

## Full Paper

# Behaviors of the Curtain Wall Façade in the Tall Building Under Dynamic Actions- An Overview and Recommendations

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### Abstract

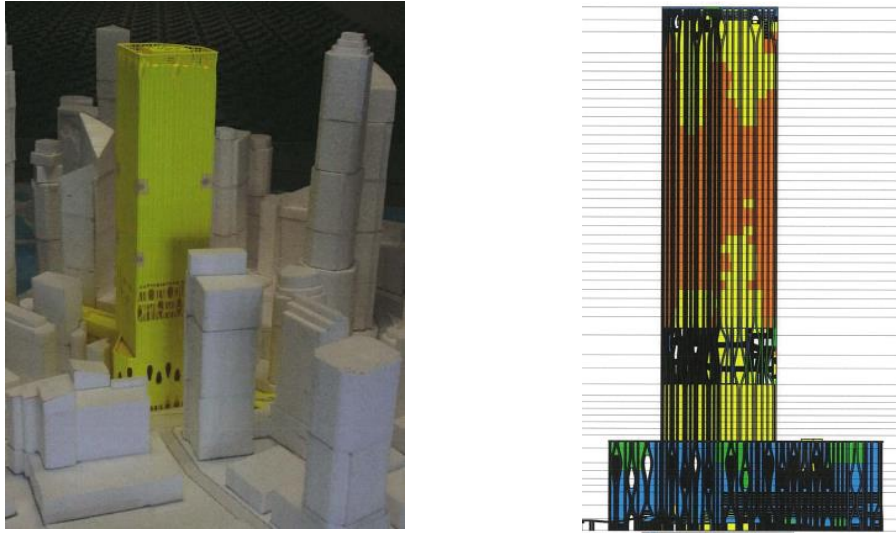
The flourishing growth of tall building construction with advanced technologies adopted façade structures is the new trend around the world. This study is mainly focused on the design and construction techniques of the curtain wall façade system and its behaviors under dynamic actions. Generally, a unitized curtain wall system is used as a building lope in the tall building due to its faster installation techniques. The provision of stack joints is a crucial part, especially at the design stage to accommodate the horizontal and vertical movement of the tall building under cyclic wind and seismic action. The effect of the deflection, story drift index, and column shortening of the tall building is analyzed using Finite Element Analysis (FEA) with 41 store building model on the façade wall is well discussed and recommended suitable measures to increase the life span of the façade wall under heavy dynamic repeated loading. On the other hand, lateral torsional buckling of the mullion, especially for the long span plays a vital role in the material and cost of the curtain wall panel. Therefore, this study is focused on the provision of the Anti-Buckling Clip (ABC) to increase the lateral torsional buckling capacity as well as flexural buckling capacity without increasing the stiffeners of the mullion.

**Keywords:** Stack Joint, Curtain Wall Façade, Anti-Buckling Clip, Lateral Torsional Buckling

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### Introduction

The curtain wall façade is used as a building envelope in the construction industry to achieve the expected aesthetic view of the tall building with an acceptable level of comfort in the interior environment with accommodating the following important properties, such as; fire protection, required ventilation, weather protection, static and dynamic load resistance [1]. In addition, the façade wall should act as a barrier structure to avoid people falling from height [2]. Also, important considerations are to be given to the façade structures at the design, fabrication, construction, and operation stages to avoid unforeseen failures due to heavy cyclic loading due to wind and seismic loading [3]. It is important to consider the vortex shedding and funneling effect of the cross-wind action, especially due to twin or more tower construction at certain spacing, and this type of building arrangement develops the critical dynamic wind forces in the building envelope including torsional effect [4]. Therefore, wind tunnel tests and simulations are to be performed to obtain the actual behaviors of the building façade and wind pressures along the facade structures as shown in Figure 1[5].



**Figure 1.** Wind tunnel test arrangement and variation of the wind pressure along the facade

In order to prove the structural stability and adequacy of the materials' strength, VMU (Visual Mock-Up) and PMU (Performance Mock-Up) are to be developed and testing is to be carried out under dynamic load action. Curtain wall façade can be categorized as Unitized Curtain Wall (UCW) and Stick Curtain Wall (SCW), based on the fabrication and installation procedures as shown in Figure 2. The whole unit of the UCW panel is fabricated at the factory (including mullion, transom, and, glass) and installed the whole panel at a specified location of the building, for SCW, the frame (mullion and transom) is fabricated and installed the frame at the site without glass panel. Glass panel will be fixed after completion of the frame installation and this type of curtain wall is normally used for the low-rise building [6][7].



a) UCW

b) SCW

**Figure 2.** UCW and SCW curtain wall setup

Curtain wall façade should be designed to withstand the self-weight of the panel, wind load, seismic load, and barrier load, and structural adequacy should be ensured through the following design checks under serviceable and ultimate limit state [8][9]. Such as;

- a) Flexural capacity check
- b) Shear capacity check
- c) Lateral Torsional Buckling capacity check
- d) Deflection check
- e) Axial load carrying capacity check

Generally, a curtain wall panel is designed as a simply supported beam and the top or bottom of the panel is hooked to transfer the self-weight and the other end is resisted horizontally to avoid the movement of the structure. Also, sound transmission and energy efficiency of the curtain wall system is ensured the after installation of the façade wall [10][11].

