Precast Hollow Reactive Powder Concrete Panel (RPC-PH Panel)

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Abstract. Precast hollow RPC panel is a breakthrough to reduce the dead weight of the structure. The presence of hollow in the panel also contributes to a sustainable and more environmental-friendly construction because it is reducing natural materials such as sand, gravel, and cement-making materials. The hollow area is filled with Styrofoam. Styrofoam is a material that is quite well known as an element core filler because of its low density and good thermal insulation. So, RPC-PH panels have the advantage of being lightweight and being a good thermal insulator. This panel could be used as an alternative to replace conventional walls and slabs. An experiment using non-linear finite element analysis was conducted to analyze the strength of this panel. Results of the analysis show that the axial capacity is 12.19 MPa, shear capacity is 1.03 MPa, in-plane bending capacity is 1.39 MPa and out plane bending, capacity is 0.0054 MPa.

Keywords: RPC Panel, non-linear FEA analysis, Styrofoam

1 Introduction

Concrete is one of the widely used materials for construction because of its several advantages. Nevertheless, it also has some disadvantages. One of the disadvantages is high density. Conventional concrete density is ranging from 2240 – 2400 kg/m^3. This high density causes a high overall dead load of the structure which will then affect total construction cost.

Hollow RPC panel is a solution to this problem. This panel is made of high-strength concrete with a certain thickness as the surface layer and Styrofoam as the inner or the hollow filling material. Reactive powder concrete is chosen because it enhanced performance such as toughness and corrosion resistance [1]. This panel can be used as an alternative to conventional walls and reinforced concrete floor slabs. This panel has several advantages, light and strong.

Besides, this panel is also environmentally friendly, because the hollow area reduces the use of natural materials such as sand, gravel, and cement-making materials. Because the aggregates used in concrete such as gravel and sand are obtained from natural exploitation which of course can have a negative impact on environmental sustainability. Therefore, the hollow panel will not only reduce the building's own weight but will also have a positive impact on the environment.

The use of Styrofoam as additional material in construction is actually not a new thing. Research has investigated the use of Styrofoam as an artificial aggregate in the manufacture of lightweight concrete (LWC). In LWC, Styrofoam is used as a substitute for coarse aggregate. Expanded polystyrene (EPS) was used as a substitute for coarse aggregate in concrete in 1957. However, the addition of EPS resulted in a decrease in the strength of the concrete. The segregation that occurs in the concrete mix causes a significant decrease in the quality of the concrete, especially the compressive strength, which is only 10 MPa. This causes the concrete composite with Styrofoam is not much in demand. [2]

In this breakthrough, Styrofoam will not affect the strength of concrete because it is not mixed into the mortar or used as a substitute for aggregate. Styrofoam is only used as a panel filling material. Thus the strength of the concrete can be maintained and the mass of the panels can be lighter.

Styrofoam is a material that is quite well known as an element core filler because of its low density and good thermal insulation [2]. So, RPC-PH panels have the advantage of being lightweight and being a good thermal insulator. With all its advantages, RPC-PH panels can be a new breakthrough in construction in the future.

2 Material and Testing Method

2.1 Methodology

This research was conducted using numerical analysis method and experimental method. The numerical analysis method chosen is the finite element method (FEM). Analysis using FEM at this early stage is faster and more economical for the research process. Because by using numerical analysis, researchers do not need to conduct trials in the laboratory, which of course takes time and money.

In the finite element method, an element is modeled into a mathematical model that represents the element. This mathematical model is made by discretizing the continuum structure into elements where the nodal points are related to each other so as to form a network according to the shape of the original elements. This method is considered adequate enough to solve various continuum mechanics problems with an acceptable level of accuracy and tolerance of deviation.

2.2 Specimen

Error! Reference source not found. shows the design of the Styrofoam RPC sandwich panel which will be analyzed using the finite element method. The surface layer is high-strength RPC concrete with dimensions of 1.2 m wide and 0.2 m thick. The core layer is filled with Styrofoam with dimensions of 1 m wide and 1 m height. There are 2 layers of Styrofoam on the panel which is bordered by an RPC layer of the same dimensions as the surface RPC layer. The sides of the panels are coated with

0.1 m thick RPC. Thus the initial design dimensions of the panels are 1.2 m (width) and 2.6 m (height).

