Structural System in Architecture
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Lecture No -38
Structural System for High-rise Buildings-I

Welcome to the NPTEL online certification course on Structural Systems in Architecture. This is the 38th lecture and this is the third lecture of the module 8 or the week 8. And this lecture's topic is Structural System for High-rise Buildings-I.

Concepts Covered

- Introduction
- Interior System
- Rigid Frame System
- Vertical Shear Wall System
- Frame Shear Interaction System
- Outrigger Structures

Learning Objectives

- To discuss the fundamentals of High-rise building structural systems.
- Outlining the structural concept of Interior System.

Introduction

Till mid 1800's the maximum height for the buildings was 4-6 stories due to several factors:

1. Too many steps to climb up & down daily
2. Masonry wall thickness is too high at base, eating up floor space
3. Framing could go up so high before become unstable in wind

Traditionally the function of tall buildings has been as commercial office buildings. Other usages include residential, mixed-use, and hotel tower. Tall building development involves various

complex factors such as Economics, Aesthetics, Technology, Municipal Regulations, and Politics. Among these, economics has been the primary governing factor.

Figure 1 Henry Bessemer

The Bessemer Process was the first industrial process for the mass-production of Steel from molten pig iron. The inventor Henry Bessemer took out a patent on the process in 1855.

In 1857, Elisha Otis and the Otis Elevator Company began manufacturing passenger elevators. Invention of Elevator allowed vertical transportation of people and goods without stair.

Figure 2 Elisha Otis

The Early Skyscrapers

Chicago is the birthplace of the skyscraper. The Home Insurance building (1885) in Chicago, (ten storied with 42 meter in height) is generally referred as the first high rise building (Architect: William Jenney). The Home Insurance Building was built followed by the Great Chicago Fire, 1871.

Figure 3 The early skyscrapers

The physical envelope of construction was traditional load-bearing system. Thick masonry external walls creates comfortable indoor thermal environment. Large window and high ceiling was provided to allow the daylight to the interiors. Maximizing the financial return over a fixed plot

size, initiates the development of modern high rise building in North America during mid-nineteenth century.

Classification of Structural System of High-rise Building

The structural system of a high-rise building can be classified into the following categories:

- **Interior System**

  The Interior system is categorized as an interior structure when the major part of the lateral load resisting system is located within the interior of the building.

- **Exterior System**

  If the major part of the lateral load-resisting system is located at the building perimeter, a system is categorized as an exterior structure.

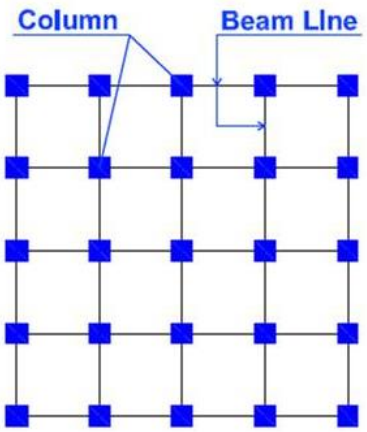
Interior System

The interior system can be further classified into the following categories:

- Rigid Frames System
- Vertical Shear Wall (or Shear Truss) System
- Frame Shear Interaction System
- Outrigger Structures

Rigid Frames System

Rigid Frame or moment-resisting frames (MRF) are consists of horizontal (girder) and vertical (column) members rigidly connected together in a planar grid form. Such frames resist load primarily through the flexural stiffness of the members. The size of the columns is mainly controlled by the gravity loads. Progressively column sizes increases towards the base. The size of the girders is controlled by stiffness of the frame to ensure acceptable lateral sway of the building.



