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Strength Analysis of Portable Blast Room Using Modular Glass Reinforced Plastics Wall Panel by Finite Element Method

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Abstract. In the shipbuilding and ship repair industry, the most common surface preparation technique used is abrasive blasting. The abrasive blasting and the other surface preparation techniques are the significant sources of shipyard waste and air pollution. The one of any kind techniques to reduce the hazardous air contaminant associated with the abrasive media is blasting room. The abrasive blasting operation is isolated by the blasting room to reduce the exposure to the shipyard environment. The portable blasting room design has been developed using the modular wall panel system. The research is focused on the strength analysis of portable modular blast room using glass reinforced plastics as the wall panels. The research method has two main steps during the strength analysis of the portable blast room. At first, the geometric form of the modular blast room was developed and defined to obtain the finite element model. Secondly, the load and boundary condition was defined, considering the wind load and the structure weight which are exerted to the blast room structure. The displacement method was adopted for the numerical analysis.

Introduction

Abrasive blasting is the system of blowing abrasive particles from a blast machine, using the power of compressed air. Three primary components compose a blast equipment setup i.e. air compressor, blast machine, and abrasive. The sufficient air pressure and volume must be produced by the compressor to convey abrasive from the blast machine to the surface being blasted. Air pressure is typically high, at 100 pounds per square inch, and nozzle velocities can approach 650 - 1,700 feet per second [1]. The lack of one part of the components may reduce the productivity of abrasive blasting system.

In the shipbuilding and ship repair industry, the most common surface preparation technique used to clean production objects such ship hull, parts, components, plates and profiles is abrasive blasting. Abrasive blasting might be conducted in the new building ship production process such as fabrication, sub assembly, assembly, erection and coating/painting. Instead of the new building process, the abrasive blasting also significantly be utilized for maintenance and ship repair activities. The abrasive blasting and the other surface preparation techniques are the significant sources of shipyard waste and air pollution. Therefore the abrasive blasting should be conducted within the blasting room as a control action to the waste and pollution in the shipyard environment. An abrasive blast room is the core to any modern abrasive blast system. Confining the blasting operation to a controlled clean environment enables efficient abrasive recycling.

There have been a number of different reports on the abrasive blast room development for the improvement of abrasive process, work environment and reducing the manufacturing cost. Walter L. Keefer [2] produced the blasting room for cleaning of castings. The invention is applicable to core knockout rooms in which water jet is employed to breakdown and blast away the molding cores used in the founding of large hollow castings. Leroy C. Haker [3] developed a grid-like floor of sand blast room which the abrasive material resulting from sand blasting operations may fall and recycled. Richard E. Lewis [4] produced a tent-like portable blasting room enclosure with a central entry opening in the roof. The blasting room enclosure is mounted on rollers and a track extends parallel with the air return ducts to permit the blasting room enclosure to be moved between the first and second floor areas so that parts to be cleaned can be removed and placed in the open floor area while sandblasting is taking place in the other adjacent floor area.

Recent development has shown the application of containerized blast room which offer an affordable solution when weatherproofed or transportable blast room is required, Fig. 1(a). Besides standard shipping size, the containerized blast room provides an enclosure built on the principles of a shipping container, but manufacture to any size. The other type of portable blast room is modular blast room. Modular blast rooms are made primarily from a standard 2mm galvanized steel formed panel complemented with heavy duty doors and door frames, Fig. 1(b). It can be built up to almost any shape and size from a 10ft cube to a booth capable of enclosing a rail carriage and beyond.

The portable blast room that commonly used to support the abrasive cleaning activities usually made from steel and galvanized steel. These metal materials have advantages for the strength of the structures of blast room to withstand the load. However the weight of the steel panel is heavy compared than composites. Since the portable blast room should be compact, light and flexible, therefore the lightweight materials are adopted such as glass reinforced plastics or carbon reinforced plastics.

The needs and requirements for adequate structures of modular portable blast room using glass reinforced plastics (GRP) has motivate this research to focused on the structural analysis of modular glass reinforced plastics wall panel for portable modular blast room. The modular wall panels were assembled for the portable blast room. The knockdown and modular system was adopted to give the flexibility, adaptability and simplicity for the installation of the portable blast room.