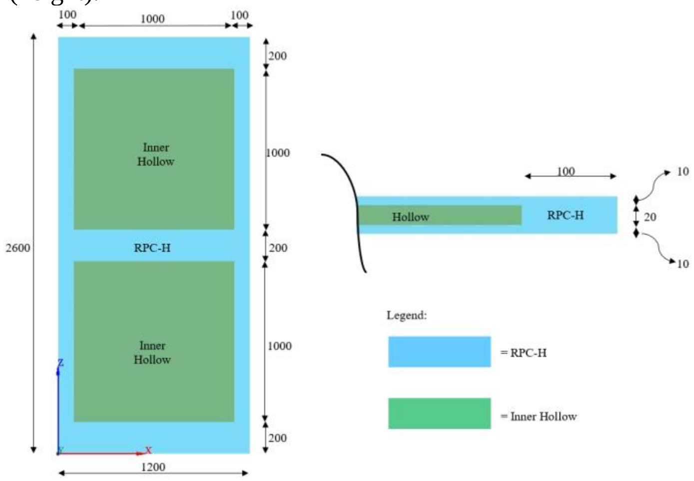

Fig. 1. Dimension and detail (mm) RPC-PH panel

2.3 Properties and Boundaries

Analysis of RPC-PH panel capacity is using Midas FEA program with modeling limitations and criteria for numerical simulation as follows:

1. The elements used are 8 nodal solid elements.
2. The limitation of compressive stress is $f_c' = 50$ MPa, and the crack stress is $f_r = 12$ MPa.
3. The analysis type is nonlinear static with 2 types of failure, i.e.:
    a. Material failure occurs when the applied stress exceeds the allowable stress or collapse stress.
    b. Geometry failure occurs when the displacement that occurs has changed the geometric shape significantly.

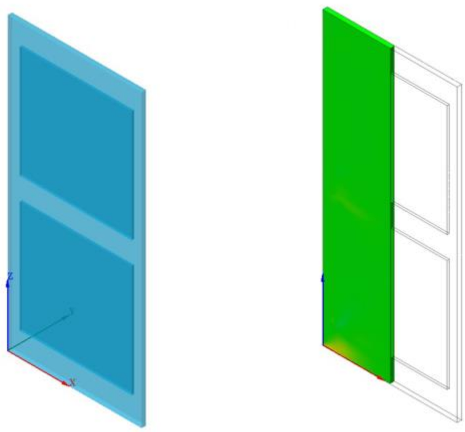

Fig. 2. Precast hollow reactive powder concrete panel (RPC-PH)

3 Result and Discussion

3.1 Compressive Axial Capacity

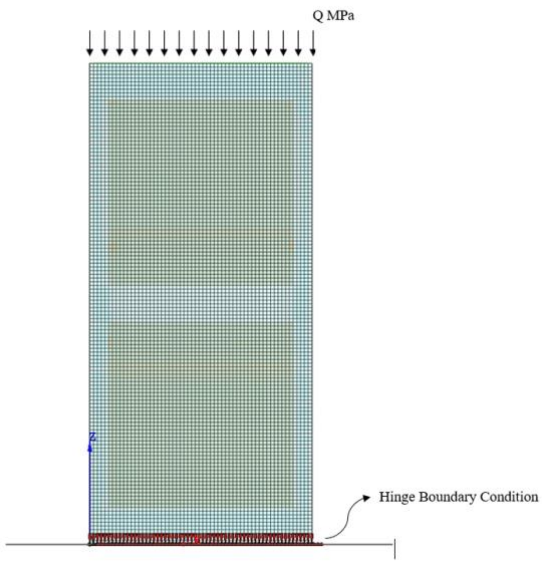

Fig. 3. Vertical axial capacity analysis modeling

The failure of the RPC-PH panel was caused by lateral buckling due to the panel geometry being very thin compared to other dimensions. The load capacity that can be carried axially is Q = 12.19 MPa, the maximum displacement in the direction of the load that occurs in the vertical direction is 3,413 mm, the compressive stress + = 26.9 MPa and the tensile stress - = 59,559 MPa.

