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Parametric Study on Environmental Friendly Blast Wall Systems

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Abstract: Protecting people and structures against blast loading that can happen due to several reasons such as wars, terrorism or even accidental explosions, has become of great concern during the last decade. Blast walls is considered as one of the most effective ways to protect important structures against such hazards. However, limitation in technology of construction using high –technology blast wall systems are a huge obstacle specially in developed countries. Moreover, using high-technology materials in construction industry are very polluting process along with the high expenses during construction phase. As a result, designers tend to propose solutions with readily available materials for blast wall construction, to minimize construction effort as well as decrease its environmental impact. In this paper a parametric study is conducted to draw the attention on using simple blast wall systems in dissipating the blast shock wave energy and assessing its performance.

Keywords: Blast, blast wall, OSB, sand, sustainability.

1. Introduction

Due to the repetitive terrorist attacks that is widely happening all over the whole world, many research parties that have military bases conducted a design manual to study the blast pressure and its parameters that affecting the highly important structures/buildings. Many parameters are involved in blast wall design to resist the applied pressure such as; the explosion weight, standoff distance and the blast wave amplitude. On the other side, some design manuals studied different parameters related to the other elements involved in the Blast incident. Some of these elements are the architectural and structural shape, the landscape shape and distance around the concerned building, blast resistance techniques according to the material selected and used.

Unfortunately, there are some gaps in the blast design of structures. The first gap is that the blast design is considered when the importance factor of the structure is high. However, lately, due to political and culture changes, historical and ordinary structures become highly exposed to explosion risks, either intentional or accidental explosions. As a result, studying the behavior of existing structures subjected to blast loading become a must, as it will ensure occupants security towards terrorist events. The second Gap is the materials involved in the blast loading resistance.

The technology played an important role in enhancing and inventing new materials with special application to be used in resisting high blast loading. However, these materials have high establishing cost, and material's extraction and operational phases have the highest impact on the environment from an energy consumption point of view. For instance, in Iraq, constructing 21 Km of reinforced concrete-walls for bombing protection cost around 12.5 million Dollar. In addition to the cost, these huge blocks affected the mobility and resulted in losing the Iraqi culture and architectural identities[1] .Many studies are conducted to examine different types of high-tech blast wall/panel systems made of high-tech materials to mitigate blast loading. However, most of the countries cannot provide this type of high-tech blast wall material. As a result, this study aims to suggest blast wall system with ready-made/available materials that are environmentally friendly, to be low in cost and can be applied on existing structures for bombing protection.

2. Literature

Many researches are conducted to study the effect of the blast loading on existing structures, a comparative study between two cases is conducted by Isabel Abott [2] ,the 1995 bombing of the

Alfred P. Murrah Building in Oklahoma, and the 2001 attack on the Pentagon it is concluded that the redundant and ductile design of the Pentagon provided considerable resistance to impact loads, and contributed greatly to delay the onset of progressive collapse. In other article, some materials are listed by Daniel Watch and Deepa Tolat [3] to be used as a retrofit upgrade. These upgrades may be used to either reduce the hazard of debris impact or to strengthen the structure to resist loads. Also, it is stated that by using Advanced analytical methods in testing these upgraded materials, the cost will be minimized as the structural team will focus on the portions of the building that will sustain damage. Ankur Yadav[4] studied the effect of blast loading on four structures with different systems. These systems are: ordinary reinforced frame system, Frame system with increased column cross section, combination of shear wall and frame system and finally combination of steel bracing and frame system. It is concluded that the presence of either the shear wall or the bracing system have an effect in reducing[5], scoped in their study on the behavior of different constructive materials, due to blast loading, in its full scale. The structural material ranged from strong elements such as; columns and beams to weak elements such as; masonry panels. Some studies focused on using different retrofitting techniques for increasing the existing structure behavior towards blast loading, Mohd Shariq et al. [6][7] studied different structure elements with different retrofitting materials and its behavior under blast loading. The first study is conducted using CFRP wrappings and jacketing with steel angles and applied along different column height locations. From this study, it is concluded that retrofitting the RC column with CFRP is more effective and high blast resistance compared to steel angles jacketing. The second study is conducted on a wall retrofitted by using two different techniques, one at a time; CFRP wrapping and mild steel wire mesh of different thickness. It is concluded that the CFRP is more effective in resisting and enhancing the wall behavior compared to the steel wire mesh.