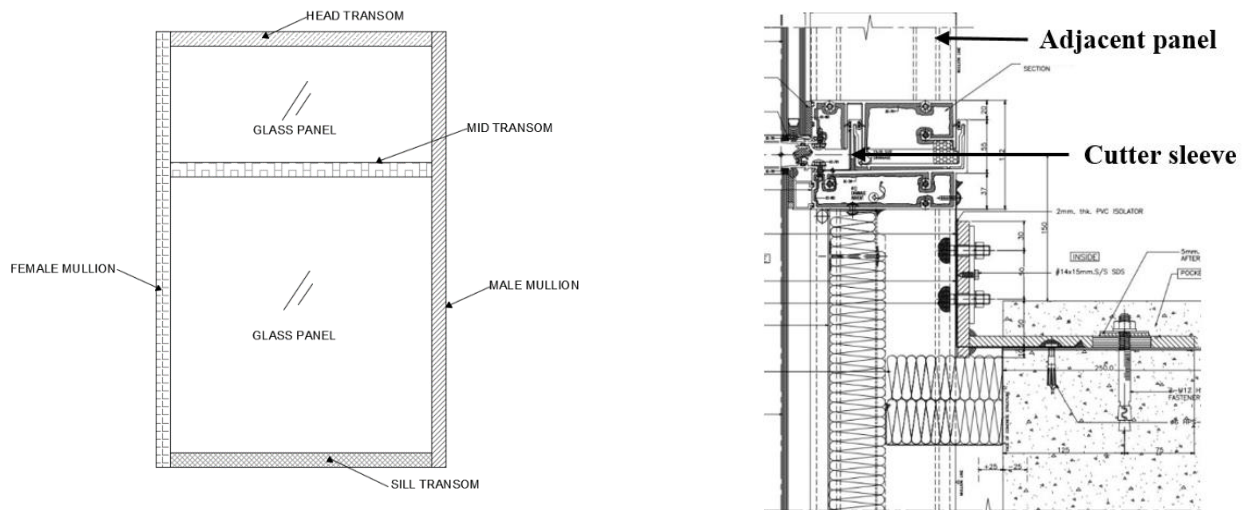


Figure 3. Curtain wall arrangement with fixing detail[12]

This curtain wall system mainly acts as a barrier structure, therefore curtain wall panels should be checked against to the barrier load, such as; line load, area load, and point load to ensure structural adequacy and safety against falling from height. In addition, the load-resisting capacity of the glass panel is to be assessed under the above-mentioned loading to ensure the safety of the structures [13].

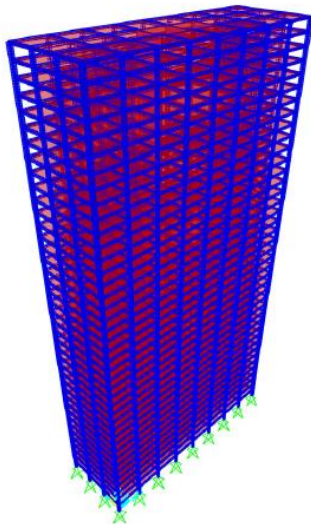
Table 1. Barrier load with building occupancy class [14]

Building Occupancy Class	Design Loads		
	Line load in kN/m run applied 1100mm above finished floor level	UDL in kN/m <sup>2</sup> applied to the whole of the infill panel below the line load height	Concentrated load in kN applied to any part of the infill panel below the line load height
1	0.36	0.5	0.25
2	0.74	1.0	0.5
3	1.5	1.5	1.5
4	3.0	1.5	1.5

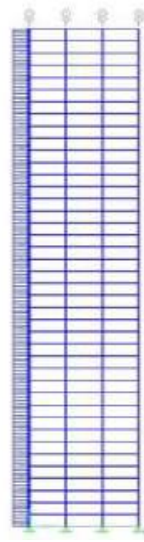
Also, a barrier load should be applied at 1m height from the finish level of the floor and generally 0.74kN/m line load is applied to the curtain wall panel. The strength and deflection are checked with possible combinations of other lateral loads.