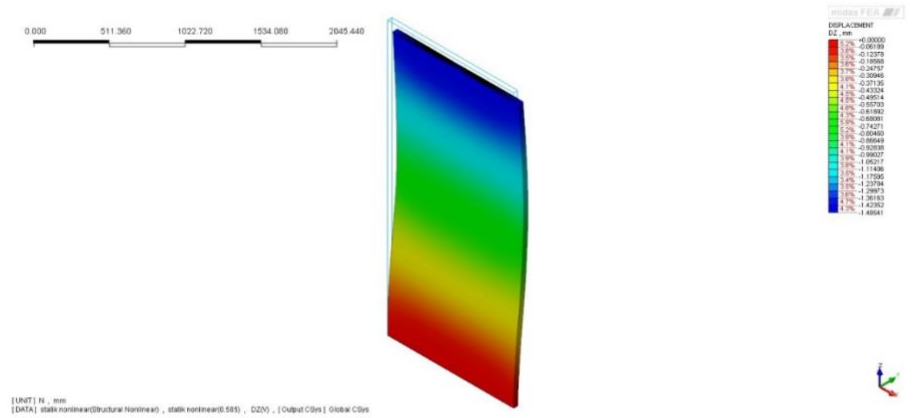

Fig. 4. Vertical displacement due to axial load

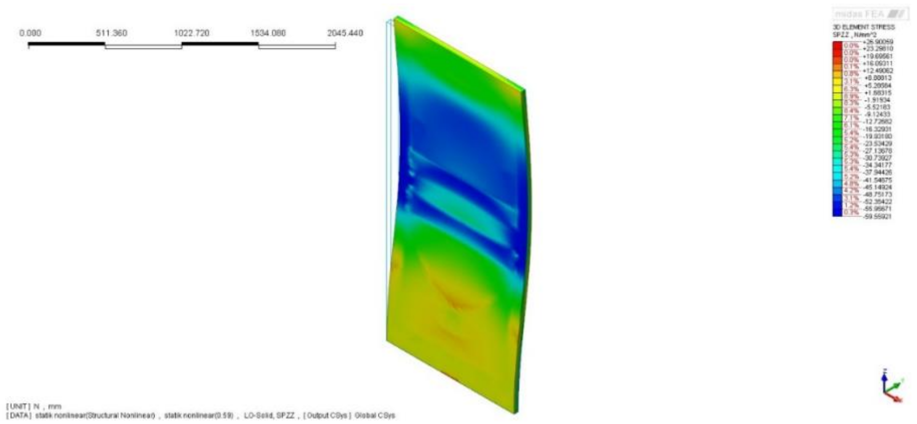

Fig. 5. Maxium stress due to axial load at failure condition

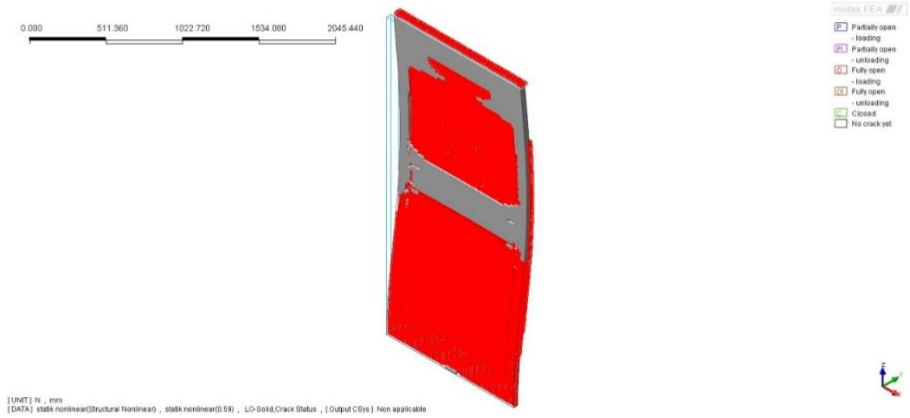

Fig. 6. Failure model due to axial load

3.2 Shear Capacity

The failure form of the RPC-PH panel is caused by cracks around the support due to shear. The load capacity that can be carried by shear is Q = 1.03 MPa, the maximum displacement in the direction of the load that occurs in the horizontal direction is 2.4448 mm, the compressive stress + = 16,022 MPa and the tensile stress - = 26,586 MPa.

