The support systems of unique high-rise buildings

Victor Shumeyko[1,*]

[1] Don State Technical University, pl. Gagarina, 1, Rostov-on-Don, 344010, Russia

Abstract. Tall buildings and skyscrapers perceive significant vertical loads and, moreover, have to resist large lateral effects which form strong gusts of wind and seismic events. In the world for the high-rise buildings with the nuclei of the stiffness are using streamers – outriggers, which connect the external column and the core form the support system and resist lateral loads. High-rise buildings construction grows promptly around the world and causes new problems which shall be solved on the basis of the modern constructive opportunities, by means of exact engineering assessment. Systems of outrigers and belts are very important in the modern engineering, because they provide effective control over side shifts of a building. They play an important role in high-rise unique buildings constructions, being a link between the central kernel and outer columns. The article deals with the design scheme of conventional conveyor of belts and outriggers – bandages, explores their applications, advantages and disadvantages of various options, problems with their design. Presented material enables the design of unique high-rise buildings to choose the most optimal design solution.

1 Introduction

Today the world apply to a unique high-altitude buildings as symbols of leadership and economic power. The transition to the construction of high-rise buildings dictates the rising cost of land. At the same time modern urbanization by high-rise buildings of urban space extends in height and depth of the underground facilities. The height and depth of the buildings today is the greatest interest in the construction of large towns and cities.

The modern development of structural analysis, design and software, together with achievements in the field of the finite-element method, generated creation of a set of structural and architectural and innovative forms [1].

Regulatory restrictions in construction defines and solves some problems, and geometrical structure of basic system elements allows to define efficient design. Undoubtedly, a factor which defines design of high-rise buildings in most cases is not only tension, but also dependence on lateral movement.

There are numerous constructive systems used for high-rise buildings which counteract to lateral movement, such as: frames, girders, cross core frames, framed pipes, trusses [2], etc.

*Corresponding author: vi_shumeyko@mail.ru

2 Problem definition

The growth of high-rise construction in the leading countries of the world and in Russia stimulates the development of new technologies and materials, as well as posing new challenges [3]. These problems include:

- Development of new structural and architectural forms on the basis of an innovative approach;
- ensure of rigidity and stability of objects under the influence of significant lateral wind loads [4], and impacts from the earthquake, protect against progressive collapse.
- The problem of designing and constructing high-rise unique buildings, organization building and construction technologies;
- Provision of facilities equipment and utilities;
- Development and improvement of regulatory documents;
- and others.

In the design and construction of high-rise unique buildings and structures is very important to overcome the impact of large wind side loads [5], to minimize lateral movement, keeping the architectural forms of buildings [6].

Regulatory restrictions in construction defines and solves some problems, and geometrical structure of basic system elements allows to define efficient design. Undoubtedly, a factor which defines design of high-rise buildings in most cases is not only tension, but also dependence on lateral movement.

Currently, many structural systems used worldwide in the design of skyscrapers, which are successfully operating with the lateral loads, resisting lateral shear [7]. One of them – the use of outriggers and tape bandage of belts [8]. An outrigger are called struts connecting the core to the outer columns, which are installed on certain floors of buildings. These systems act as dampeners, reducing horizontal vibrations of the building.

Altitude outrigger reference design includes the core stiffness, coupled with the side walls of the outer columns, Shear, braced – connection systems, cantilevered trusses or beams [9].It should be noted that for all its effectiveness outrigger system creates some difficulties and challenges:

- there is the difference of the longitudinal strain of the columns and core of the building, you want to minimize;
- Is necessary to ensure a rigid connection of the columns and core of the building;
- The design of the system should be minimized in columns and cross-sectional areas of the nucleus as this greatly depends on the longitudinal load.

According to the current technology typically outriggers include work after installing load-bearing structures. This eliminates the extra effort in the outriggers and columns of uneven rainfall and the core columns.

The support system of high-rise buildings can mainly be divided into two types:

- Conventional outrigger support systems;
- Conveyor belts or bandages. In conventional systems, outrigger beams, frames or farm directly connect the core and located outside of the trunk columns of the building. Columns are usually located on the outer edges of the building. This system forms a rigid structure that provides the core elements of the joint work of the building and resistance to overturning moments. Under the action of the side, wind or seismic loads additional outrigger support includes all the elements of the work system to resist the load.

Tape belts also transmit tilting moments from the core elements of the suspension, but without direct connect directly to the core with retractable cable ties [10]. The effectiveness of such a system is provided by intermediate floor - diaphragms that create rigidity in its plane. To enhance the rigidity of the outrigger, and branded of belts fulfill their height in one or two floors. Tape belts are most often used in three types: frame, solid and truss.

3 Results and Discussion

Studies show [11, 12] that the most optimal belt belts in comparison with belts by web and solid waist are farms that have a number of benefits [13]:

1. There is no need to put outrigger beams, walls and farm buildings from the core to the outer columns. Their job is successfully executed from the farm belt bandage. A complex compound outrigger with a core and a special docking technology implementation is not required
2. There are fewer restrictions on the placement of the external columns. It is easy to select the column that will connect directly to truss belt, forming a support system.
3. Tipping points are reduced as a result of the reverse torque acting on each truss belt.
4. All external supports resist tilting moments, not only outrigger support.
5. Reduces extra stresses acting on the foundations and pillars.
6. Different longitudinal deformation of columns and nucleus is not substantially affect on waist truss design because overlapping rigid diaphragm in its plane is sufficiently flexible in a direction perpendicular to its own plane.

