

# Aerodynamic Optimization and Mitigation of Wind Load For the Tall Building: Review

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**ABSTRACT:** For Investigating the corner modification and its effectiveness on wind-induced load a detailed study has been done. The purpose of this study is about the suppression of lateral load. the major factor is designing a tall building in which safety and habitability will be vital. Aerodynamic optimization is an effective technique that significantly reduces the along-wind and across-wind response. It has the potential for decreasing the effect of vortex shedding which gain attention in recent years. This paper summarises the different approach that gives effective result for designing a tall, flexible design for the building. this paper aims to deliver useful information for wind-resisting design which reduces lateral load effectively. moreover, aerodynamic optimization technic is almost 74% more efficient than aerodynamic form techniques.

**KEYWORDS:** Tall Building, Aerodynamic Optimization, Corner modification, Vortex Shedding, Lateral Load.

## I.INTRODUCTION

During the past decades, the tall building becomes a new trend around the globe because of the rapid growth of population and limited land surface area which lead to the construction of high-rise buildings. Therefore, the next generation tall building becomes more flexible, taller, slandered. The demand for residential space, economic demand, business, and new structural systems lead to a focus on the vertical development. [1]. With the height of 828m, the current tallest building in the world is Burj Khalifa located in Dubai, and the next tallest building in the world will be The Kingdom tower over the height of 1000m, (<http://www.skyscrapercenter.com/List/future-tallest-100-buildings>, 2012).

In the past several years, tall building shapes were traditionally conventional having rectangular, square, circular and triangular, etc. (e.g. World trade center (New York), 432 Park Avenue (New York)), these building shapes were less connected to seismic load due to eccentricity by torsional induced vibration, [2]. It is defined that shapes of the structures play a vital role in resistance against the lateral load so the bluff structures are more prone to resist the lateral load such studies found by Lee [3], Irwin [4], Nakamura [5]. The current trend of supertall building shapes are free-wheeling building shapes which shows by helical, opening, set-back, taper, and combination of these reflect the engineers and architects challenging spirit. Nowadays the safety of the structure is confirmed by advanced structural system and high-grade materials, As the lateral load is increased with height, it increases the concern of the lateral-induced response dynamic response.

Many investigators have been working on building aerodynamic optimizations. A pioneer work on building aerodynamics was conducted by davenport (1971) investigated shape effects by using the aerodynamic model test. The aerodynamic treatment is divided into two parts, horizontally and vertically aerodynamic treatment. Horizontal treatment illuminates modification of corner in building geometry-shape such as rounding, recessing, and chamfering, however vertical aerodynamic treatment refers the changing the section along the height of building such as set-back, opening, twisting, and tapering. Therefore, vertical aerodynamic treatment found to be more effective for across-wind load[6].

Fig 1. summarizes the widely used corner modifications in literature.

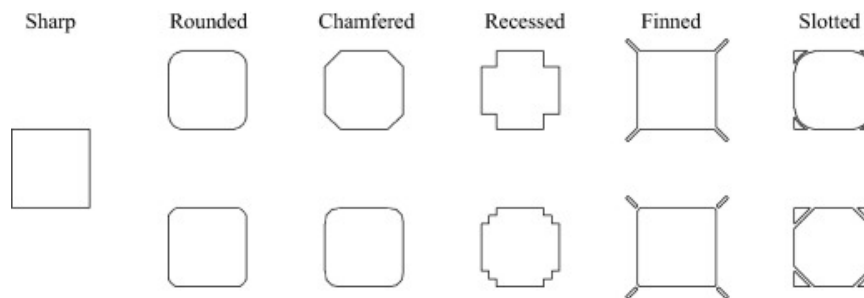


Fig. 1. Examples of tall building corner mitigations

The rectangular structure is weaker to the lateral response unlike cylindrical, elliptical, triangular shape, these shapes offer larger structural efficiency, however, wind-induced load depends on the outer shape of the structures [7].