(a) (b)

Fig. 1. (a) The containerized blastroom; (b) The modular blastroom

Materials and methods

The glass reinforced plastics was used as a material of modular wall panel for portable blasting room. Typically the glass makes up 20-30% by volume of the material content. The cost effectiveness of the material in making complex shape, with semi-skilled labor has contributed to its well-known material. Generally the structures built in GRP have not been considered as high performance structures. The GRP manufacture has been appropriate using fast hand lay ups, in a workshop environment that has variable conditions. Thoroughly manufacture considers the material quality, the fiber orientation, the fiber volume fraction and the void content of the laminate.

The research method has two main steps during the structure analysis of modular glass reinforced plastics wall panels for portable blasting room. At first, the geometric form of modular wall panels was developed and defined to obtain the finite element model. The displacement method was adopted for the numerical analysis. Secondly, the load and boundary condition was defined, considering the wind load and the structure weight which are exerted to the blast room structure.

Wall Panel Dimension and Configurations. The development of the portable modular blast room system started with determining the modular wall panel unit main dimensions. The main dimensions are length, width and height of wall panel unit. The length was determined with regards to the simplify handling and storage, when the wall panels were dismantled. Considering the condition, the length of the wall panel was created similar with the width i.e. 100cm × 100cm square plane. Otherwise, the wall panel thickness was 8 cm. Since the main dimensions of modular wall panel unit have been made, then the configuration of modular blast room is determined. The design criteria required for a properly sized blast room should consider some factors such as the largest size of work piece, the largest weight of work piece, the material handling method, the number of hours of blasting per day, and the base material of the work piece. The size of the largest which is determine the dimension of modular blast room is defined as the maximum size of steel plate that used as ship building material. The requirement of minimum length, width and height of the modular blast room is determined by the maximum work piece dimension and give the proper clearance by adding four to five feet on each side of the work piece[5]. Regarding the various size of the work piece, the possibility of the minimum configuration of the modular blast room was determine as large as 6m×4m×4m. The detail particulars of configuration are presented in Fig. 2(a).

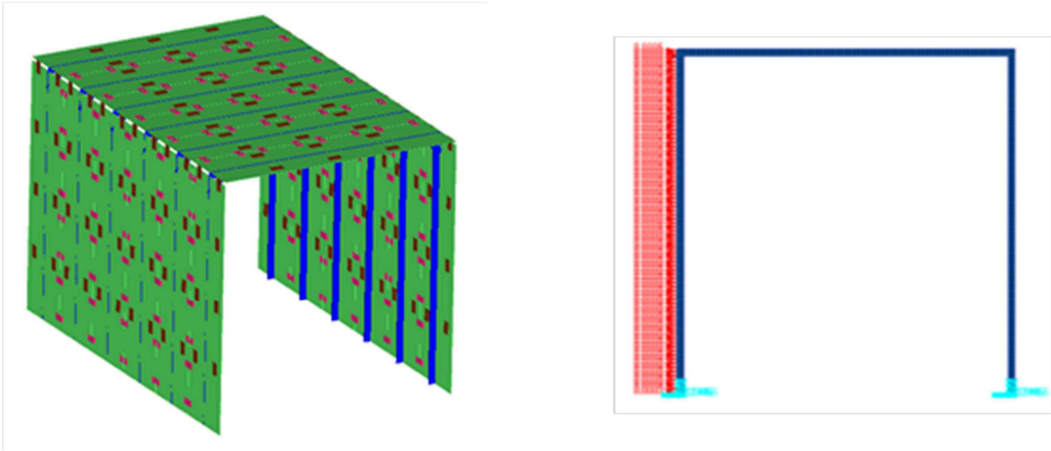
Wind Load and Boundary Condition. Wind is a dynamic phenomenon that varies randomly during the period of time. Generally wind speed in the atmospheric boundary layer increases from zero at ground level to a maximum at a height known as the gradient height. The wind speed variation with height depends primarily on the terrain conditions. Since the wind speed never remains constant at any height, therefore an average or mean value was made to resolve its magnitude. The average value is influenced by the time average employed in analyzing the meteorological data. The magnitude of the fluctuating component wind speed which is known as gust depends on the averaging time. The smaller averaging time, the magnitude of the gust speed is greater.

