IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⋇ Vol. 9, Issue 4, April 2022

DOI: 10.17148/IARJSET.2022.94120

MODERN CIVIL ENGINEERING TECHINIQUE FOR TALL STRUCTURES

RUSHABH PATEL[1], SAMIKSHA MANKAR[2], REVATI WAGH[3], HARSHKUMAR ROHIT[4], SHUBHAM CHANDGUDE[5]

CIVIL ENGINEERING, DR. D.Y. PATIL INSTITUTE OF ENGINEERING MANAGEMENT ANDRESEARCH

AKURDI, PUNE, INDIA[1-5]

Abstract: In 21st century with the help of developing technologies civil engineering structure are challenging limits which were just a dreams. With innovative ideas these challenges were tackled economically and effectively. For typical tall building challenges due to wind earthquakes are very common but simple solutions inspired from nature work effectively against them. This report presents an overview and a summary of such innovative and simple approach towards these challenges with example of Taiwan's Taipei 101 tower and provides comparison of existing techniques and modification/use of those in tall rise structure.

Keywords: High Rise Buildings,Tapering Effect, Twisting And Rotating, Outrigger And Belt Trusses, Tuned Mass Dampers.

1. INTRODUCTION

Every project in civil engineering comes with its own list of challenges. For skyscrapers that pierce through sky, this list of challenges tends to expand. Also solutions of these challenges are very complicated and limited. For Taipei 101 very first challenge stood up was a need of firm structure that could support buildings own weight along with other live load. Solution was found from example of bird cage that William Le Baron Jenney found while reading book. Reinforcing the structure at various levels laterally as it is seen in bird cage solved the problem of stiff structure capable of carrying self weight without crushing. With firm structure very another challenge arises for any skyscraper is by earthquakes. Seismic loads are said to be the prime damaging factor to any structure. Shaping building in shape of bamboo not only solved this solution but also gave traditional cultural value to Taipei 101. Not only with shape but by adding strength at intervals structure was made to withstand earthquake of high intensities.

1.1 OBJECTIVES OF PROJECT

- To study Role of Column braced structure in increment of strength of structure to sustain self weight.
- To study the uniqueness of Taipei 101 bamboo shaped structure and modification of plan in form of double step cornerrecession to alter flow patterns.
- To study role of outrigger trusses in sway damping.
- Working of tuned mass damper.
- To study the characteristics of elevators used.
- To study Foundation of Taipei 101.

1.2 SCOPE OF PROJECT

Solutions that taipei101 used are very basic and easy to incorporate. Study of this project can help understand that complicated problems can have simple solution. This study can help to built structures on places similar to Taiwan which are challenged by earthquake and typhoon on regular interval. Also other countries can incorporate small scale system of what Taipei 101 used to overcome their difficulties.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⋇ Vol. 9, Issue 4, April 2022

DOI: 10.17148/IARJSET.2022.94120

2. SHAPE OF TALL STRUCTURE

Every super structure is first created on paper before start of actual work under the part of planning and management of work.

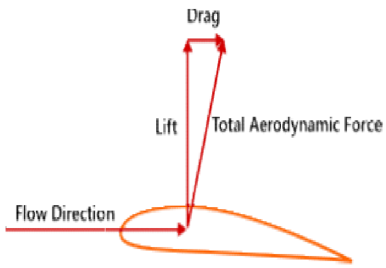
For Tall structures and skyscrapers this design helps to simulate the behavior of building under effect of extreme earthquakes and wind forces at various altitudes. This gives brief idea of failure points of structure and can be reinforced with suitable technique using various computer softwares Further these designs are tested with model under man-made nearly replicating condition of natural forces using advance technique such as wind tunnel and earthquake simulators.

2.1 Need to Control Natural forces

Wind forces or seismic forces which play major role in stability of tall buildings are dominant over a certain frequency range. Even with use of high strength material they tend to create threat to overall success since these structure are highly sensitive to wind excitation and acceleration imparted due to earthquake or wind for safety of non structural component as well as occupants of buildings these accelerations need to under specific limits.