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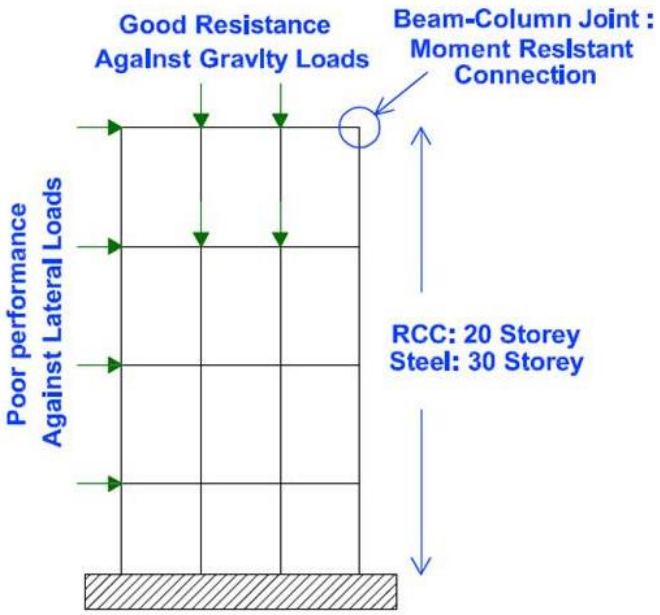

SECTION

860 & 880 Lake Shore Drive Apartments (1949) Chicago, 82 m, 26 stories, Mies van der Rohe

Seagram Building (1958) Manhattan, New York, 157 m, 38 Storied Mies van der Rohe

Figure 4 Rigid Frames System

Vertical Shear Wall (or Shear Truss) System

In this system the structure of the whole building is structurally conceptualized as vertical steel trusses, also called shear trusses. This system introduce braced frames for lateral support, which resist lateral loads primarily through axial stiffness of the members.Vertical Shear Truss System (RC coupled shear wall) can effectively resist lateral forces caused by wind and earthquakes. They are treated as vertical cantilevers fixed at the base.