Buildings and other civil engineering structure are three dimensional bodies which is designed as any kind of shape. The large variety of the building shape may have complex flow patterns which have varied pressure distribution. The complexity of wind flow is not only initiated by the shape of the building, however it is also influenced by the characteristics of the terrain and other building in the near location. The entire factor is considered for the determination of wind pressures in wind tunnel experimentally. In the case of determination of the wind load on the developed portable modular blast room, the wind load was determined as static drag forces that produce the wind pressures on the structure following the standard of Indonesia Design Load Regulations for Building and Structures, [7]. According to the regulation the blow pressure load should be taken as 40kg/m^2 for the structures which is located on the sea shore area. The wind coefficient for the vertical wall is determined as 0.9 for wind pressure and -0.4 for wind suction. Therefore the total wind load on the portable blasting room might be determined as 52kg/m^2 or 509.95N/m^2.

Through the design geometry that had been obtained, furthermore the blasting room structure was determined to withstand the given load. The wall panel structure was designed as a hollow box that was intended to reduce the weight of the panel unit. Additionally, the bolted clevis was adopted for the connection system between the panel units. Prior to supporting sandblasting process, an evaluation of the portable blasting room strength must be established and confirmed. The estimation of structural response behavior due to operational loads is important for a reliable design. The strength assessment of portable blasting room was focused on investigation of the strength of wall panel unit and the interconnection system structure using finite element method. The finite element (FE) model was developed for the portable blasting room analysis. The detailed formulation of laminated plate element and strain energy for finite element was explained by Ferreira[8]. The requirements that should be considered by the developed FE model are:

- All main structural members are to be presented in the FE model
- Clevis are to be modeled by beam element having axial and bending stiffness
- Wall panels are to be modeled by shell element having out-of-plane bending stiffness in addition to bi-axial and in-plane stiffness

Boundary conditions have been defined as simply supported at the both ends of the FE model. The nodes on the wall panel at the both end of the portable blasting room are to be fixed. The material properties were defined as the properties of fiberglass reinforced plastics (FRP). The loading conditions were used in the analysis including the wind load and the equipment weight load. The illustrations of the FE model are described in the Fig. 2(b).



(a) (b)

Fig. 2. (a) The blastroom wall panel configuration; (b) The boundary and load condition

Results and discussion

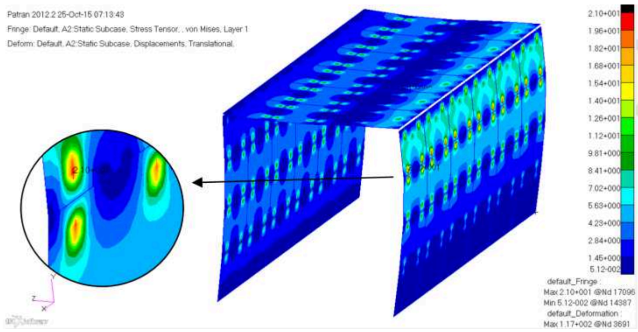
The FE model that has been defined with the loading and boundary condition was analyzed using finite element method. The linear static analysis was chosen to solve the problem case. The structure of the portable blasting room was modeled using 28,800 shell elements and 3,704 bar elements. The shell elements were mixed using quadrilateral and triangular elements. CPU time required for the analysis is 2 minutes on an AMD V120 Processor 2.2 GHz with 2 GB RAM running. The illustration of the results of numerical analysis might be seen in Fig. 3-4.

The results of the numerical analysis is Von Mises stress plotted on the finite elements for particular parts of the structure. The stress results presented correspond to the layer that exhibits the highest stress. The deformation of the FE model was exaggerated for visualization purposes.

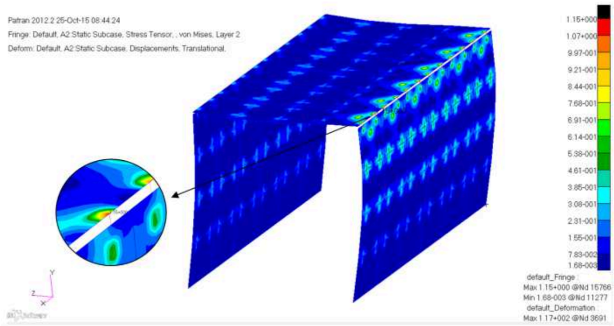
In general, it may be seen that the boundary conditions perform quite well, as there is no visible effect on the stress field. At the wall panel the stress distribution is uniform and not affected by the boundary conditions. The nodes which constraint was defined also have shown no stress concentration.