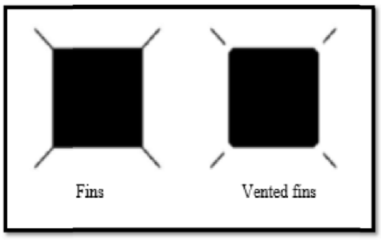
2.2 Forces acting on Tall structures due to Wind

Forces due to wind are classified as forces acting along the direction of wind, Forces acting in perpendicular direction also called as crosswind forces and Torsional moments. Forces in the direction and perpendicular direction are usually referred as Drag and Lift respectively.



2.3 Modification in Shape

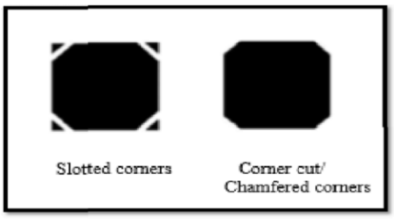
2.4 Minor Modification



2.4.1 Fins and vented fins

The fitting of fins served only to increase the critical wind speed without any noticeable disruption to vortex shedding process. Athigh range of reduced velocities, Fins and vented fins are highly suggested since it was found that fins or vented fins reflected significant reduction in effect without any other method.

2.4.2 Slotted Corners, Chamfered Corners

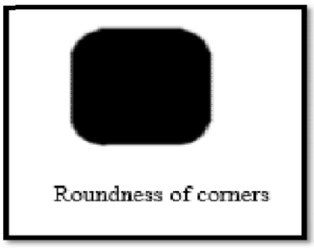


DOI: 10.17148/IARJSET.2022.94120

As fins failed to produce effective results when it comes to alongwind forces, slight modification in just end of corners of building found to be very effective in both the direction at same time. Along with that these kind of modification were found to be also effective to suppress the aeroelastic instability.

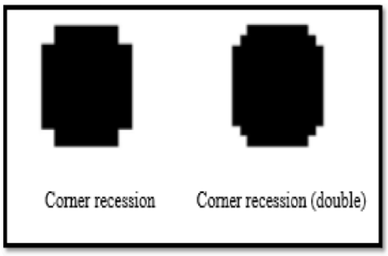
2.4.3 Roundness Of Corners

The corner roundness is one of the effective means of improving the aerodynamic behaviors of the tall buildings against the wind excitation. Looking at Geometry, we can clearly states that effect of lateral drifts ismore on rectangular cross section while cross sections such as cylindrical elliptical are less vulnerable to these forces. Therefore these shapes often provide higher effect in aerodynamic modification allowing construction to greater heights withoutdanger to safety and economy. Wind pressure loads forround shapes can be reducedby 20% to 40% as compared to rectangular section for design purpose.



2.4.4 Corner Recession

Corner recession particularly means providing cuts on corner of plan. Cuts may vary in size such as 5%, 10 %, 20% of the total width. Various researchers tested sample model to study and determine most ideal condition for rise of tall structures with minimal wind resistance. Increase in size of cut was found to be more effective in reduction of peak amplitude but large cornerecession resulted in aeroelastic instability. Hence corner cuts with 10% size of width were termed as most effective modification.



2.5 Major Modifications

2.5.1 Tapering Effect

Having taperingor non uniform cross section along height creates wide range of vortex shading frequencies which specially help in reduction of crosswind forces. Tapering effect for reducing fluctuating acrosswind forces appeared effective whenwind direction is,normal to windward face. Maximum reduction ratio of fluctuating across-wind forces is about 20% and about 30% for suburban terrain and urban terrain respectively. Tapering effect is much more effective for suppressing the large size of vortex-shedding making it more effective in acrosswind direction.

2.5.2 Openings At Top

The addition of openings to a building provides yet another means of improving the aerodynamic behaviors of the structure againstwind forces byreducing the vortex shedding forces particularly at top. Due to provision of openings the critical reduced wind velocity shifts to higher value resulting in shifting of wind speed to higher value postponing resonant vibration too. But one shouldunderstand that these kindsof modifications are effective at higher heights only.

ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⁜ Vol. 9, Issue 4, April 2022

DOI: 10.17148/IARJSET.2022.94120

2.5.3 Twisting and Rotating

Twisting or rotation of building minimizes the wind load from prevailingdirection and disrupts vortex shading along height at a sametime. Also the uniformresponse of this shape towards all possible directions makes it effective in its uniqueway. The crosswind sensitive buildings can see their peak responses changeby 10 to20% within a 10-degree wind direction change.