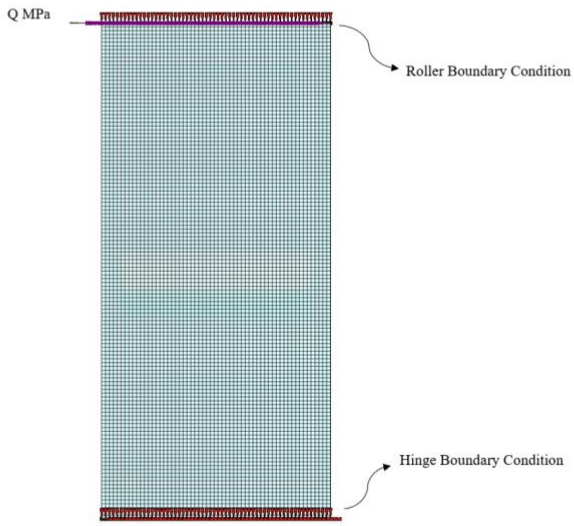

Fig. 7. Shear capacity analysis modeling

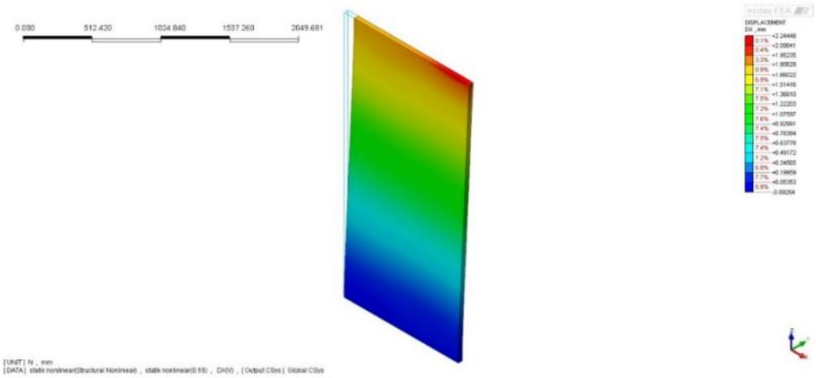

Fig. 8. Horizontal displacement due to shear load

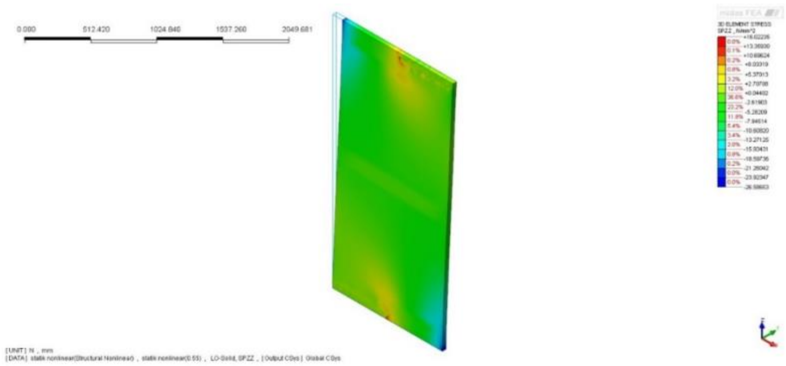

Fig. 9. Maxium stress at failure condition due to shear load

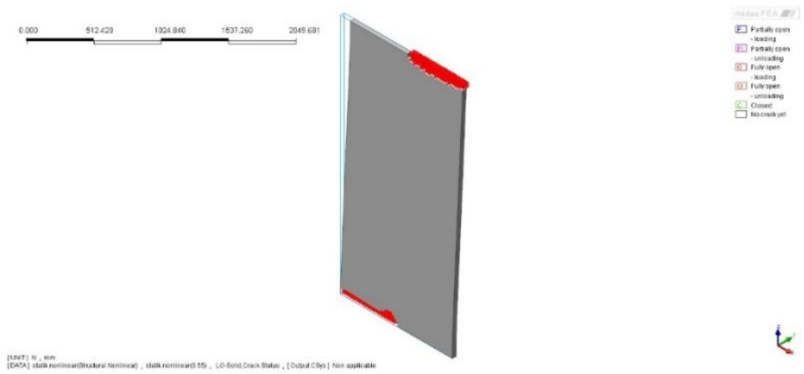

Fig. 10. Failure model due to shear load

3.3 Bending Capacity Parallel to Plane (In Plane Bending)

The failure form of the RPC-PH panel is caused by cracks around the support due to bending. The load capacity that can be carried by bending parallel to the plane is Q = 1.39 MPa, the maximum displacement in the direction of the load that occurs in the horizontal direction in the middle of the span is 0.22381 mm, compressive stress + = 12.75 MPa and tensile stress - = 4.67 MPa.

