LATERAL STABILITY OF HIGH-RISE BUILDING

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A project report submitted in partial fulfillment of the requirements for the award of the degree of Master of Engineering(Civil-Structure)

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APRIL 2005

ABSTRACT

Structural systems for tall buildings have undergone a dramatic evolution throughout the previous decade and into the 2000s. Developments in structural system form and organization have historically been realized as a response to as well as an momentum toward emerging architectural trends in high-rise building design. Traditionally, the primary concern of the structural engineer designing a building has been the provision of a structurally safe and adequate system to support the vertical loads. This is understandable since the vertical load-resisting capability of a building is its reason for existence. However, this is only true for the buildings involved if they were not too high, were not in seismic zones, or were constructed with adequate built-in safety margins in the form of substantial nonstructural masonry walls and partitions. For all the high-rise buildings, it is essential to take into account the lateral forces such as wind loads, seismic inertia-forces, blast loads, etc. to ensure the stability of buildings.

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CHAPTER 1

INTRODUCTION

The issues involved with structural design and technology are ones of both natural and human implications. A structure must be designed to carry gravity, wind, equipment and snow; resist high or low temperatures and vibrations; protect against explosions; and absorb noises. Adding to this the human factor means considering rentable spaces, owner needs, aesthetics, cost, safety and comfort. Although one set is not mutually exclusive of the other, careful planning and consideration are essential in an attempt to satisfy and integrate both.

1.1 Advances in Structural Systems

Over the history of tall building structures, the changes in technology have been tremendous. Part of this comes from the daily strategies of human living. In the early years of skyscrapers, urban centers included mostly structures with a storefront next to the street, offices in the stories immediately above, and, finally in the upper levels, apartments for city dwellers. These types of buildings were difficult to arrange to take total advantage of structural and mechanical systems. Offices needed large open spaces with large loads from mechanical and electrical systems. The living quarters, with their more intimate spaces, needed closer column spacing, and had fewer vents and wires required to meet needs of comfort. Shallow floor-to-floor heights in the apartment areas were possible since they could be accommodated by a flat plate design. Offices needed grid or pan systems covered by drop ceilings to allow HVAC and electrical systems to be delivered to desired locations within each square. As the automobile became a transportation reality, people moved to the suburban areas and commuted to the city for work. This eliminated most mixed-use issues and allowed new forms of tall buildings, which could accommodate wider column spacing desired by businessmen.

In recent years, the trend is returning to mixed-uses as limited natural resources, the expense, time and stresses of commuting draw people back into the city center. Hence, architects and engineers are returning to the challenges of structural design to accommodate people's total daily life. In addition to the past needs of storefronts, offices and apartments, parking is a major consideration in any new structure within the city. Considering structure alone, there are two main categories for high-rise buildings--structures that resist gravity and lateral loads and those that carry primarily gravity loads. Since skyscrapers have the largest needs for resisting high magnitudes of wind, the lateral load resisting system becomes the most important.

1.2 Design Criteria

Tall buildings are designed primarily to serve the needs of an intended occupancy, whether residential, commercial or in some cases, a combination of the two. The dominant design requirement is therefore the provision of an appropriate internal layout for the building. At the same time, it is essential for the architect to satisfy the client's expectations concerning the aesthetic qualities of the building's exterior. The main design criteria are, therefore, architectural, and it is within these that the engineer is usually constrained to fit his structure. Only in exceptionally tall buildings will structural requirements become a predominant consideration.

The basic layout will be contained within a structural mesh that must be minimally obtrusive to the functional requirements of the building. Simultaneously, there must be an integration of the building structure with the various service systems – heating, ventilating, air conditioning, water supply and waste disposal, electrical supply and vertical transportation – which are extensive and complex, and constitute a major part of the cost of a tall building.

Once the functional layout has been established, the engineer must develop a structural system that will satisfy established design criteria as efficiently and economically as possible, while fitting into the architectural layout. The vital structural criteria are an adequate reserve of strength against failure, adequate lateral stiffness and an efficient performance during the service life of the building.

This chapter provides a brief description of the important criteria that must be considered in the structural design of a tall building. Most of the principles of structural design apply equally to low rise as to high rise buildings, and therefore for brevity, special attention is devoted to only those expects that have particular consequences for the designers of high rise buildings.

1.3 Design Philosophy

Vertical changes in the structural form of tall buildings occurred in the construction period that followed World War II. Over the same period, a major shift occurred in design philosophy, and the code formats have progressed from the earlier working stress or ultimate strength deterministic bases to modern more generally accepted probability based approaches. The probabilistic approach for both structural properties and loading conditions has led to the limit states design philosophy, which is now almost universally accepted. The aim of this approach is to ensure that all structures and their constituent components are designed to resist with reasonable safety the worst loads and deformations that are liable to occur during construction and service and to have adequate durability during their life time.

The entire structural or any part of it is considered as having failed when it reaches any one of various limit states, when it no longer needs the prescribed limiting design conditions. Two fundamental types of limit state must be considered:

i. the ultimate limit states corresponding to the loads to cause failure, including instability; since events associated with collapse would be catastrophic, endangering lives and causing serious financial losses, the probability of failure must be very low.

ii. the serviceability limit states, which involve the criteria governing the service life of the building and which because the consequences of their failure would not be catastrophic are permitted a much higher probability of occurrence. These are concerned with the fitness of the building for normal use rather than safety and are of less critical important.

