



# A Note on the Structural Assessment of Perforated Panels used in Façade

Muhammad Tayyab Naqash<sup>1\*</sup>

<sup>1</sup>Department of Civil Engineering, Islamic University of Madinah, Saudi Arabia.

## Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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## ABSTRACT

Different materials such as glass and composite cladding panels are common in the façade industry due to their architectural appearance. The direct sun rays enter the building and might produce discomfort to the occupants, especially in office and institutional buildings. Nowadays, perforated panels are widely used in facades and becoming more popular in the middle east. These panels are a formal exploration inspired by the Islamic patterns used in traditional Mashrabiya. This paper provides an overview of the application of Mashrabiya "perforated panels" and present structural assessment using software codes such as Robot and SAP2000 for vertical and horizontal installed cases. These panels are fabricated in different sizes with different thicknesses depends on their applications and uses. In this paper, rectangular, square fixed at the roof and vertically fixed panels are assessed. These are usually supported by steel or aluminium tubes designed for a wind load specified by project specifications. The cases presented here for the perforated panels are checked for the induced stresses and deflections obtained from the numerical model using shell elements. The adopted framing systems and fixing detailing has been found satisfactory according to different acceptance criterion. The paper gives helpful design tools for the façade engineers.

**Keywords:** Mashrabiya; perforated panels; aluminium sheets; decorative panels; façade; curtain wall; structural assessment; Islamic art; Islamic architecture.

## 1. INTRODUCTION

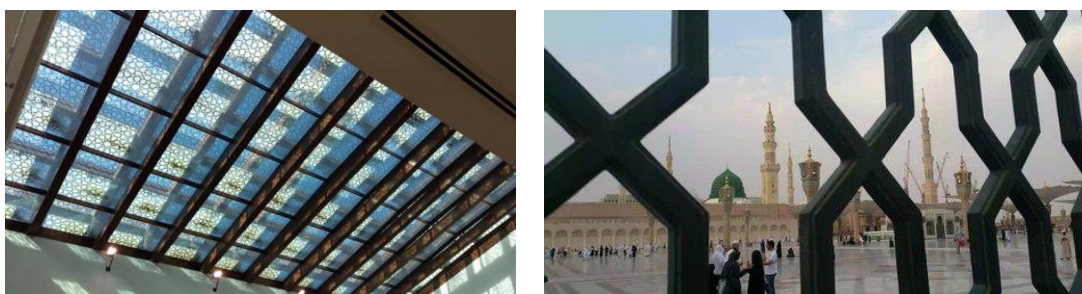
### 1.1 General

Curtain walls are considered an envelope of transparent material to allow admittance of sunlight and are generally supported by lightweight material such as Aluminium. It keeps the weather out and the occupants in. The applications of perforated metal panels in modern, cultural, and Islamic architecture are the most prominent. It includes but is not limited to facades' cladding, decoration of interiors, covers of columns, furniture, balustrades, staircases design, and arrangement of protective walls and enclosures [1-3]. In addition to decorative aesthetic design, it provides architects with additional benefits such as sunshade, noise reduction, lightweight fencing, energy-saving, and access control. Perforated facades amaze with their diversity and artistic imagination. These panels are used to decorate commercial buildings and social infrastructure, which create privacy for the occupants. These panels may perform a significant role in regulating temperature and air ventilation of buildings and a dosed light permeability providing illumination from outside [4-8]. Some practical applications of perforated aluminium panels are; security & safety screens, facades, sunscreens, ceiling tiles, privacy screens, feature walls, and partitions. The history of Mashrabiya is dating back to the period when Arabs entered Africa. However, it is not easy to pinpoint its first use because of the ever-evolving nature of architecture [9].