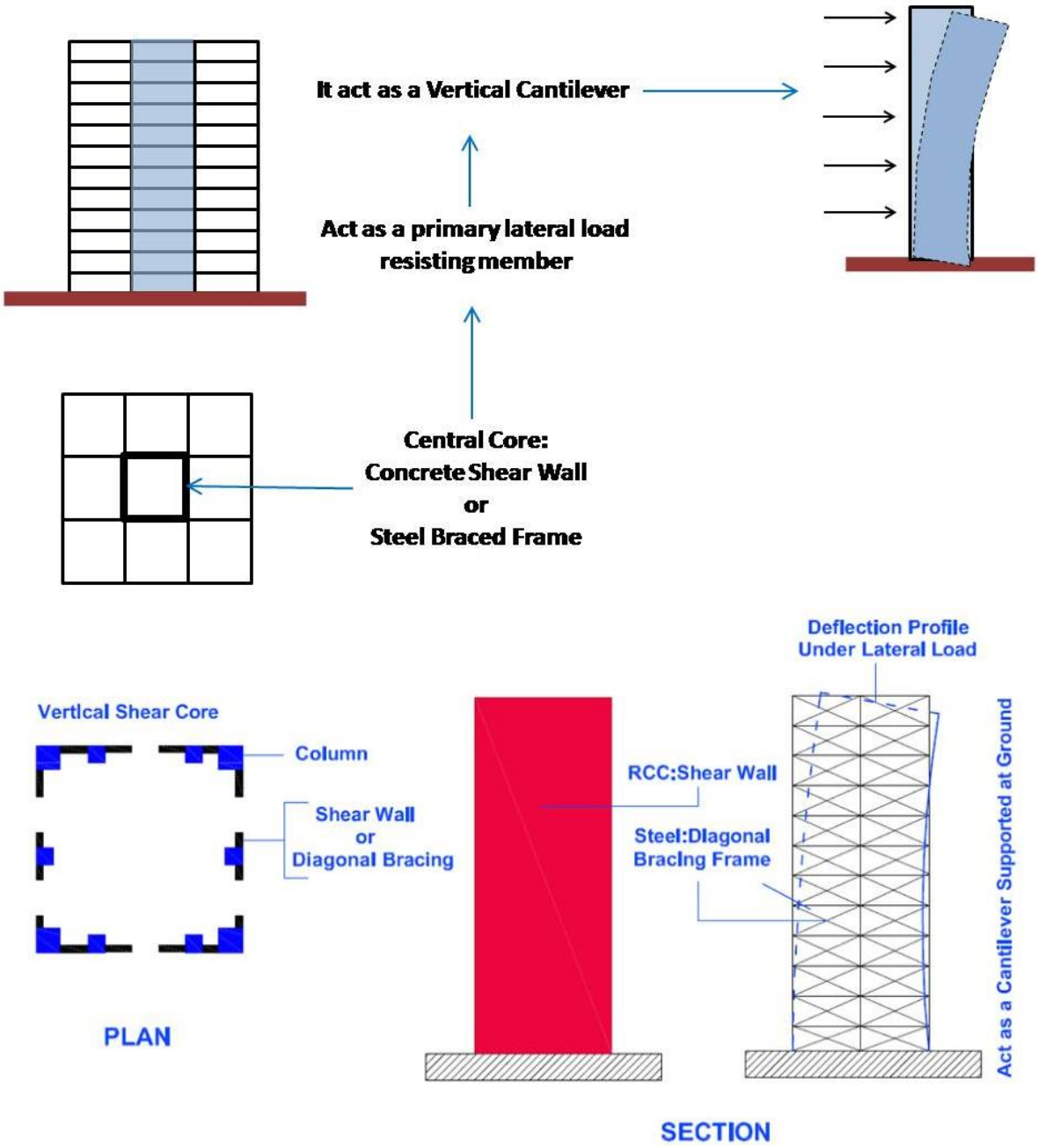

Figure 5 Vertical Shear Wall (or Shear Truss) System

Frame Shear Interaction System

Rigid Frame is not efficient for buildings over 30 storeys because the sway caused by the bending of columns is excessive.

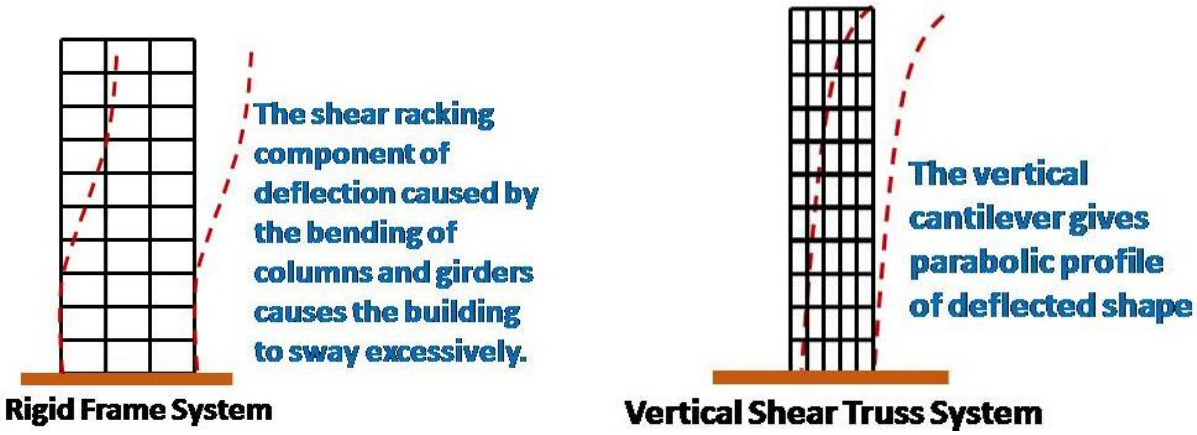

Figure 6 Rigid Frame System Vs Vertical Shear Truss System

When vertical Shear Trusses are combined with Rigid Frame, the intermediate system results in a common deflected shape of the structure.