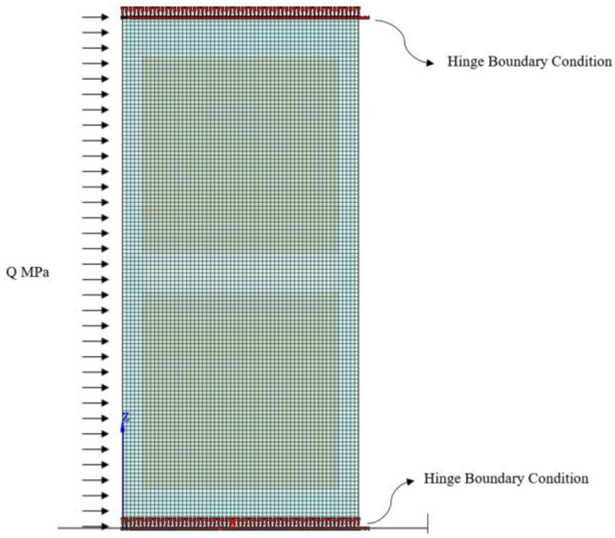

Fig. 11. Modeling of flexural capacity analysis parallel to the plane

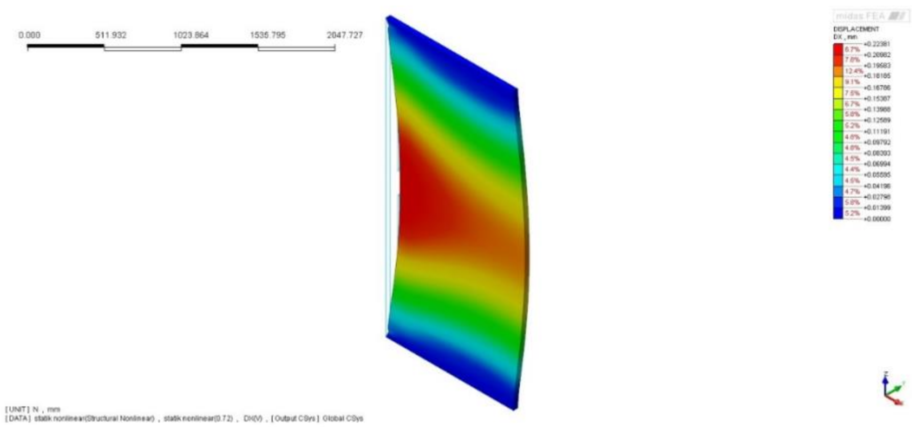

Fig. 12. Flexural displacement at mid-span due to in plane bending

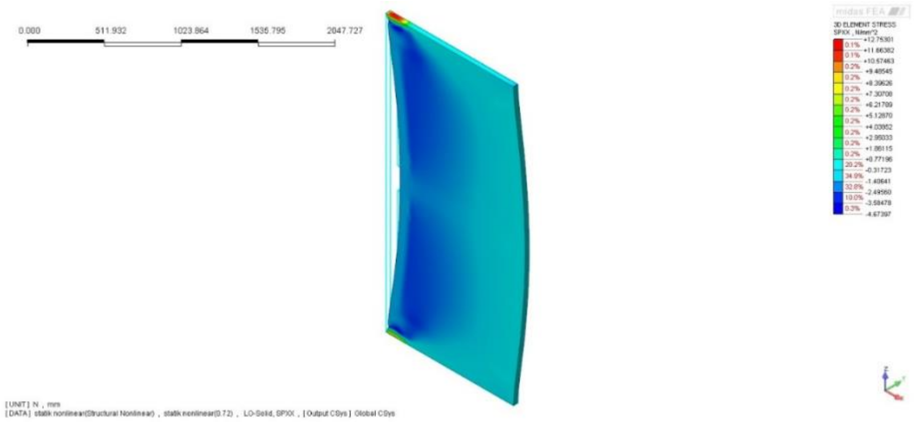

Fig. 13. Maximum stress at failure condition due to in plane bending

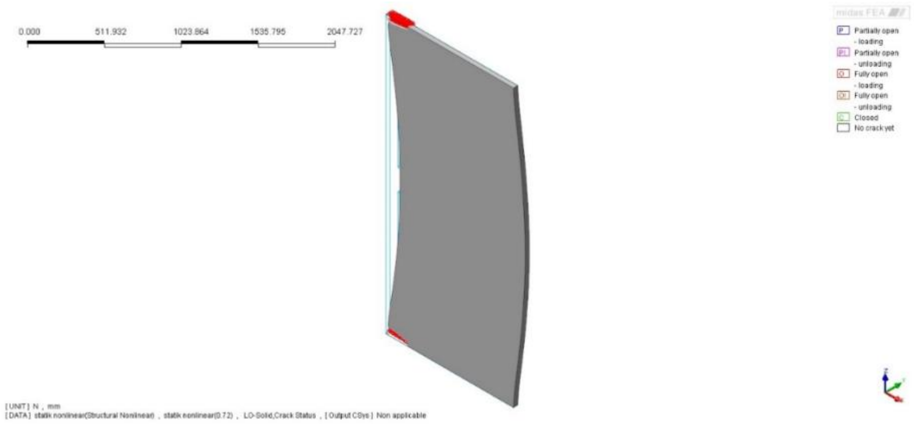

Fig. 14. Failure model due to in plane bending

3.4 Bending Capacity Perpendicular to Plane (Out Plane Bending)

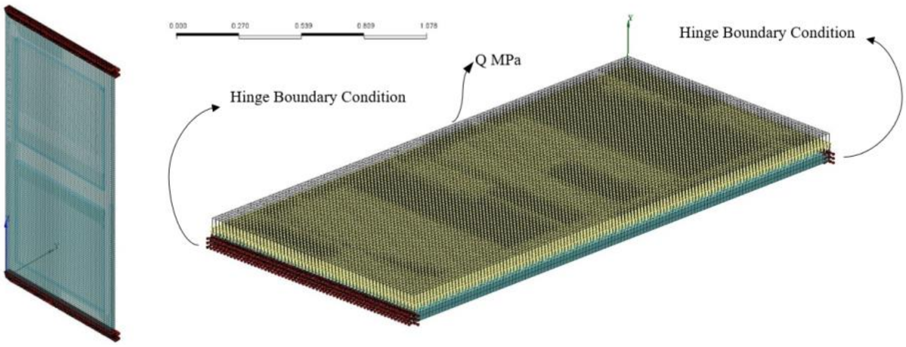