It is found that the steel wire mesh reduces the displacement of the wall due to blast, however, the mesh can be considered to be a sacrificial mesh due to its sever rupture under blast loading. An investigation on axially loaded clay brick masonry wall is conducted by S M Anas et al.[8], two numerical models are tested using finite element method (ABAQUS software). The research adopted the air blast response in the two models, and the blast is applied as an experimental blast peak overpressure obtained from the collected literature. The results are obtained in terms of maximum displacement damage dissipation energy for the different wall thickness. Qurat ul Ain et al. [9] studied Two-Way RCC Slab with Unconventionally Placed Reinforcements under blast loading. To improve the blast resistance of the two-way concrete slab, a numerical modeling is adopted in the study using ABAQUS/CAE software. Displacement, damage dissipation energy, and crack patterns is evaluated for the adopted system.

As the main scope of this research, is to study an environmental friendly blast wall system, it is vital to understand the effect of the different material properties and its effect on environment. Many materials are proposed for blast loading resistance. However, the scope of targeting environmental friendly material become widely studied recently. Luca Guardigli [10] conducted a life cycle assessment analysis on wood and reinforced concrete material. This method is used successfully in sustainable building design and construction. A Comparative study is conducted by Chunheng Zhou et. al [11] to assess the fiber reinforced concrete panel between Kenaf and glass fibers. The comparison is done with respect to structural function and insulation function of the two panel types. It is concluded that the KFRC has a better thermal insulation compared to the GFRC. Other materials are introduced in the construction and proved to have a good environmental impact. One of these wood based materials is oriented strand board (OSB).

Fabiane SallesFerro et. al [12]and Enrico Benetto et. al [13] scoped on covering the life cycle of OSB from a cradle-to-gate perspective, highlighting the production system of the OSB. The study adopted the life cycle assessment to obtain the OSB environmental effect using different production processes and alternative materials involved in this processes. Many tests are conducted on physical and mechanical properties of Oriented Strand Board Green Building (OSB) [14]. In this paper, a part of continuative research targeting the study of eco-friendly material to be used in blast wall system manufacturing, and testing these materials under different blast load pressures. The obtained result will be observed and it will indicate some guidance on how to apply these eco-friendly wall systems on existing and moderate importance structures to protect it against explosions.

3. Methodology

This paper suggests investigating the performance of low-tech materials in increasing the blast-resistant system efficiency to increase the blast resistance with low cost and minimal effort. The suggested blast wall systems performance is analyzed using different approaches.

The research sequence adopted in this part of the study is as follows;

- Suggesting an eco-friendly OSB (Oriented Strand Board) blast wall system.
- Representing the experimental testing conducted on the OSB wall system under blast loading.
- Material modeling validation of the OSB wall on a Finite Element Method based software (Autodyn).

OSB is a form of wood panel manufactured using waterproof heat-cured adhesives and rectangular shaped wood strands arranged in cross-oriented layers (figure 1). The wood strands used are of 8 to 15 centimeters long and they are usually resulted from crooked, knotty and deformed trees that would otherwise go unused. The mechanical properties of OSB such as strength, resisting deflection, warping and distortion are similar to plywood.

Figure1: Oriented Strands Board

The hydrocode Autodyn is one of the most efficient codes used to simulate blast load problems and it's used in this paper to model the blast wall. The Lagrangian formulation was chosen to simulate the wall and Euler's formulation for the blast wave. The main advantages of this numerical formulation are the fast solution due to fewer computations per cycle; the high accuracy in describing the material interfaces; the automatic satisfaction of the mass conservation; the ability to apply various boundary conditions; and the availability to handle damage and plasticity.

4. Case Study

4.1. The Experimental Study description

The case study used is adopted from a previous experimental study that was conducted by Hussein [15]on a blast wall in form of sandwich panel (wood-sand- wood) and the panels were formed of OSB wood with OSB sheet thickness of 1cm, the whole section thickness is 30cm as shown in figure 2a as well as the detailed dimensions of the wall used in the experimental study, the connection system details are presented in figure2b. The wall was subjected to blast load (TNT) charges of 0.226kg and 0.34kg. A scaled distance factor (Z m/kg1/3) is used to analyze and compare the output results, and the steps of the test setup are shown in figure 3.