For example, consider two high-rise buildings in Russia with the use of outrigger system is a tower "Lakhta Center" in Saint - Petersburg and the tower "Federation" in the "Moscow – City" (moscow-city.online/build/federation/).

The tower "Lakhta center", which is 465 meters high, were designed four outriggers on technical floors, two stories high. They are located sequentially through 14 floors. The fifth atypical Outrigger as a 1.5-meter concrete slab is provided on the 82 - floor (Fig.1).

Tower as it consists essentially of four buildings set one above the other and connected by outriggers, which give spatial rigidity of the construction. The maximum deflection at the level of observation platform from the vertical at the strongest static gusts of wind is only 27 cm. The tower is able to withstand an earthquake up to 6 points.

The "Federation" complex, which includes the building of the "West" and "East", the unique building "East" in many respects dominates in Russia and Europe. It includes 97 floors, has a height of 374 meters and a four-level underground part. The main structural bearing part consists of a central core and of 25 independent perimeter colonies. According to the height of the building were designed two-storey outrigger technical floors (Fig.2). Outriggers increase rigidity of the building, provide the calculated horizontal deformation of structures and stability of the building as a whole [14, 15].

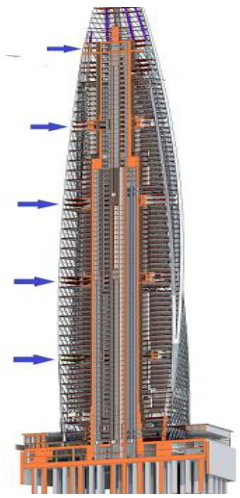

Fig. 1. Location of the outriggers of the tower "Lakhta Center" in Saint – Petersburg

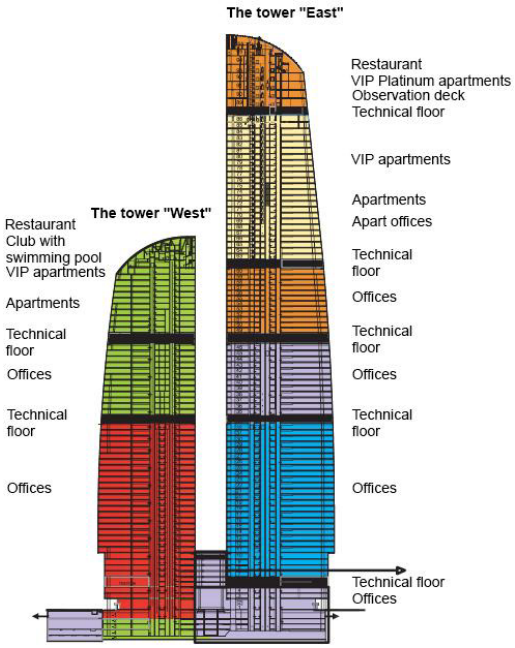

Fig. 2. The "Federation" complex, the tower "the West" and "East"

4 Conclusion

The support system will work more efficiently if solve the following questions correctly:

- selection of position of outrigger system;
- choice of the type of belts of the support system;
- consider the impact of the size of a tall building.

The effectiveness of the support system is also influenced by the rigidity of the building core and ribbon belts. A result of studying the available foreign sources can establish that for practically all high-rise buildings with a unique stiffness cores are used different types of outrigger support systems that increase the rigidity of the buildings.

References

1. K.S. Moon, Structures and Architecture: Concepts, Applications and Challenges — Proceedings of the 2nd International Conference on Structures and Architecture (ICSA), 785-790, (2013).
2. V.I. Shumeiko, Scientific review, **11(2)**, (2014).
3. V.I. Shumeyko, O.A. Kudinov, Engineers Don Gazette, (2013).
4. S. Liang, L. Zou, D. Wang, G. Huang, Wind and Structures, an International Journal, **19(5)**, 565-583 (2014).
5. Y. Zhang, P. Sarkar, H. Hu, Journal of Fluids and Structures, **50**, 547-564, (2014).
6. H. Charles, T. Thornton, H. Homan, K. Arup, M. Neville, High-rise buildings, **5**, 5-8, (2013).
7. Y. Granik, Magay Unique and special technologies in construction, **1**, 20-31, (2004).
8. V.I. Shumeyko, Scientific Review, **13**, 97-100, (2016).

9. V.I. Travush, D.V. Konin, Bulletin of Trace, **2**, 83, (2009).
10. H. Wu, J. Ding, J. Cui, B. Zhang, Journal of Building Structures, **35**, 8-15, (2014).
11. H. Wang, H. Qian, F. Fan, X. Zhi, China Civil Engineering Journal, **47**, 1-8, (2014).
12. S. Lee, A. Tovar, Engineering Structures, **74**, 122-129, (2015).
13. N.A. Chernuha, P.I. Gorelik, D.O. Lepeshkina, N.A. Chervova, Construction of unique buildings and structures, **9(36)**, 18-32, (2015).
14. K. Deng, P. Pan, A. Lam, Y. Xue, Structural Design of Tall and Special Buildings, **23(15)**, 1158-1170, (2014).
15. K. Moon, Proceedings of the 13th East Asia-Pacific Conference on Structural Engineering and Construction (EASEC), 354-355 (2013).