3. THE OUTRIGGER AND BELT TRUSS SYSTEM

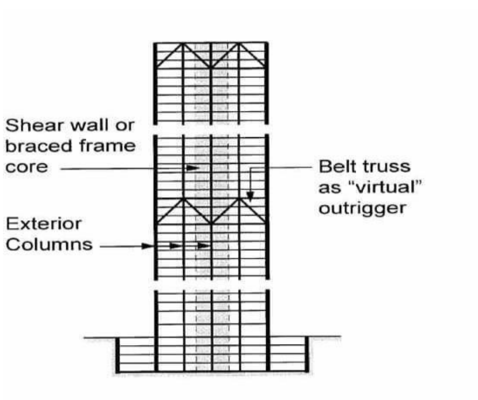
The outrigger and belt truss system is one of the lateral loads resisting system in which the external columns are tied to the central core wall with verystiff outriggers and belt truss at one or more levels. The belt truss tied the peripheral column of building while theoutriggers engage them with main or central shear wall. The aim of this method is to reduce obstructed space compared to the conventional method. Outrigger and belt trusses, connect planar vertical trusses and exterior frame columns. Outrigger system can lead to very efficient use of structural materials by mobilizing the axial strength and stiffness of exterior columns.

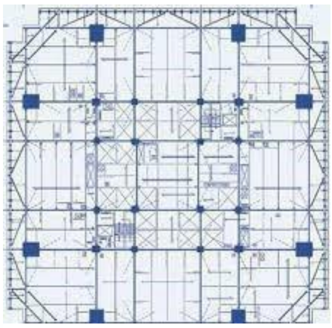
3.1 The Use Of Outriggers In High-rise Buildings To Control The Forces

The incorporation of an outrigger which connects the two elements together provides a stiffer component which act together to resist the overturning forces. When an outrigger-braced building deflects under wind or seismic load, the outrigger which connects to the core wall and the exterior columns, makes the whole system to act as a unit in resisting the lateral load.

3.2 Belt Trusses As Virtual Outriggers

The use of belt trusses as virtual outriggers avoids many of the problems associated with the use of conventional outriggers. The principle is the same as when belt trusses are used as virtual outriggers. Some fraction of the moment in thecore is converted into a horizontal couple in the floors at the top and the bottom of the basement.



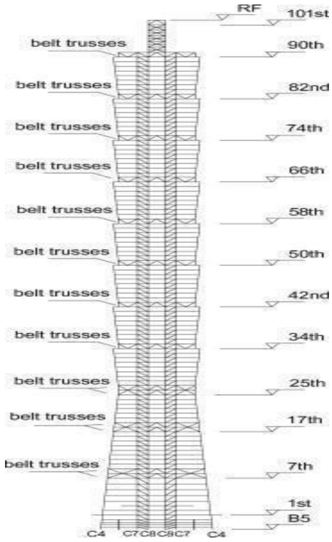


3.3 APPLICATION OF OUTRIGGER TRUSS SYSTEM IN TAIPEI 101

Outrigger trusses, located at eigth floor intervals,connect the colums in the building's core to those on exteriors. It makes central braced core,but then improves its strength and stiffness by connections to several perimeter columns on each building face through outrigger trusses with top and bottom chords in corporate within the framing of two 26 adjacent floors and diagonals through occupied space ,preferably to mechanical rooms.

Belt trusses just above each other module setback gather and transfer perimeter weight to two outrigger 'supercolumns' on each face ,so the member sizesneeded for gravity loads provide axial stiffness as well.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Impact Factor 7.105 ⁙ Vol. 9, Issue 4, April 2022
DOI: 10.17148/IARJSET.2022.94120



Location of Belt trusses

4. TUNED MASS DAMPER

4.1 Introduction

A tuned mass damper (TMD), also known as a harmonic absorber or seismic damper, is a device mounted in structures to reduce the amplitude of mechanical vibrations. Their application can prevent discomfort, damage, or outright structuralfailure. They are frequently used in power transmission, automobiles, and buildings.