In the experimental Study, an open-space blast test was conducted to evaluate the performance of the wall system and investigate its effect on decreasing the blast pressure behind the wall. For this purpose, several probes were installed to measure blast pressure distribution in front and behind the considered blast walls.

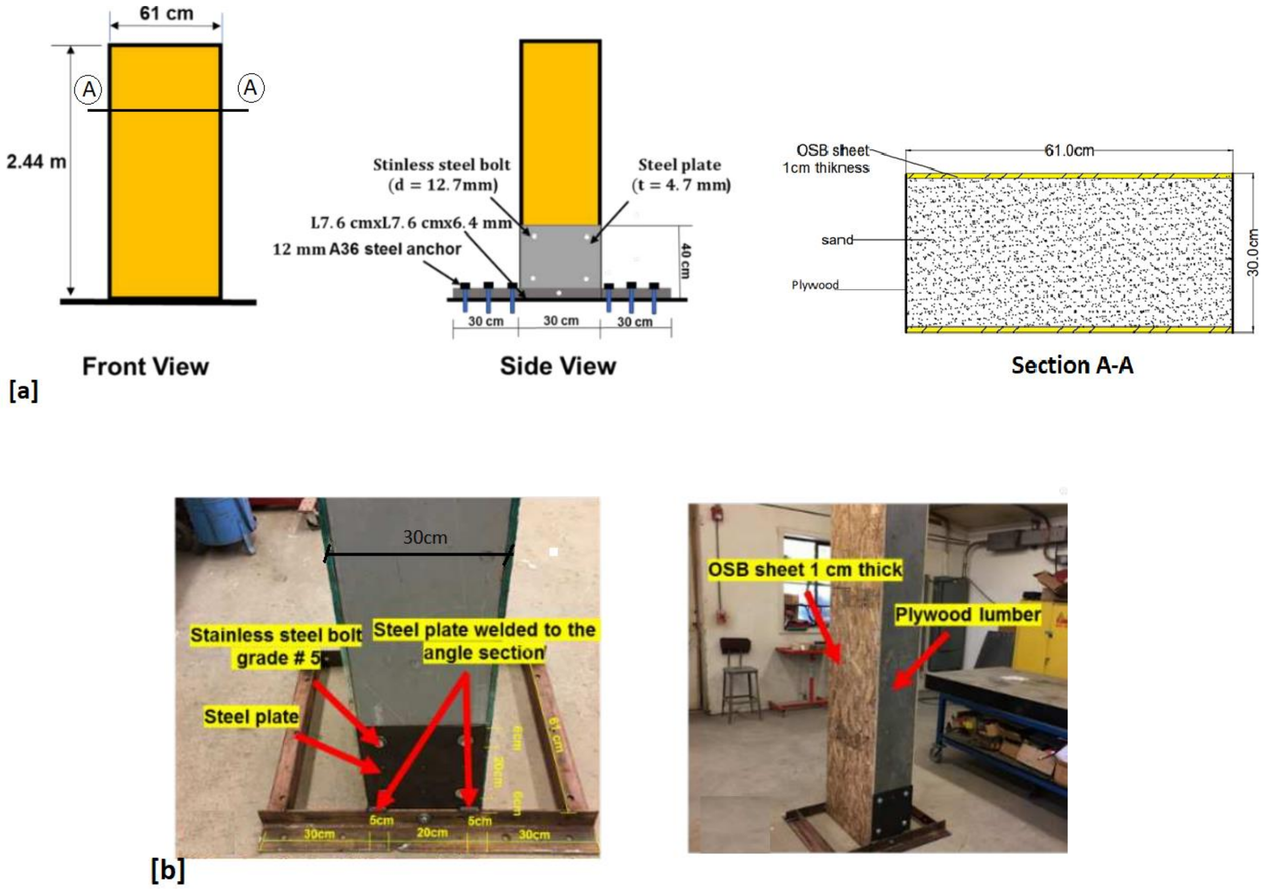

Figure 2:[a] detailed dimensions for the wall ,[b] the connection system details [15]

Figure 3: blast wall test setup [15]

The measurements of the free-air blast pressure test are compared with Kingery-Bulmash analytical model results [16]and showed good agreement as presented in figure 4, these values are used to validate the numerical model adopted by the current research.

