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Analysis of Facade Structure Used at Cuise Terminal

Prathamesh Patil[1], Snehit Savadi[2], Satyajeet Shinde[3], Shivam Deokate[4], Dr. P.B.Nangare[5]

[1]*Student of Civil Engineering Department at Aissms College of Engineering, Pune.*
[2]*Student of Civil Engineering Department at Aissms College of Engineering, Pune.*
[3]*Student of Civil Engineering Department at Aissms College of Engineering, Pune.*
[4]*Student of Civil Engineering Department at Aissms College of Engineering, Pune.*
[5]*Head of the Department, Civil Engineering Department at Aissms College of Engineering, Pune.*

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Abstract - The external building envelopes, or facades, affect the interior atmosphere and user comfort in addition to improving the building's appearance. They provide a partition between the interior and the outside world. Various technologies are employed to increase lighting and ventilation, lower energy consumption, and make facades more ecologically friendly. Windows and facades, which serve as a physical barrier between interior and exterior spaces, are among the most delicate and vulnerable parts of buildings because of their comparatively low tensile strength and generally brittle behavior when compared to other conventional materials, as well as a variety of interconnected structural and non-structural elements. In order to prevent casualties and injuries in the event of failure and to ensure appropriate safety levels, multidisciplinary approaches, as well as specific fail-safe design criteria and analysis methods, are necessary, particularly under extreme loading conditions. The unitized curtain wall system is new in the construction industry compared to the RCC structure and steel structure. The curtain wall system has been developed over the years into an innovation of a highly engineered design. The MICT terminal's façade is designed to provide a modern, aesthetic appeal while ensuring functionality and durability in Mumbai's coastal environment. The façade system contains corrosion-resistant materials, such as glass and aluminum, which are made to withstand high salinity levels and monsoon conditions.

***Key Words*:** Façade, Lightening and Ventilation, Structural and Non structural Components, Steel Structure, RCC structure, Aluminium, Glass.

1.INTRODUCTION

There has been a pressing need in recent years to reduce energy consumption, and one of the sectors with the largest consumption is the building sector. However, both active and passive building design options have the ability to reduce energy consumption. Here, we pay particular attention to the building envelope and how it might achieve energy efficiency while adjusting to changing weather and climatic circumstances. About 80% of an environmental reaction is contained in the enclosed structure, resulting in a safe construction that integrates with its surroundings. Dynamic facades are much more multipurpose; they regulate ventilation, lighting, and heating and cooling loads. The modified facades promote daylighting and make the best use of natural ventilation. Additionally, the energy of the building can optimize the systems' energy use and give consumers favorable indoor conditions. The technological and environmental features of sustainable building skins, as well as their significance in addressing environmental needs, are examined in this research along with applications in different climate zones.

The sustainability performance of a building is greatly influenced by its façade, which is its outermost layer. In addition, it serves as a filter between indoor and outdoor spaces, controlling temperature, creating breezes, and purifying air and water to promote energy efficiency and public health. Reducing the overall bulk and orientation of the main facades and roof surfaces is the first step towards making a building facade sustainable. Furthermore, several strategies have been used in contemporary building envelopes to reduce the energy needs of the building systems. Modern facades can save a lot of energy by utilizing sustainable materials, integrating plants with the facade, optimizing daylighting to generate solar and wind energy, and utilizing smart and adaptive devices.

1.1 Objectives

- To Analysis Dead Load, Live Load, Wind Load acting on Semi Unitised Curtain Wall (SUCW) Façade System.
- To calculate deflections of building due to wind loads by SpreadSheet.
- To Validate the result by using STAAD-Pro software.