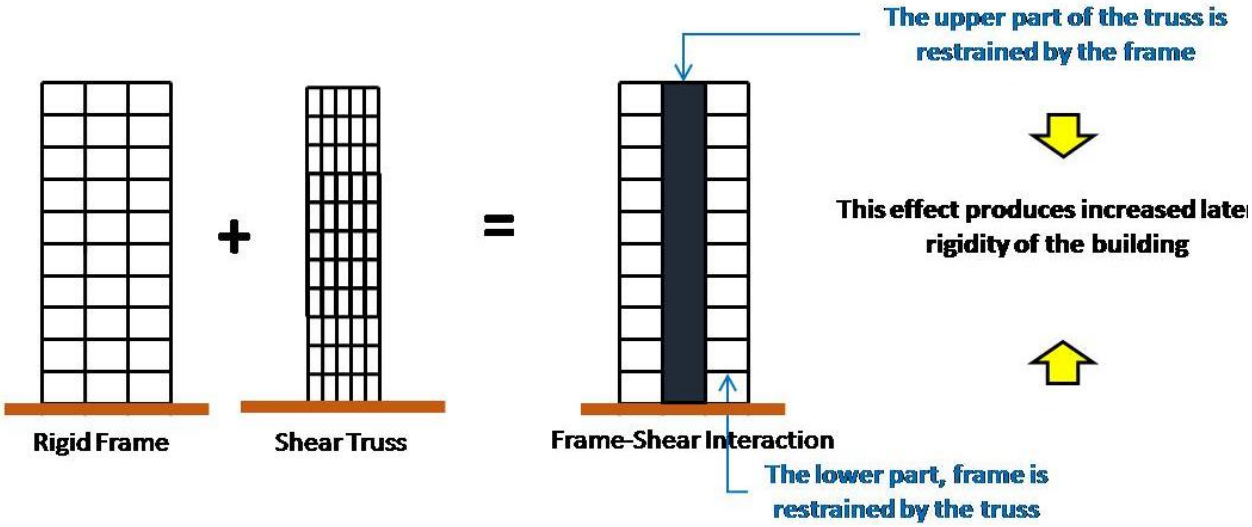

Figure 7 Frame Shear Interaction

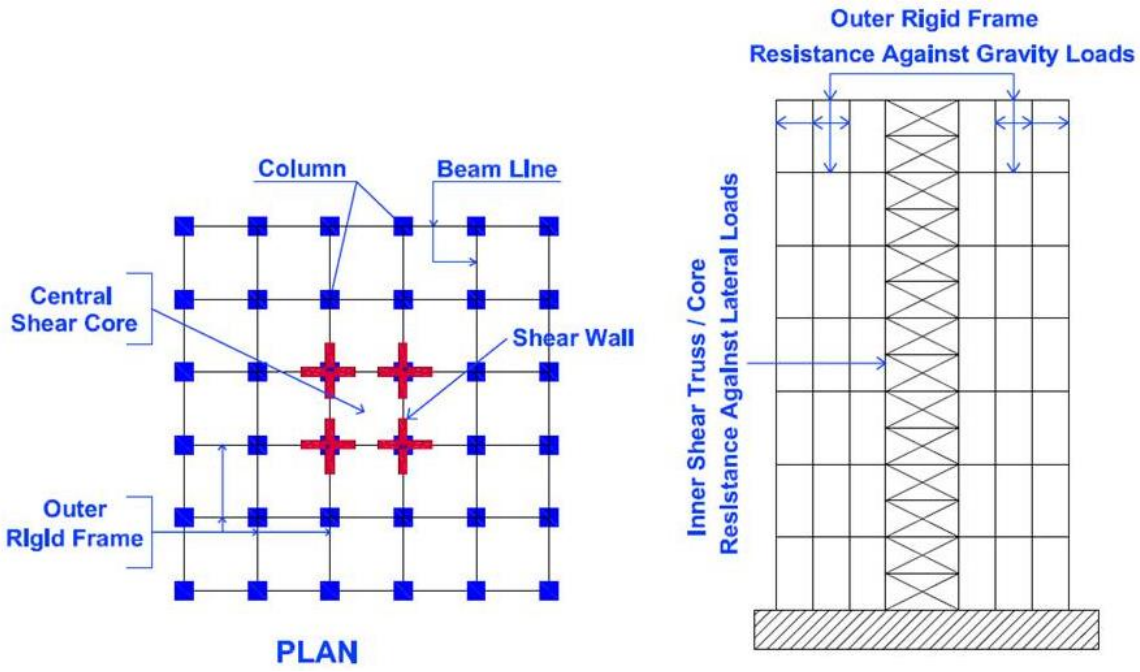

Figure 8 Structural details

If the frame shear interaction structure were to be compared with a human body then the inner shear truss would be the spinal cord and the outer rigid frame would be the rib-cage.