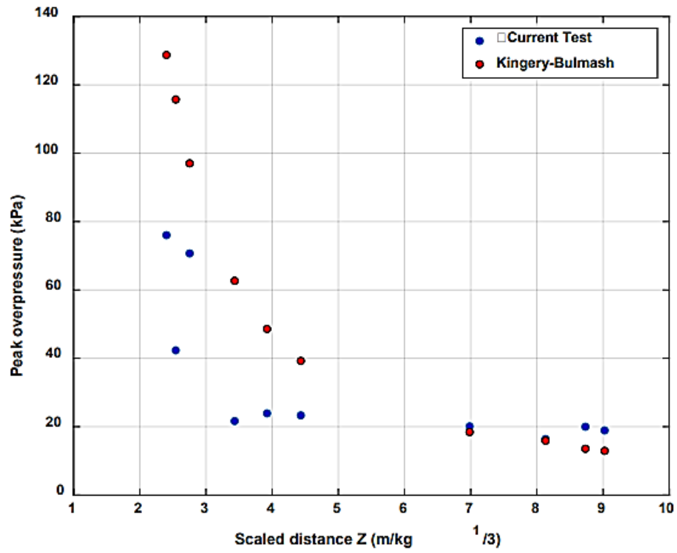

Figure 4: Measured peak overpressure of experimental test versus Kingery-Bulmash measurements [15]

In this study, as an extension for the research done by Hussein [15], a validation need to be conducted using Autodyn software in order to expand the parameters that will be studied in the future work.

4.2. Autodyne Program Validation

The experimental specimen adopted is numerically modeled using Autodyn. The Model carried the same dimensions and same material properties as the one used in the experimental study: the thickness of OSB sheets is 1cm, while the whole wall thickness is 30 cm, its length is 60cm and its height is 2.44m. The model is assumed to have fixed boundary conditions, a steel base is used to apply the fixation for simulation purpose.

The material properties of OSB is obtained from previous study [16] and defined in Autodyn as a new material as presented in figure 5, the other materials involved in the study are taken as defined in Autodyn default values.

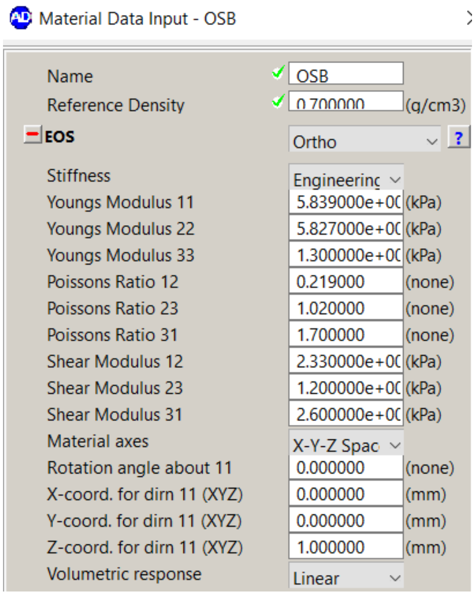

Figure 5: OSB material properties [16]

An assumed scaled distances of Z= 6.99 and 8.01 are used to validate the numerical model, with a TNT charges of 0.34kg and 0.226kg placed at standoff distance of 3.96m from the wall as shown in figure 6, the TNT charge is modeled in Autodyn in form of 2D wedge in a separate file then it is inserted as a spherical charge to simulate the actual blast load