4.2 TAIPEI 101 TUNNED MASS DAMPER

To achieve stability and lessen the impact of violent motion, a gigantic tuned mass damper was designed. The damper consist of a steel sphere 18 feet across and weighing 728 ton, suspended from the 92nd to the 87th floor. Acting like a giant pendulum, the massive steel ball sways to counteract the building's movement caused by strong gusts of wind. Eight steel cables form a sling to support the ball, while eight viscous dampers act like shock absorbers when the sphere shifts. The ball can move 5 ft. in any direction and reduce sways by 40 percent. Two additional tuned mass dampers, each weighing 7 tons, installed at the tip of the spireprovide additional protection against strong wind loads.

5. FOUNDATION IN TALL STRUCTURES

5.1 Introduction

Without Presence of strong base success and life span of skyscraper isalwaysat risk. Hence special attention is given to the foundation of buildings. Withpresenceof hard strata its possible to attain the required strength bearing foundation but on the island of Taiwan and for Taipei 101 it became a difficult taskdue to presence ofwater table at comparatively low depth.
Every design will have to satisfy the following conditions:-

- The factor of safety against failure of the foundation and of the supporting soil has to be adequate => ultimate limit state (ULS)
- The settlement of the foundation as a whole and in particular differential settlements under working load should not be solarge as to affect the serviceability of the structure => serviceability limit state (SLS)
- The safety and stability of nearby buildings and services must not be put at risk => ultimate limit state (ULS) / serviceability limit state (SLS)

Taipei 101 is designed to withstand the typhoon winds and earthquake tremors that are common in the area east of Taiwan. Evergreen Consulting Engineering, the structural engineer, designed Taipei 101 to withstand gale winds of 60 metres per second (197 ft/s), (216 km/h or 134 mph), as well as the strongest earthquakes in a 2,500-year cycle.Taipei 101 was designed to be flexibleas well as structurally resistant, because while flexibility prevents structural damage, resistance ensures comfort for the occupants and for the protection of glass, curtain walls, and other features. Taipei 101 used high performance steel construction and 36 columns, including eight "MEGA COLUMNS" packed with 10,000 psi (69MPa) concrete. Outrigger trusses located at eight floor intervals, connect the columns in the building's core to those on the exterior.

6. CONCLUSION

Civil engineering projects are incomplete without challenges and issues. Taipei 101 also encountered many projects and instead of going for complicated techniques architects and engineers found their solution from Mother Nature. This report can help understand the various aspects that are considered during construction of tall structure. Also it may help to tackle issues that structure is facing through the study mentioned. For example, Simple inertial force of TMD countered sway effect. In same way some simple technique can become a solution for problems which seems to be unsolvable.

REFERENCES

1. Davenport AG. The response of six building shapes to turbulent wind, Philosophical Transactions, Royal Society, A269(1971) 285-394.
2. Kwok KCS, Bailey PA. Aerodynamic devices for tall building and structures, Journal of Engineering Mechanics, ASCE,No. 4, 111(1987)349-65.
3. Melbourne NH, Cheung JCK. Designing for serviceable accelerations in tall buildings, 4th International Conference onTall Buildings, Hong Kong and Shanghai: 1988, pp. 148-155.
4. Kim YM, You KP. Dynamic response of a tapered tall building to wind loads, Journal of Wind Engineering and IndustrialAerodynamics, 90(2002) 1771-82.
5. Shieh, S. S., C. C. Chang, and J. H. Jong, Structure design of composite super-columns for the Taipei 101 Tower, Proceeding of International Workshop on Steel and Concrete Composite Constructions, National Center for Research onEarthquake Engineering of Taiwan, 8–9 October 2003, 25–33, 2003.
6. Gu M, Quan Y. Across-wind loads of typical tall buildings, Journal of Wind Engineering and Industrial Aerodynamics, 92(2004) 1147-65.
7. Dennis C. K. Poon, Shaw-song Shieh, Leonard M. Joseph, Ching-Chang Chang, “Structural Design of Taipei 101, the World’s Tallest Building,” Council on Tall Building and Urban Habitat (CTBUH), October 2004.
8. Suresh Kumar K, Irwin PA, and Davies A. Design of tall building for wind: wind tunnel vs. codes/standards, Third National Conference on Wind Engineering, Calcutta, India, 2006, pp. 318-325.