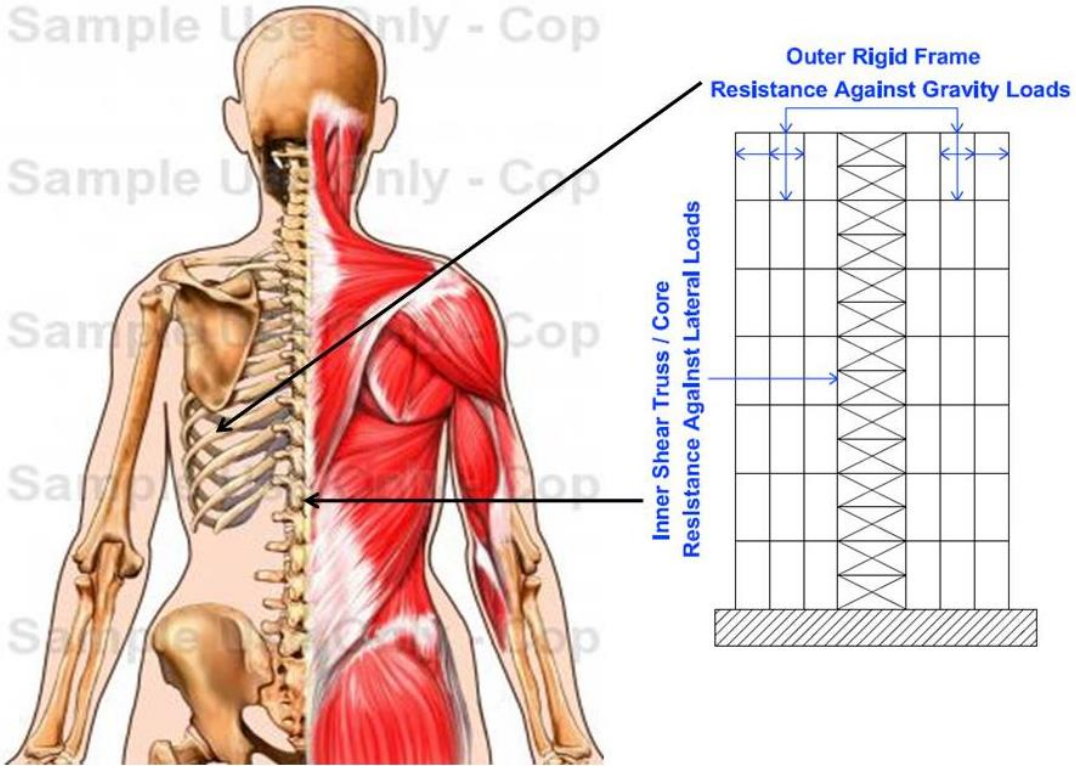

Figure 9 Comparison with the human body

The Empire State Building (1931)

New York, 381m, 102 Storied

311 South Wacker Drive (1949)

Chicago, 293 m, 65 storied

Figure 10 Examples

Outrigger Structures

The outriggers are generally in the form of horizontal trusses in steel structures, or walls in concrete structures. Outriggers serve to reduce the overturning moment in the building core that would otherwise act as pure cantilever.