## II.LITERATURE REVIEW

**Yi Li, Xiang Tian, et al 2018** investigated how corner modification affects the wind-induced effect by using a square, chamfered, recessed, and tapered model. study shows that along-wind side chamfered and tapered model effectively resist and show a better aerodynamic effect.

**Ashutosh Sharma, Hemant Mittal, et al 2018** investigated different geometry models likes; square, rectangular, triangular, circular, helical, and tapered. Study shows that various model with corner modification accomplishes better aerodynamic result and reduced vortex shedding.

**Chaorong Zheng, Yu Xie, et al 2018** investigated combined aerodynamic control (a combination of active and passive aerodynamic control) study shows that the chamfered model has better aerodynamic control in along-wind excitation and tapered model effectively resist across-wind excitation.

**Chaorong Zheng, Zhao Liu, et al 2018** investigated that vortex shedding increases at a 60-degree wind angle for supertall building and aerodynamically coupled vortex shedding increases along-wind excitation and across wind excitation both.

**Yong Chul Kim and Jun Kanda 2013** investigated vortex shedding on the conventional square model with set-back, tapered, and chamfered shapes. Studies reflect that the mean-pressure coefficient is different throughout the structure so vortex shedding phenomenon formation moves upside by pressure.

**(Xie et al., 2009; Xie, 2012)**. when twisting angle increases it increases the effectiveness. However, by taking into consideration of both aerodynamic benefits and potential difficulty for the cladding system, the designers were convinced that the 1201 twist version with top openings for turbines should be the overall best one for twisted building, which represents about 15% reduction of design wind loads compared with its original configuration of 1001 twist.

**(Browne and Kumar, 2005)** Investigates some commonly used techniques of corner modification. To confirm the effectiveness of these corner modification, a thumb rule is taken is about the dimension of corner modification should be 10% of building width. The strategy of corner balconies could be looking for an aesthetical alternative to conventional helical strikes which are normally used to prevent vortex excitation. Some research illustrates that's commonly design balconies significantly reduce vortex shedding and lateral loading.

### III. METHODOLOGY

#### General approach of aerodynamic optimization

##### 3.1. Along-wind and Across-wind response

In tall structures, wind-resisting design is important to identify the different wind response that affects the lateral design. For mega-tall structures, it is found that across-wind response governs the design factor, and sometimes it causes excessive vibration in terms of structure's serviceability.

The main factor which dominates the across wind-load in mega-tall building is illustrated in fig. 2. Demonstrates the typical across-wind spectrum comparison with an along-wind force spectrum. The along-wind force spectrum primarily reflects the wind turbulence properties, and the across-wind force spectrum is determined by flow separation and vortex formation, known as "signature turbulence". If both can be compared then across-wind response is highly sensitive to wind speed. When the wind speed is lower or normal the along-wind load effectively dominant but when the wind speed increases the across-wind load highly sensitive.

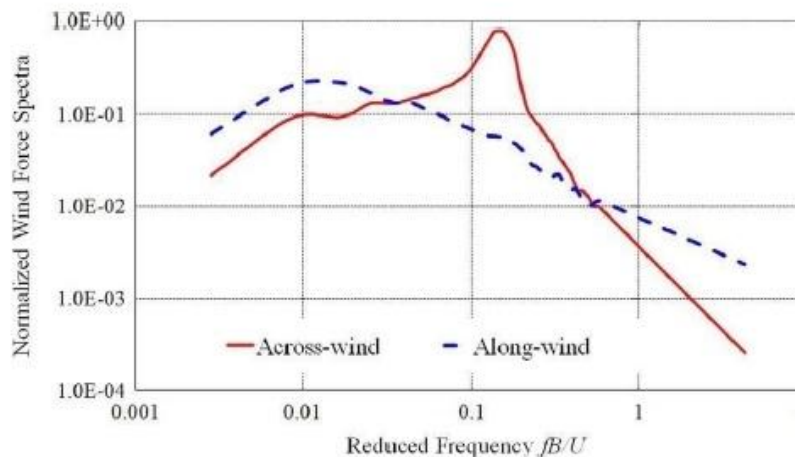


Fig.2. (Jiming Xie 2014)