Fig. 15. Flexural capacity analysis modeling perpendicular to the plane

The failure form of the RPC-PH panel is caused by cracks in the support due to shear. The magnitude of the load capacity that can be carried by bending is Q = 0.0054 MPa, the maximum displacement in the direction of the load that occurs in the perpendicular direction in the middle of the span is 5.51283 mm, the compressive stress + = 14.62 MPa and the tensile stress - = 13,911 MPa.

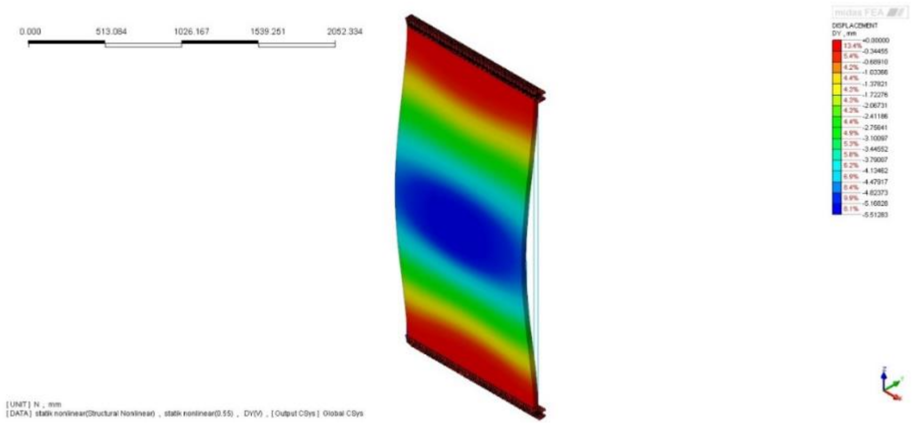

Fig. 16. Perpendicular flexural displacement at mid-span due to out plane bending