In Fig. 3(a), the maximum stress of the first layer (fiberglass layer) was occurred at the connector of the wall panels (bolted clevis). It can be explained that the stress was induced by the stress concentration on the connection joint of the wall panels. These stresses are about 21 MPa, significantly smaller than the permissible stress (68.9 MPa). The maximum stress of the second layer (polyurethane core), in Fig. 3(b) is about 1.15 MPa which was occurred at the connection between roof panels and wall panels. It may be explained that the connection between roof panels and the side wall panels using the bolted joint which is located in the middle layer of the roof panels. The final layer of the blast room panels shows that the maximum stress is located at the similar region of the maximum stress on the first layer, the stress is about 23.8 MPa, slightly higher than the stress at the first layer of wall panel deck, in Fig. 3(c). It is indicated that the maximum stress on the final layer was induced by the stress concentration on the connection joint of the wall panels as the first layer. Finally, the beam of the portable blast room, Fig. 4(a) shows that the maximum stresses are about 23.3 MPa, which is located at the connection joint of roof panel beam and the wall panel beam.

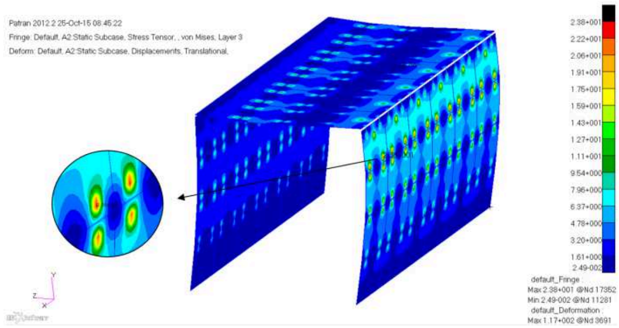
As expected, the results of the strength analysis shows that the structure of portable modular blast room is reliable to support the wind load on the side wall of the structure. The maximum stress was occurred at the connector of the wall panels below the permissible stress (68.9 MPa) with the maximum displacement is 41.2 mm, in Fig. 4(b). Regarding the maximum stresses and displacement, it might be determined that the structures of the portable modular blast room are safe and reliable for supporting the abrasive blasting process as an isolation room.



(a)

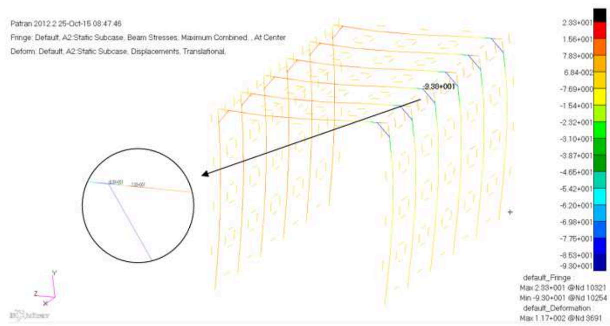


(b)

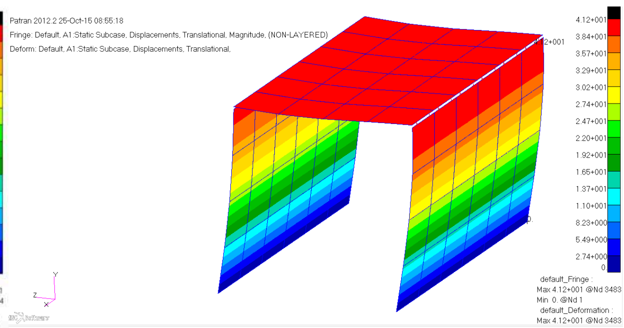


(c)

Fig. 3. (a) The stress distributions on the bottom layer; (b) The stress distributions on the second layer (polyurethane core); (c) The stress distributions on the third layer (FRP top layer)



(a)



(b)

Fig. 4. (a) The maximum beam stress distributions; (b) The maximum displacement of the portable blast room

Conclusion

An investigation of portable blast room strength using modular glass reinforced plastic wall panel to support abrasive blasting process in coastal area was made, utilizing the simulation and numerical analysis.

The evaluation of portable modular blast room strength was calculated using finite element method comprising, to build FE model (meshing), to define the load and boundary conditions, to define the material properties and structure scantlings.

Wind pressure and suction was selected for the load of the strength analysis. Hence, the maximum stress was 23.8 MPa which was occurred at the connector of the wall panels, significantly smaller than the permissible stress (68.9 MPa). It is concluded that the structure of portable modular blast room is safe and reliable for abrasive blasting isolation room.

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