Perforated metal has been used in Islamic architecture for centuries ago. These days, it is more popular than ever before. The rationale is that perforated metal is a building material that can fulfill many needs in terms of decorative and purely practical [8,10-11]. These panels are such versatile that it suits architects to incorporate

them in many ways in their design. The perforated panels' material is aluminum, stainless steel, galvanized steel using different patterns and flairs to provide an aesthetical view to the buildings and other structures with privacy, functionality, and decorative lighting. As solid walls provide maximum privacy, glass walls let natural sunlight in. Therefore if both privacy and natural sunlight are required, perforated metals provide the perfect solution. When installed along with a ceiling, perforated metal precludes echoes; therefore, it can be used as a protective covering to either absorb or reflect or scatter sound. A perforated metal sheet is lighter than a non-perforated sheet of the same size and thickness while retaining its durability. Using perforated metal sheets provides control over sunlight and ventilation. A significant benefit of perforated metal reflects heat build-up from the sun, maintaining a consistent temperature and, therefore, saving energy. Perforated metal sheets can be made from various materials and manipulated into various sizes, thicknesses, shapes, and perforation designs. Since buildings constructed with environmentally friendly materials are in high demand, metal is a green material that satisfies that demand. It is recyclable not just once but often [12-16].

As a disadvantage, metals such as steel and aluminium typically cost more than other construction products such as timber, concrete, brick, or stone. Additionally, metal, particularly steel, will rust and lose strength with time, and susceptible to fracture. Typically, metal is treated with an additional protective coating to combat moisture or salt and other corrosive elements. Also, these sheets are not easy to make corrections in the field. In summary, perforated metal has many positive attributes, both aesthetic and practical, that make it a top choice for many projects. Nevertheless, it is not the perfect material type for every project, but worth considering, however.



**Fig. 1. Perforated panels (left) roof trellies installed horizontally (b) installed vertically**

## 2. NUMERICAL MODELING

The perforated panels are checked for induced stresses and deflection obtained from the numerical model (Autodesk Robot, SAP2000, etc.) carried out for the shell elements. The support conditions and the assumed constraints and releases are essential during the modeling phase. The panels are usually simply supported when installed horizontally; nevertheless, these can be hanged from the top to transfer the gravity load at the top. When the transfer of gravity loads is assumed to be transferred at the bottom, the lateral deflection might be enhanced. The adopted framing systems and fixing detailing are checked according to different acceptance criteria as per adopted codes. These calculations are related to the aluminium sunshade. These sunshades are assumed to be subjected to full wind on their face using project specifications by considering wind blowing perpendicular to its face. The dead load, usually aluminium panels and structural steel elements, is calculated by the software. The wind loads calculated as per the project specified wind speed and recommended code is considered for the analysis. The induced complex stresses under the ULS and the central deflection in the aluminium panel are checked according to the allowable limits. The stress check is generally carried out by comparing the allowable material stress with the induced stresses. Similarly, the central deflections are

usually limited to span/90 as recommended by codes [17-18].

### 2.1 Façade Trellies or Vertical Panels

Here the structural modeling and the necessary checks are made for perforated panels installed as fencing. For the Mashrabiya shown in Fig. 2, 8 mm thick aluminum perforated panels are used supported by steel tubes. The maximum size of the Mashrabiya panel is 1975 mm x 1950 mm. A wind load of 1.2 kpa is considered acting on the Mashrabiya according to the specified wind speed. The perforated panel is checked for the induced stresses and deflection obtained from the numerical model in Autodesk Robot using shell elements. The adopted thicknesses for the panels, framing systems, and fixing detailing have been found safe according to different acceptance criteria.

The complex stresses in the Mashrabiya under ULS (41.05 MPa < 160 MPa) –whereas deflection in the model under SLS (21.38 mm < 1950/60 = 32.5 mm ) Hence safe.

In this section, structural checks of Mashrabiya used for fencing Fig. 3 right are shown. These are 5 mm thick aluminum perforated panels (2380 mm x 1180 mm) surrounded by steel tubes 50 SHS (3mm thick). Wind load of 1.2 kpa is calculated for the specified wind speed as per project specifications.