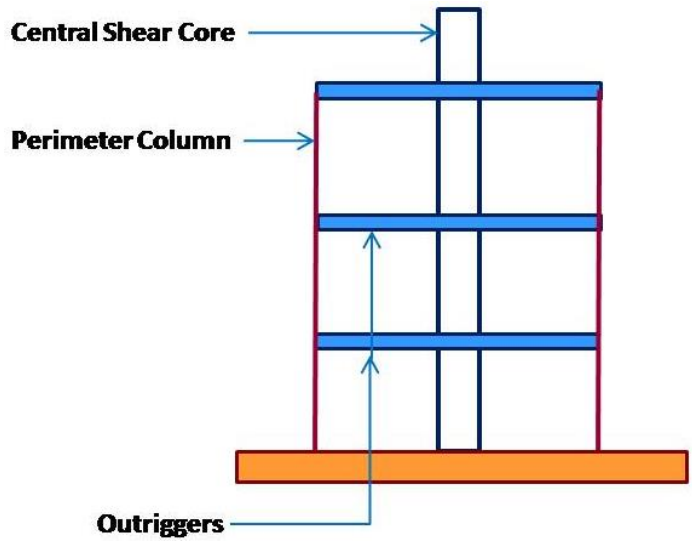

Figure 11 Outrigger structures

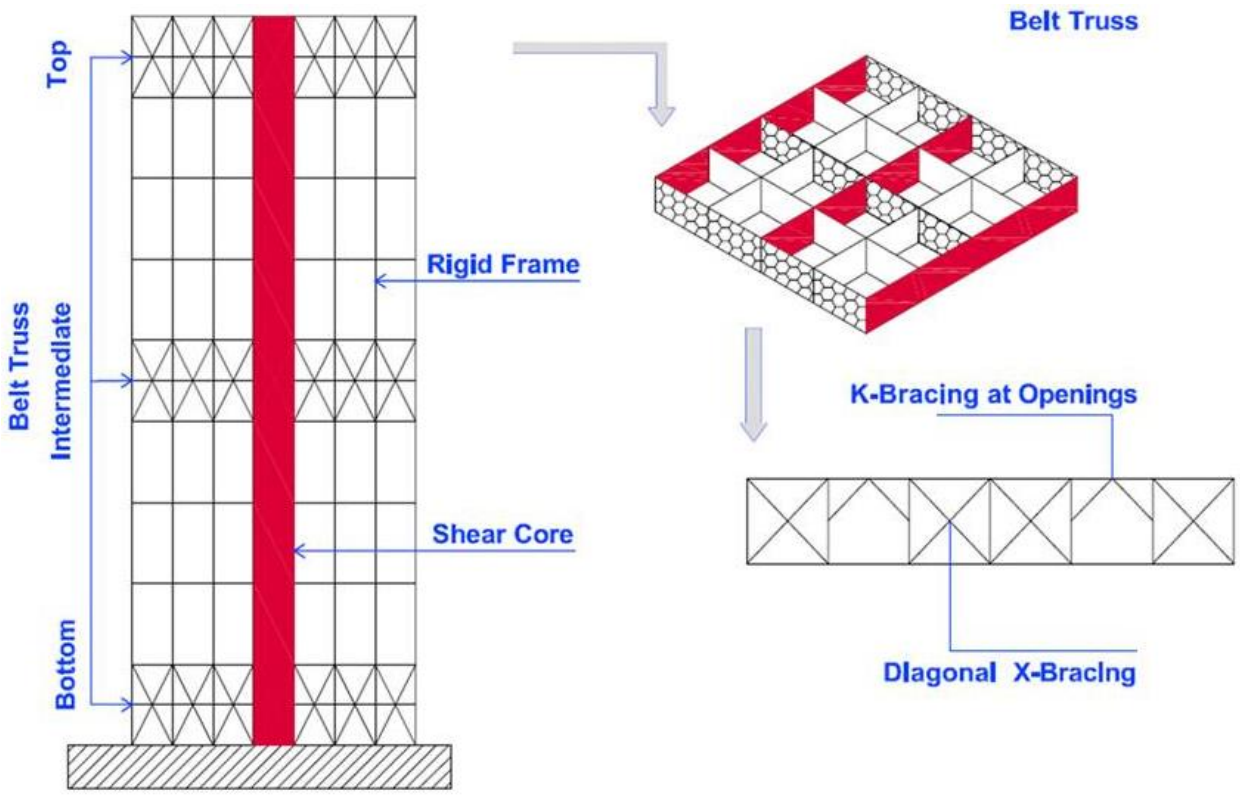

Figure 12 Structural Details

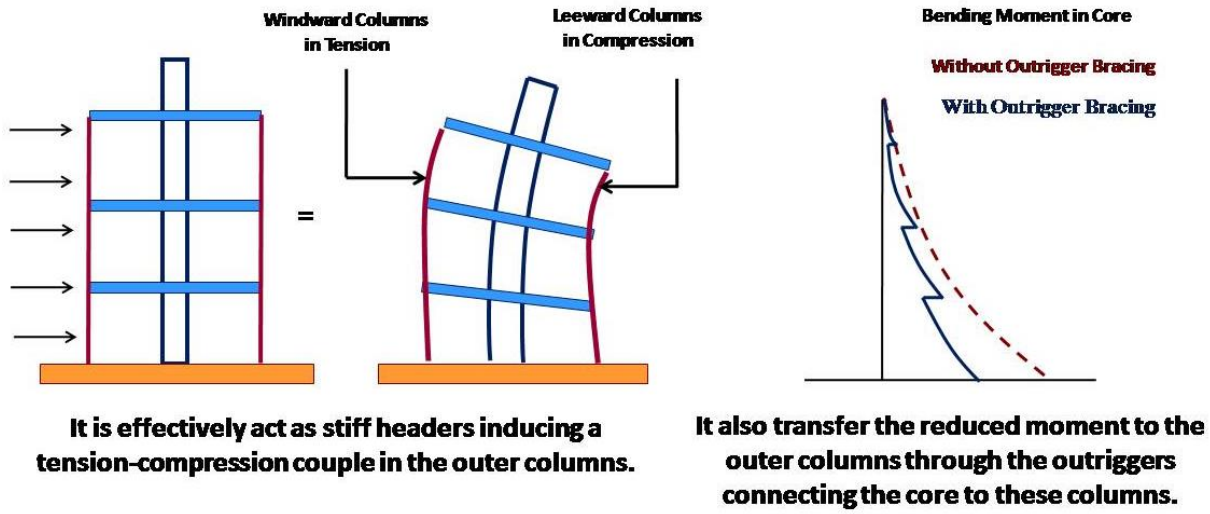

Figure 13 With and without outrigger bracing

Outrigger systems have been historically used by sailing ships to help resist the wind forces in their sails.

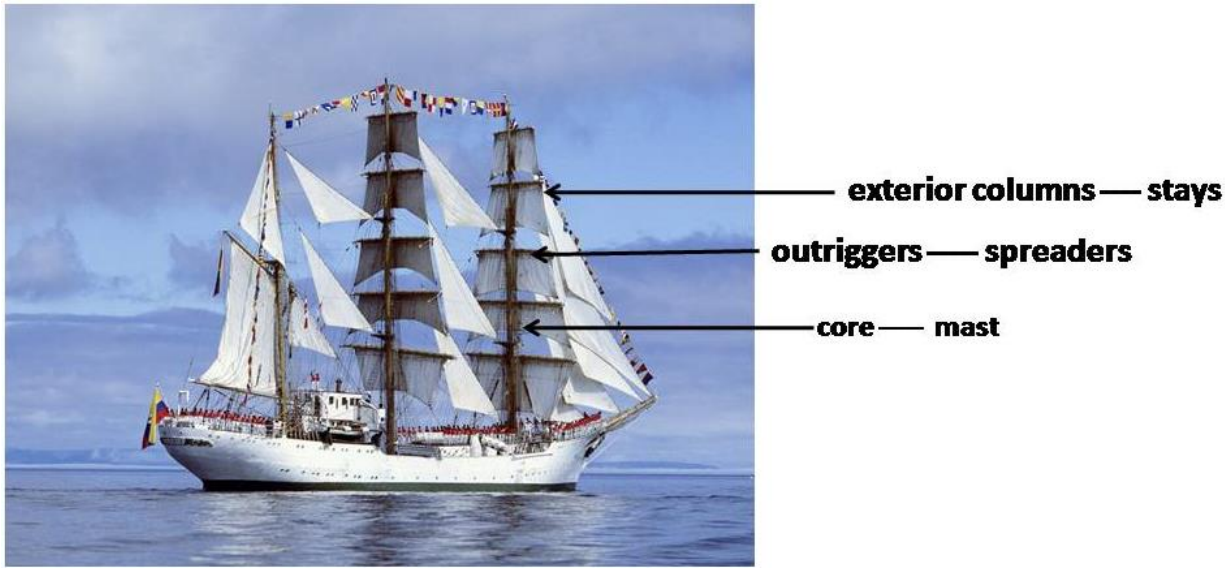

Figure 14 Historical use of outriggers

Taipei 101(2004)

Taiwan, 509 m, 101 Storied

Jin Mao Building (1999)

Shanghai, China, 421 m ,88 Stories

Figure 15 Examples

References

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- **Structural Developments in Tall Buildings: Current Trends and Future Prospects** by Ali, M.M., Moon K.S. (2007) Architectural Science Review.
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Conclusions

Finally, I'd like to conclude by stating that the structural system of high-rise building is developed and based on gravity and lateral load resisting concept. The high-rise structural system is classified into two ways: Interior and exterior system type. Interior system of structure mainly depends upon rigid frame and shear core.