For Optimization of across-wind response two basic approaches can be used:

1. If the magnitude of vortex excitation reduces by modifying the cross-section of the structure such as recession, opening, and rounding.
2. Reducing the synchronization and correlation of fluctuation forces by changing the shape of building with height such as twisting and tapering.
3. Across-wind dynamic behavior is a significant source that creates excessive wind loading and distress motion for mega-tall building.

The most common source of across-wind excitation is vortex shedding generally bluff kind of structures are vulnerable in severe wind flow which more exposure of the structure makes it weaker. At low wind speed, the vortices shed are flowing symmetrical manner and it will be safe from unnecessary force from the lateral direction. But at high wind speed Vortices shedding become unsteady and vortices shed alternatively around the exposure of the building. The alternative vortices shed create asymmetric pressure on the lateral and side faces of the structure and increase the periodic transverse forces.

##### 3.2. Geometrical modification

A well-recognized example of aerodynamic modification on building geometry is Taipei 101 tower, the cross-section of the building has to be square but when the wind tunnel test performs a corner recession techniques developed which reduce the over-all design load about 25%.



Fig.3. (Jiming Xie 2014)

The aerodynamic optimization approach would be apart when along-wind or across-wind responses have been dealing together. However various approaches that give benefit both, many approaches focus on one and many. For along-wind response optimization, the normal approach is to decrease the drag coefficient by modifying the structure's corners, like making corner chamfering, rounding, and recessing. opening is sometime a feasible option for reducing wind force. By the use of tapering effect in across wind response, since the vortex shedding is inversely proportional to the structure width it is varying building height so that huge frequencies expand over them wide-angle so its effect significantly reduced.

While aerodynamic modifications bring in benefits of reduced design wind loads and building motions, these modifications often create conflicts with other design aspects. A good design has to compromise many design aspects. For this reason, it is important to have an approach to estimate the level of effectiveness for various aerodynamic options, so that the pros and cons of these options can be assessed and compared with each other.

However aerodynamic modification gives benefits and decreases design load and building motion. All these modifications sometimes create conflict with other designs. So the pros and cons of all aspects must be discussed and compared with each other.

#### IV.RESULT & DISCUSSION

Corner modification generally aimed to decrease wind-induced load, it is founded that the shape of the structure plays a vital role in decreasing lateral load and response of the structures. During Taipei, 101 wind tunnel test corner recession decrease the lateral load about to 25% of its design load.it is also investigated that single and double recessed corner with 7.5 % recessed ratio gives the best result in terms of reduction in load or modification both. Providing chamfering in structures about 10% can decrease 40% along-wind response and 30% across-wind response. In terms of CFD andANN, modeling result shows that using optimal corner modification mean drag coefficient reduced 30%.in high rise structure it is investigated that the chamfering model gives the reduction in load approx. 40% along-wind response and 30% across-wind response. Providing slots in corner decreases the base moment by 30%.

#### V.CONCLUSION

For mega-tall building design, aerodynamic optimization of building shape is a key part. In this paper, corner modification discussed however these modifications mostly involve with architectural design and structural shape. Shape of the building governed by site condition architectural and engineering finding and also an economical aspect. Although aerodynamic modification significantly decreased wind-induced load and usually Eliminated. Aerodynamic optimization having through major or minor changes in the shape of the building which disturbs the vortex shedding phenomenon minor modification increases shear layer reattachment and narrow down the wake width which directly

affects the lateral forces and the result shows 30-60% decrease the wind load. Major modifications mostly affect the vortex shedding pattern throughout its height.

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