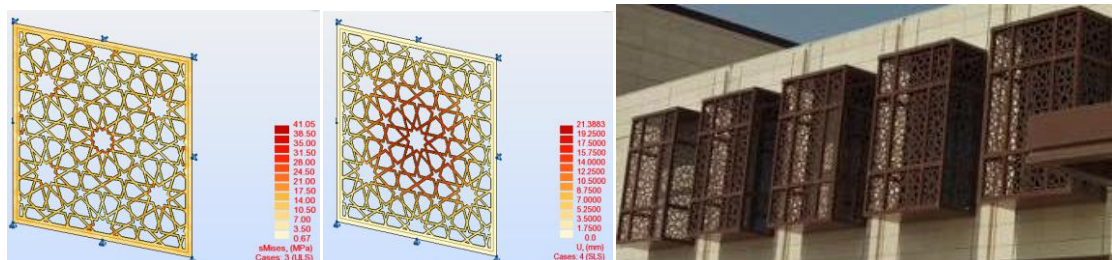


Fig. 2. Stresses and Deflection (left), installed Mashrabiya (right)

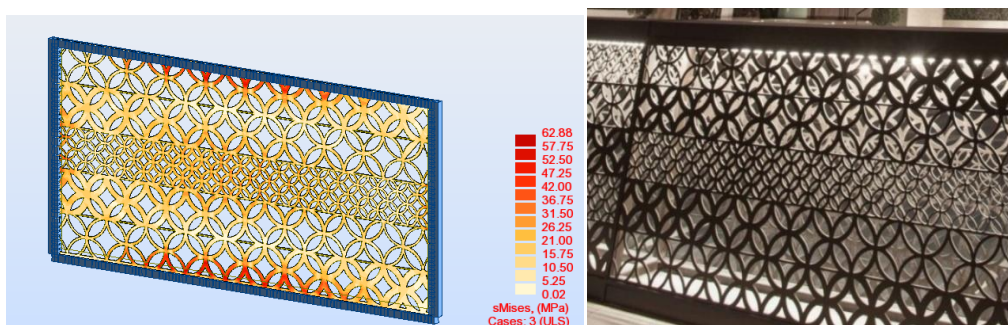


Fig. 3. Stresses in the Mashrabiya under ULS (left) and installed panel (right)

Stresses in the Mashrabiya under ULS (62.88 MPa < 160 MPa) as shown in Fig. 3 (left), hence safe. Central deflection due to the serviceability limit state in the perforated panel equals 16.38 mm under the acceptable limit of span/60, say 20, as shown in Fig. 4. The adopted 5 mm thick Aluminum perforated panels are safe.

### 2.2 Roof Trellies or Horizontally Installed Perforated Panels

A wind load of 1.4 kpa has been considered in this case (3mm horizontal roof sunshades shown

in Fig. 5 as per the project specifications. The trellises are 1200 mm x 800 mm installed at the roof level.

Stresses in the perforated panels shown in Fig. 6 (left) equal 123.9 MPa under an allowable stress limit of 160 Mpa, therefore satisfactory. The deflection in the panels under the SLS shown in Fig. 6 (right) equals 9 mm, which is less than span/60 (1000/60 = 16.7 mm), therefore within the permissible limits and hence used within the project.