1.2 Need for Study

Cruise terminals are critical infrastructure facilities that require robust and reliable structures to withstand various environmental loads. Semi-unitized curtain wall facade systems pose unique design challenges due to their complex geometry, material combinations, and load transfer mechanisms. Cruise terminals are often located in coastal areas prone to seismic activity and high winds, necessitating careful consideration of facade design. Optimizing facade design can significantly impact energy efficiency and sustainability, reducing operational costs and environmental impact. Efficient facade design can minimize construction costs, reduce installation time, and enhance maintainability. A well-designed facade ensures passenger safety and comfort, critical factors in the cruise industry. Investigating new materials and technologies can enhance facade performance, sustainability, and aesthetics.

1.3 Limitation

Cost: Curtain walls can be more expensive to install and maintain compared to other types of building envelopes, such as masonry or concrete walls.
Weight: Curtain walls can be relatively heavy, which may require additional structural support and increase construction costs.
Leaks: Curtain walls can be prone to leaks if not properly installed or maintained, which can lead to water damage and other issues.
Thermal performance: Curtain walls may not provide as much insulation as other types of building envelopes, which can result in higher heating and cooling costs.
Aesthetics: Some people may not like the appearance of curtain walls, as they can be perceived as cold and impersonal.
Complexity: Curtain walls can be complex systems that require specialized knowledge and skills to install and maintain.
Maintenance: Curtain walls may require more frequent maintenance and cleaning compared to other types of building envelopes.

2. Analysis of Facade

2.1 About Facade

The MICT terminal's façade is intended to offer a contemporary, aesthetically pleasing appearance while guaranteeing longevity and functionality in Mumbai's coastal setting. The façade system uses materials that are resistant to corrosion, such as glass and aluminum, and are made to endure monsoon conditions and high saline levels. Thermal insulation, soundproofing to improve passenger comfort, and glass components for natural light are important technological components. It is anticipated that this cutting-edge façade design would save maintenance expenses and increase energy efficiency. Large glass panels, aluminum cladding, and unique façade modules that represent the terminal's current architectural goals are being installed by specialist contractors.

An important component of the Mumbai International Cruise Terminal's (MICT) architectural and technical design is the Steel and Unitized Curtain Wall (SUCW) façade system. This cutting-edge façade solution is essential to guaranteeing that the terminal satisfies strict requirements for robustness, energy efficiency, and visual attractiveness. This is a detailed examination of the SUCW façade system and its significance within the MICT project.

2.2 Comparison Between Conventional Type of Structure and Facade Structure

I] Conventional Structure

A conventional structure typically refers to the traditional, load-bearing system used in building construction. It focuses on the overall integrity and function of the entire building framework.

Features:

• Load-Bearing: Traditional constructions are made to support loads directly through the walls, columns, and beams that comprise the building's framework. These loads can be dead, living, or environmental, like wind or snow.
• Materials: Conventional structures are usually composed of brick, steel, concrete, or wood, and their design takes into account the fact that these materials are necessary for both structural stability and aesthetic appeal.
• Efficient and Functional: The exterior shell, or facade, and the structural system both have functional roles in traditional structures. The building's exterior performance and appearance are interwoven with its structure.
• Cost: Because conventional buildings don't require extra complexity like facade treatments or non-structural aesthetic components, they are frequently more affordable.

Examples:

1. Residential homes built with timber frames or concrete slabs.
2. Commercial buildings with steel or concrete frame systems that form the load-bearing structure and exterior walls.

Advantages :

- Simple, proven design and construction methods.
- Efficient in terms of load distribution and building performance.
- Cost-effective for buildings where functionality and basic aesthetics are the main goals.

Disadvantages :

- May lack aesthetic flexibility; the structure and appearance are more integrated and can feel less "customizable."
- Not ideal for creating dramatic or non-traditional facades.

II] Facade Structure

The external or outer envelope of the building is the primary emphasis of a façade construction, which isolates the interior's functional elements from its visual identity. The facade, which frequently serves as a non-load-bearing skin, may or may not support the building's structural load-bearing function.