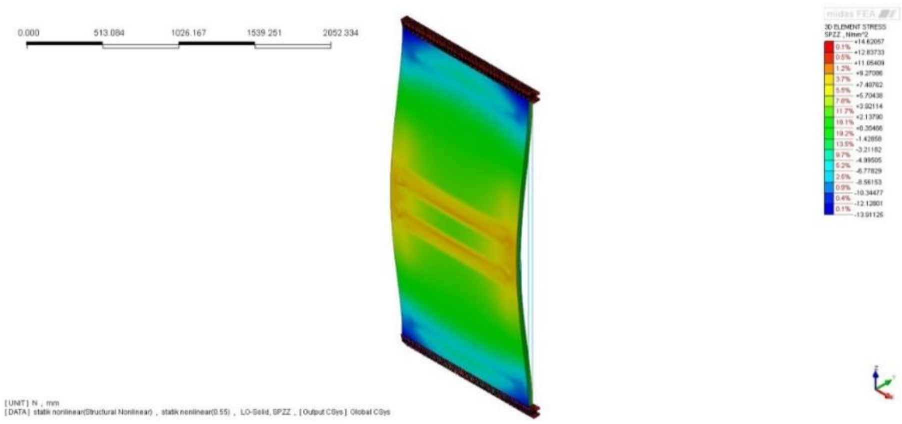

Fig. 17. Maximum stress at failure condition due to out plane bending

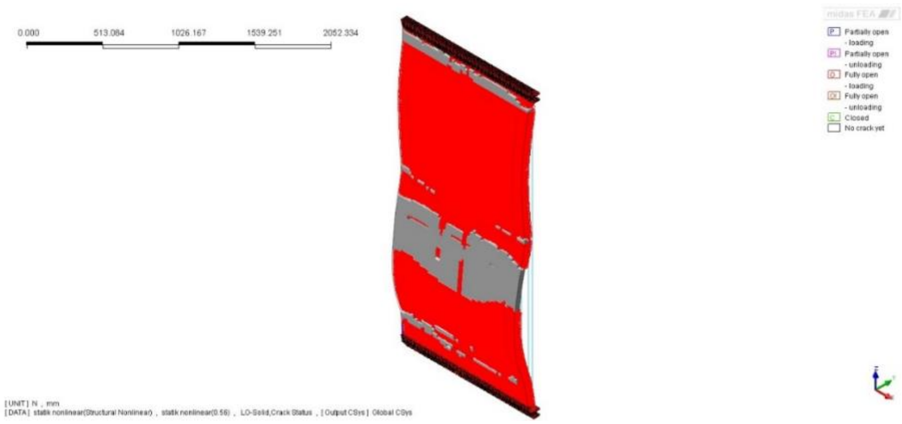

Fig. 18. Failure model due to out plane bending

4 CONCLUSION

Table 1. Summary of Load Carrying Capacity

No.	Analysis Type and Loading	Ultimate Capacity MPa	Nodes and Element
1	Axial (Vertical Load)	12.1875	28704 nodes, 17142 elements
2	Shear	1.0290	
3	In Plane Bending	1.3925	
4	Out Plane Bending	0.0054	

The conclusions based on the modeling and analysis carried out with MIDAS FEA software are as follows:

1. The largest capacity of the panel is the axial capacity with a load of 12.1875 MPa and the smallest capacity is the out-plane bending capacity with a load of 0.0054 MPa.
2. RPC-PH panel has high axial strength compared to bending and shear strength.
3. Failures that often occur in the panel are cracks in the bearings due to bending and shear.
4. RPC-PH panel requires reinforcement in the panel body area and support to prevent cracks that lead to panel failure.

References

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