A particular limit state may be reached as a result of an adverse combination of random effects. Partial safety factors are employed for different conditions that reflect the probability of certain occurrences or circumstances of the structure and loading existing. The implicit objective of the design calculations is then to ensure that the probability of any particular limit state being reached is maintained below an acceptable value for the type of structure concerned. The following sections consider the criteria that apply in particular to the design of tall buildings.

1.3.1 Strength and stability

Since publication of BS 8100, increasing use has been made of the ultimate strength design method to proportion reinforced concrete sections. By this method, a given section must have an ultimate capacity equal to or greater than a factored combination of the effects due to vertical load, plus either wind load effects. The ultimate strength design method for proportioning members is presently used in conjunction with an elastic analysis of the structure to determine the design forces and deformations in the members.

The traditional working stress approach limits the stresses in a member due to working loads (gravity and lateral loads) to an acceptably safe level. The investigation of the collapse load of a structure as a whole i.e. limit analysis, for practical design purposes has not been used to any appreciably extent in reinforced concrete structures. As a result, the committee is not able to recommend design procedures based on such an analysis at present. Experience with steel structures suggests that it is essential to include stability considerations in any such analysis. The likelihood of low cycle fatigue in structures subjected to high fluctuating loads should also be considered.

1.3.2 Serviceability

It is essentially to consider the serviceability in designing for lateral loads and the most significant serviceability criteria relate to:

i. Deflection of a structure, particularly as this affects the stability and cracking of members.
ii. Motion of structure as it affects occupant comfort.

There are two types of deflection have to be considered in analysis and designing:

i. Lateral deflection: the main criteria for high rise buildings is lateral drift. This is relative magnitude of the lateral displacement at the top of a building with respect to its height.
ii. Relative vertical deflection: in tall building relative vertical movement between exterior and interior columns or between columns and shear or core walls may occur due to:

a) Thermal expansion and contraction of exterior columns
b) Different axial load stresses in columns and shear cores leading to different elastic and creep deformations of these members.
c) Differential settlement of the foundations for the shear core and adjacent columns

Drift index can be used to estimate the lateral stiffness of a building. Lateral stiffness is an important criterion in designing tall building. This is so because in order to satisfy the ultimate limit state, lateral deflections have to be limited to prevent second-order P-delta effects due to gravity loading that will causes the building to collapse. It is also to satisfy serviceability limit state, to allow the proper functioning of non-structural components and to avoid distress in the structure.

Drift index is defined as the ratio of the maximum deflection at the top of the building to the total height. The interstorey drift index is the drift index for a single storey height. This value may be used to measure localized excessive deformation. As a general guideline, lower values should be used for hotels or apartment buildings than office building. This is because the former are more disturbed by noise and movement of the building. For conventional structures, the acceptable drift index is 0.002. That is approximately 1/500.

The lateral sway motion of a tall building under turbulent wind, if perceptible, may produce psychological effects which render the building undesirable from the user's view point. The reduction of such perceptible motion to acceptable levels does become an important criteria in the design of any tall building.

Besides the deflection, other service conditions like cracking and lateral swaying have to be considered in designing. Cracking of non structural elements such as partitions, windows etc, may cause serious maintenance problems (loss of acoustical properties, leakage etc). The degree of control of structural cracking under lateral load depends upon the type of loading. For wind loading, the aim should be to keep the cracking within acceptable limits. For severe wind load, buildings may be expected to develop plastic hinging (extensive flexural cracking) in the beams at columns faces. The extent and severity of the resulting cracks can be reduced by appropriately placed shear reinforcement.

1.3.3 Fire

The mechanical properties of the structure materials, particularly the elastic modulus or stiffness and strength may deteriorate rapidly as the temperature rises, and the resistance to loads is greatly reduced. For example the yield stress of mild steel at a temperature of 700 degree Celsius is only some 10% to 20% of its value at room temperature. Over the same temperature range, the elastic modulus drops by around 40% to 50%. The critical temperature at which large deflections or collapse occurs will thus depend on the materials used, the nature of the structure, and the loading conditions.

1.3.4 Ductility

Ductility of a structure is its ability to undergo increasing deformation beyond the initial yield deformation while still sustaining load. The energy absorption capacity of a member or a structure under load is related to the ductility in that it is equal to the work done in straining or deforming the structure to the limit of the useful deflection.

1.4 Objective

The purpose of this study is to make a comparison between the existing analytical methods and the computer methods for building structure lateral analysis. The parameters that will be studied are :

i. Deflection of Building
ii. Moment of Structural Element (Column/Wall and Beam)
iii. Shear of Structural Element (Column/Wall and Beam)
iv. Axial Force of Vertical Element (Column/Wall)

The comparison of this study is very important. This is because designers lately rely too heavily on computer analysis when designing. Theoretical and computer analysis results should always in practice be checked safety ensured and fulfillment of the economical aspect. This even more important for the case of very high or complicated buildings. This was also done in K.L.C.C Petronas Twin Tower whereby, Etabs was use for the analysis.

1.5 Scope of Work

Two structural models are going to be studied here. Model 1 is a R.C rigid frame; and model 2 is shear wall and frame iteration. Both models are resisting horizontally uniform distributed load.

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