Features:

• Non-Load Bearing (generally): Unlike the main structural framework, facade structures are normally lightweight, non-load bearing components. They primarily shield the structure from external elements including noise, temperature, and weather.
• Aesthetic Focus: Facades are frequently made to offer a certain appearance, which raises the building's architectural appeal. This might contain components that are not essential to the building's structural purpose,

such as stone, glass, or aluminum panels.
• Envelope Design: The building's exterior and inside are shielded from one another by the facade structure. Features like windows, ventilation, or insulation may be included, and occasionally ornamental accents are added.
• Material Flexibility: Facade materials come in a wide range and are frequently selected for their visual appeal rather than their structural soundness.

Examples:

Curtain walls in skyscrapers: a non-load-bearing facade made of glass and metal that is hung from the building's frame.

Cladding systems: exterior covering (metal, wood, stone, or composite materials) applied to the outside of a building that acts as a protective layer but does not bear structural load.

Advantages :

High degree of aesthetic customisation; capable of producing distinctive, eye-catching designs; frequently enables improved light management, insulation, and energy efficiency, particularly in contemporary designs.
Capable of producing architecturally intricate structures that conventional load-bearing walls would not be able to.

Disadvantages :

Involves additional costs in design, materials, and construction.

Not structural in itself, so it depends on a supporting structural system (e.g., steel or concrete frame) to hold it in place.

Maintenance can be more intensive, especially for facades made of glass or complex materials.

2.3 Essential Elements of SUCW Façade

Superior Sturdiness and Resistance to Corrosion: Because MICT is close to the sea, the materials used for the façade must be able to withstand deterioration from the salty winds and moisture. The SUCW system's steel and aluminum are coated and treated to improve their resistance to corrosion, and the unitized glass panels are made to endure extremes in temperature and UV radiation. This reduces upkeep and guarantees that the façade will continue to be both aesthetically pleasing and structurally sound over time.

Thermal Insulation and Energy Efficiency: The MICT SUCW system is intended to maximize the terminal's energy use. By reflecting heat and lowering solar gain, the high-performance glass with low-emissivity coatings found in the unitized curtain wall panels helps control indoor temperatures.

Fast Installation and Modular Assembly: The modular design of the unitized curtain wall system is one of its benefits. Because the panels are preassembled off-site, quality control and high-precision production are made possible. This reduces installation time and on-site personnel, which is essential in the quick-paced MICT project with short turnaround times. The modular design of the SUCW system also makes it simpler to replace individual panels, which enhances flexibility and maintenance over time.

Integrity of Structure and Seismic Resistance: For a big, open structure like the cruise terminal, further structural support is provided by the steel and aluminum framing in the SUCW system. The technology gives the terminal a strong, durable exterior by being designed to withstand wind loads, torrential rain, and even seismic activity.

2.4 Building Parameter

Height of the Building : 23.00 m

Length of the Building : 253.00 m

Width of the Building : 43.00 m

Dead Load Calculation :

Dead load due to glass, aluminium, & steel

Req. data :

Height of the Building : 23.00 m

Length of the Building : 253.00 m

Width of the Building : 43.00 m

Thickness : 17.52 mm

Glass Length & Width :

Length : 3235 mm Width : 1250 mm

Density of Aluminium : 27.1 KN/m^3

Density of Glass : 25KN/m^3

Density of Steel : 77 KN/m^3

1. Load due to Glass

D.L = Sectional area x length x density

D.L = 3.2 x 0.01752 x 1.250 x 25

D.L = 1.7 KN

2. Load due to Aluminium

D.L = 0.02 x 0.015 x 1.250 x 27.1

D.L = 0.04 KN

3. Load due to steel

D.L = 0.15 x 0.1 x 1.25 x 77

D.L = 1.44 KN

Total D.L = 1.7 + 0.04 + 1.44

= 3.18 KN

Wind load calculation :

Wind pressure study for the various components & cladding elements of the proposed project is based on design wind speeds derived from the 50-year return period with wind speed of 44 m/s defined in accordance with IS 875 Part 3 2015: Design loads (other than earthquake) for buildings and structures– Code of Practice Part 3– wind loads.

