustrated through numerical examples.

Chapter V provides development of a model that normalizes and regulates the positive as well as the negative shear lag in tubular tall buildings. An effort has been made to nullify the severity of the shear lag phenomenon in the present chapter. The effects of shear lag in tubular structures are normalized and regulated by adopting a technique of corner modifications. The numerical model in term of corner modifications of the tubular tall building for the horizontal load has been analyzed by using finite element method.

Chapter VI aimed to study the effect of beam-column and slab interaction on the shear lag phenomenon (SLP) in tubular buildings and to estimate the design aspect regarding this phenomenon. The various aspects considered are relative stiffness of beam and columns; axial forces in the columns; base bending moment; additional bending moment; deflections; estimation of critical columns and to the find position of a point of inflection in each column. These aspects are essential to decide the preliminary dimension of the structural elements. The tubular buildings are analyzed by using STAAD Pro. v8i (2007).

Chapter VII presented the experimental study to understand the behavior of tubular buildings under any given earthquake excitation. The responses of building models with fixed base and flexible base are evaluated for a better understanding of the effect of Soil-Structure Interaction (SSI). The main objectives of the present experimental study are (i) to evaluate the changes in various responses of the shear beam for fixed base and SSI considered model (ii) to find the factors affecting the dynamic responses of the model. The response is drawn and analyzed using FFT Spectrum Averaging analyzer (B and K PULSE Lab Shop Version 18.1.0.28 - 2013-11-23). The sinusoidal excitation has been produced by using shake table.

Chapter VIII discussed the concluding remarks and scope for future work.

Each chapter incorporates the precise content of the summary produced in the corresponding chapter.