**Factors to be considered in the curtain wall design**

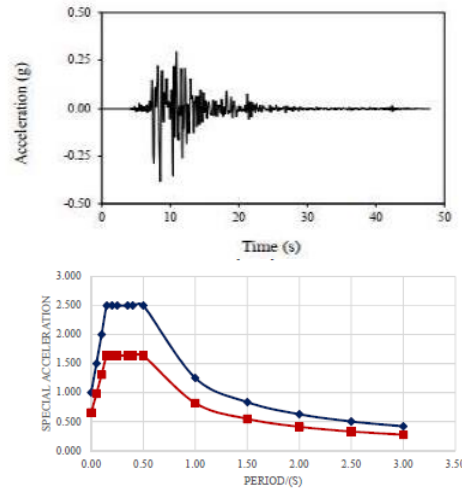
Deflection and storey drift index of the tall building play important roles in the curtain wall design. In this study, 41 storey building with 133.25m height was considered under wind and seismic action. Also, a double-shear core with a framed envelope was taken into consideration as shown in Figure 4. The wind load on the building was calculated based on Eurocode and seismic action was applied using available ground motion data as shown in Figures 5 and 6 [15][16][17].



**Figure 4.** Building arrangement

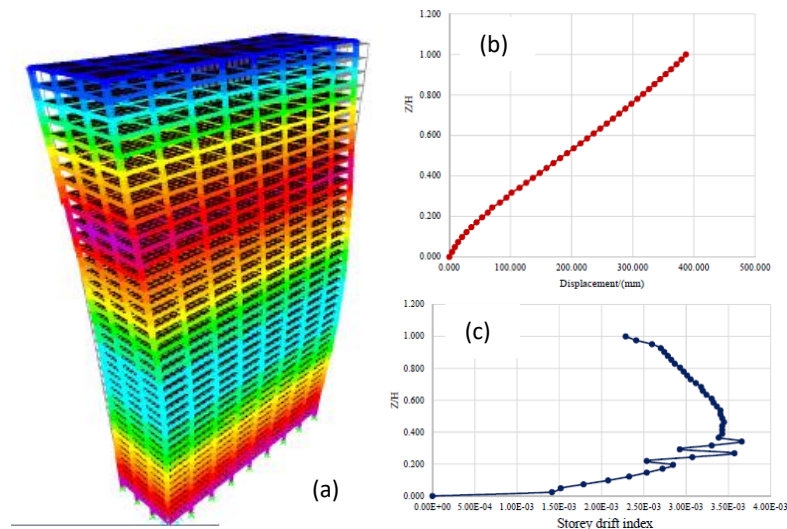


**Figure 5.** Wind action

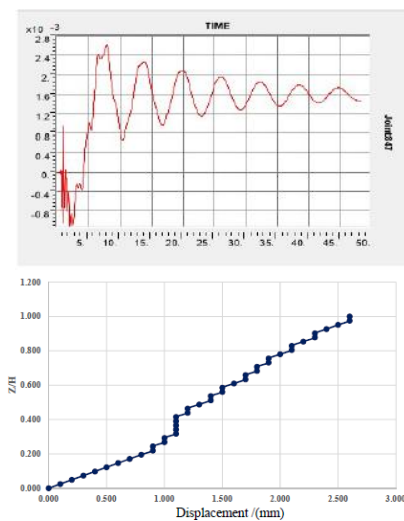


**Figure 6.** Ground motion data

Figures 7 and 8 show the variation of the deflection and storey drift index with building height for the wind and seismic action. Based on the outcomes, it is proven that deflection and storey drift index is dramatically changed with the building height and these parameters are greatly affecting the performance of the building envelope. Therefore, the provision of the stack joint with the required amount of spacing to accommodate the horizontal and vertical movement under lateral loading is shown in Figure 9.



**Figure 7.** Deflected mode (a), variation of displacement (b) and variation of storey drift index(C) under wind load



**Figure 8.** Variation of displacement under seismic load



In addition to the deflection and storey drift index, the following parameters are also, to be considered in the stack joint design of the curtain wall to avoid failures [18][19].

- a) Deflection of the slab and beam (p)
- b) Column shortening (q)
- c) Thermal expansions of the members[20] (r)
- d) Installation tolerances (x)
- e) Fabrication tolerances (y)

Improper design of the stack joint leads to cracks and damage on the glass panel as well as the curtain wall frame. The required spacing on the stack joint calculation can be represented by Equation 1.

$$\text{Minimum stack joint spacing} = p + q + r + x + y \quad \text{Equation 1}$$