INPUT DATA:

Design Life – 50 years

Basic wind speed – 44m/s (Loc. : Mumbai, Maharashtra)

K1 – Risk coefficient = 1.0 (clause 6.3.1, Table 1)

K2 – Terrain, height, structure size factor (Category 1 exposed open terrain with few or no obstructions and in which the average height of any objects surrounding the structure is less than 1.5m)

K3 – Topography factor = 1.0 (clause 6.3.3.1)

K4 – Importance factor = 1.0 (clause 6.3.4)

(As per IS 875: Part 3, Clause 7,)

Design wind speed (Vz)

Vz = Vb x K1 x K2 x K3 x K4

Basic wind pressure (Pz)

Pz = 0.6 Vz^2

For Height : 7.10m

Vb = 40m/s

K1=1

K2=1.05

K3=1

K4=1.15

Vz = 53.15 m/s

Pz= 1.68 KN/m^2

Design wind pressure

Pd = Ka x Kd x Kc x Pz

Kd = wind directionality factor = 1 for corner & 0.9 for surface (cl.7.2.1)

Ka = area averaging factor = 1 (cl.7.2.2)

Kc = combination factor = 0.90 (cl.7.3.3.13)

Pd= 1x1x0.9x1.68=1.51 KN/m^2 (Corner)

Pd=0.9x1x0.9x1.68= 1.37 KN/m^2 (surface)

Net Design Wind Pressure = (Cpe - Cpi) x Pd

Note: From table 5 of IS 875: Part 3, External coefficient is provided and as per clause 7.3.2.2, the Internal Pressure Coefficient, Cpi = +/- 0.50 is provided.

Net Wind Pressure : 2.30 m (corner)

Net Wind Pressure : 1.60 m (Surface)

For Height = 24.40m

Vb = 40m/s

K1=1

K2=1.05

K3=1

K4=1.15

Vz = 57.18 m/s

Pz= 1.93 KN/m^2

Design wind pressure

Pd = Ka x Kd x Kc x Pz

Kd = wind directionality factor = 1 for corner & 0.9 for surface (cl.7.2.1)

Ka = area averaging factor = 1 (cl.7.2.2)

Kc = combination factor = 0.90 (cl.7.3.3.13)

Pd= 1x1x0.9x1.93=1.76 KN/m^2 (Corner)

Pd=0.9x1x0.9x1.93= 1.59 KN/m^2 (surface)

Net Design Wind Pressure = (Cpe - Cpi) x Pd

Net Wind Pressure : 2.85 KN/m^2 (corner)

Net Wind Pressure : 1.90 KN/m^2 (Surface)

2.5 Deflection Due to Wind Load

Mullion Analysis

Allowable Deflection : Span/180

4362/180=24.23mm

Maximum Deflection Due to Wind Load : 12.9mm

24.23>12.9 …….ok

Transom Analysis

Allowable deflection : 3mm

Maximum Deflection Due to Wind Load : 1.736

3>1.736…….ok

3.CONCLUSIONS

The structural analysis of facade structures is crucial to ensure the safety, durability, and aesthetic appeal of buildings. By understanding the loads, stresses, and strains acting on the facade, engineers can design and optimize the structure to withstand various environmental and operational conditions. As building design and construction continue to evolve, facade structures will play an increasingly important role in achieving sustainability, energy efficiency, and aesthetic appeal. Future research and development should focus on:

1. Innovative materials: Developing new materials and technologies that can improve the performance, sustainability, and aesthetic appeal of facades.
2. Advanced analysis techniques: Developing more sophisticated analysis and simulation techniques to better predict facade behavior and optimize designs.
3. Integration with building systems: Integrating facade design with other building systems, such as HVAC and electrical systems, to create more efficient and sustainable buildings.

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