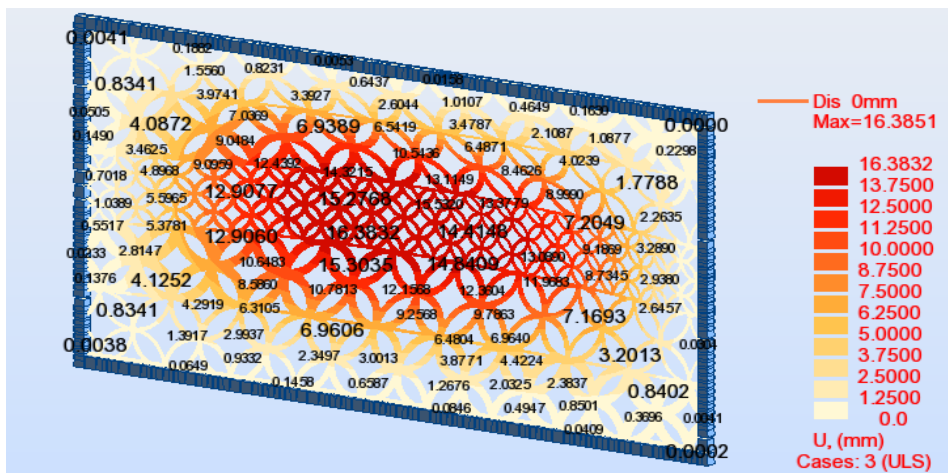


Fig. 4. Deflection in the model under SLS

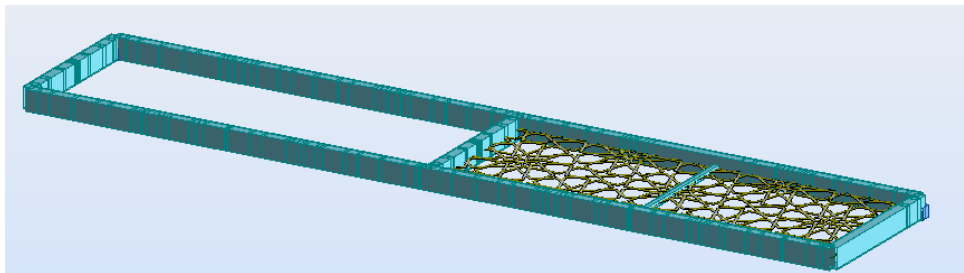


Fig. 5. Numerical model for the roof sunshade

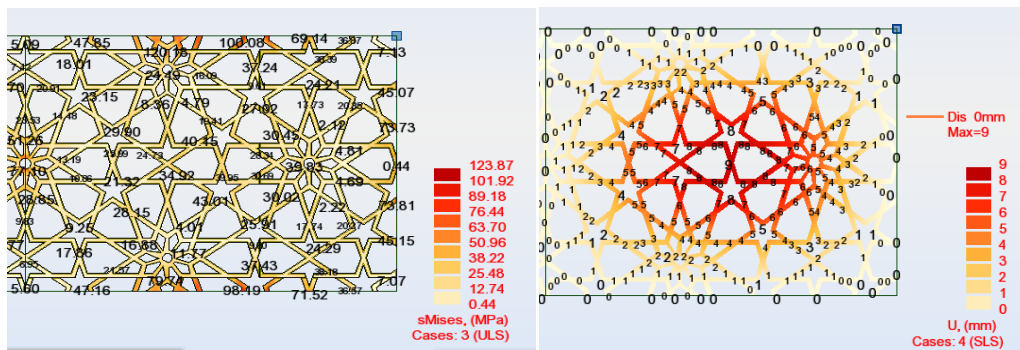


Fig. 6. Roof perforated panels (left) Stresses (right) deflection

### 3. CONCLUSIONS

The perforated metal panels offer many benefits such as versatility, durability, energy efficiency, and eco-friendly. Since metal is a green material, perforated aluminum panels minimize resource depletion due to their recyclability, promote sustainability, and invites innovation in designing structural applications. Additionally, perforations reduce the amount of metal used, which translates to reduced weight and lower fuel transportation costs to the building site.

- The consideration of shell elements in the numerical analysis allows the design and analysis of these screens. Softwares such as SAP2000, Robot etc., can be used to model these elements.
- The structural model requires to be cross-checked using conventional equations. The inertia and the area calculations for these equations can be obtained from CAD software.
- The supports at the edges are required to be checked to carry the load transfer. Any supporting structure must be checked to avoid any brittle material failures.
- The edge releases are pretty important in the numerical analysis as these screens are usually supported, and in case if they are not correctly considered the deflection, these screens might fail the brittle materials
- The anchorages require fulfillment of different requirements such as edge distances, center to center distances, and the concrete strength as per the manufacturer.

### COMPETING INTERESTS

Author has declared that no competing interests exist.

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