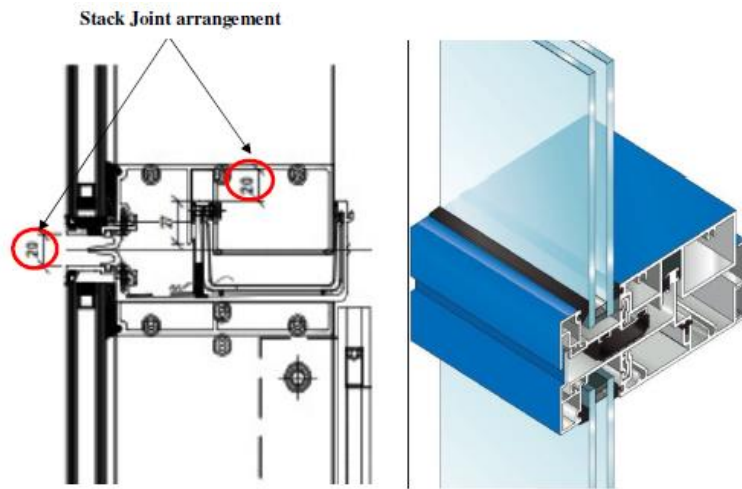


Figure 9. Stack Joint arrangement of the curtain wall

Therefore, the provision of vertical and horizontal stack joints with adequate spacing is one of the key design considerations at the time of design stage.

### Recommendations

Structural adequacy and cost of the structures play a vital part in the curtain wall façade design and more thickness is to be added to the mullion profile to satisfy the lateral torsional buckling capacity of the male and female mullion. The following techniques have been adopted in the curtain wall system to improve the structural load-carrying capacity under lateral loading.

- a) Provision of the horizontal transom with adequate spacing
- b) Provision of “Anti-buckling clip” between male and female mullion as shown in Figure 10

The provision of an “Anti-buckling clip” in between the male and female mullion act as a combined structure along the minor axis and becomes stiffened than the individual profile along the minor axis and also introduces the “Anti-buckling clip”, reducing the effective length of the mullion along the minor axis. The stress variation of the mullion profile was analyzed under lateral loading and the provision of the transom and Anti-buckling clip location can be decided accordingly as shown in Figure 11.

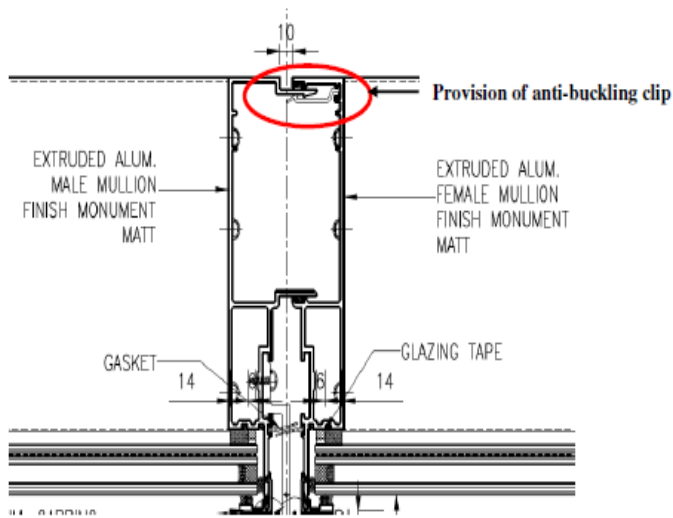


Figure 10. Provision of the Anti-buckling clip

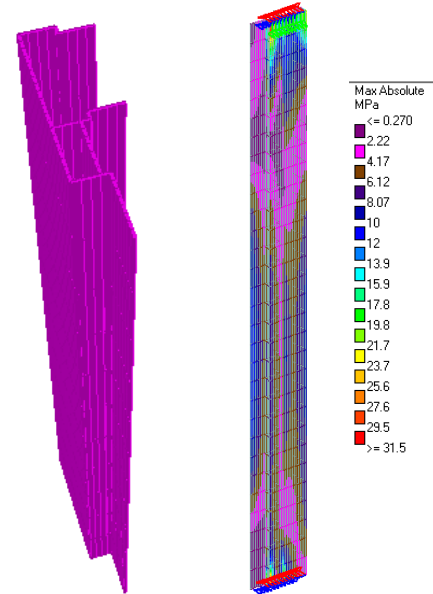


Figure 11. Stress pattern of the mullion

## Conclusion

Inadequate design of the curtain wall system leads to unforeseen failures under lateral loading. Therefore, detail analysis of the curtain wall façade is important using wind tunnel test outcomes and CFD simulations to obtain the more accurate design outputs. The provision of the transom with adequate spacing and Anti-buckling clip are highly recommended improve the lateral torsional buckling capacity of the mullion without increasing the profile thickness. The horizontal and vertical stack joint are important, and stack joint gap should be designed with the consideration of all the design parameters to avoid cracks and damage on the glass panel, mullion, and transom profile.

## Conflicts of Interest

Author declare that, no conflicts of interest.

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