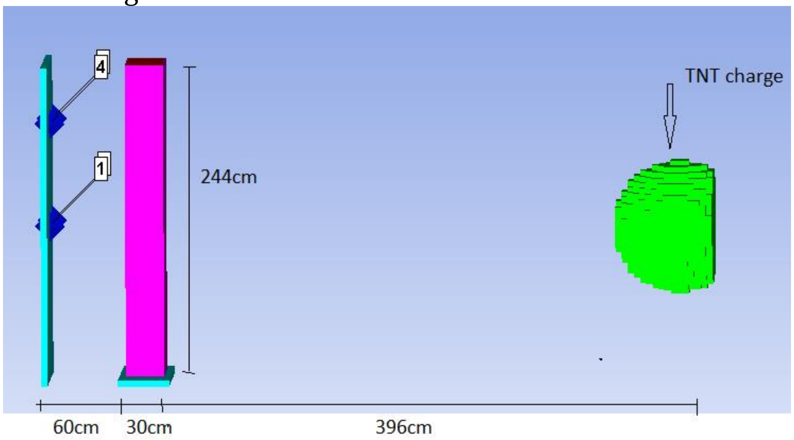

Figure 6: wall Model dimensions and standoff distance of TNT charge

The probes used in the test are presented as gauges placed behind the wall at a distance of 60cm, two gauges are placed behind the wall centerline (gauges 1 and 4) and another two gauges are placed behind the wall but at free air (not protected by the wall) as shown in figure 7. The gauges are used to compare the effect of the wall on decreasing the blast pressure.

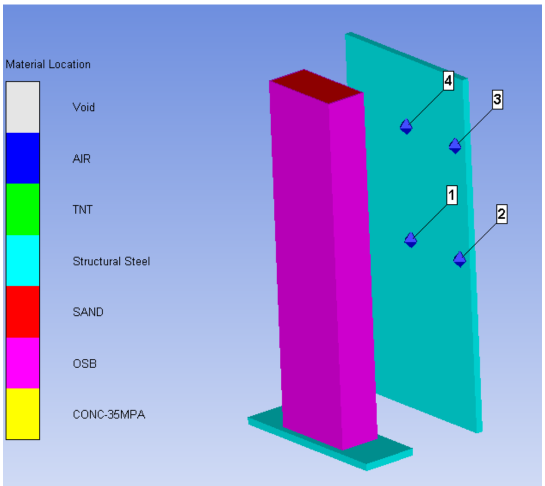

Figure 7: Wall assigned materials and gauges positions

The blast pressure values are recorded during the simulation and the peak overpressure values are compared to the experimental and numerical values and presented as shown: figure 8 presents the results of gauges 2 and 3 which are placed in free air and not protected by the wall, the over pressure values show good agreement with the experimental test results and with Kingery-Bulmash analytical model, where the values of the peak overpressure for gauge 2 for example is found to be 19KPa from the numerical model while recorded 18.3KPa for the experimental model.

Gauges 1 and 4 which are located behind the wall and protected from the direct blast load pressure recorded low over peak pressure values, the results are also compared to the experimental test and showed good agreement as presented at figure 9.

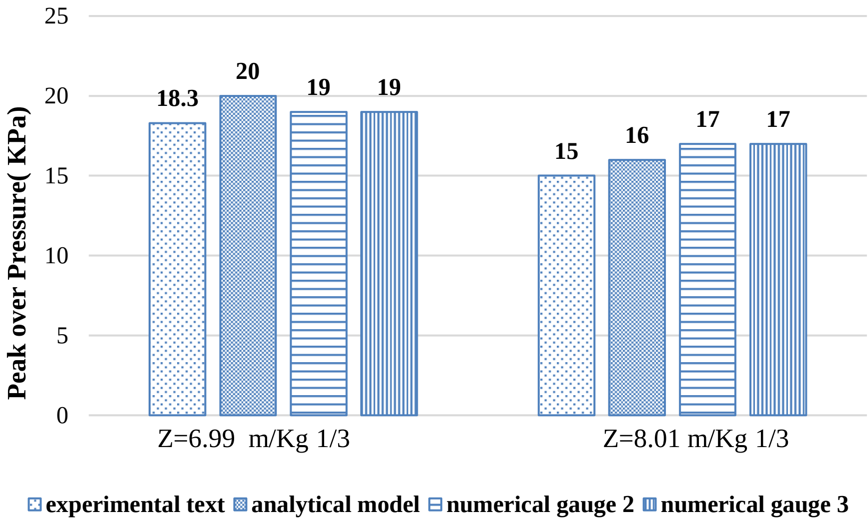

Figure 8: Compared Peak overpressure for Free air gauges

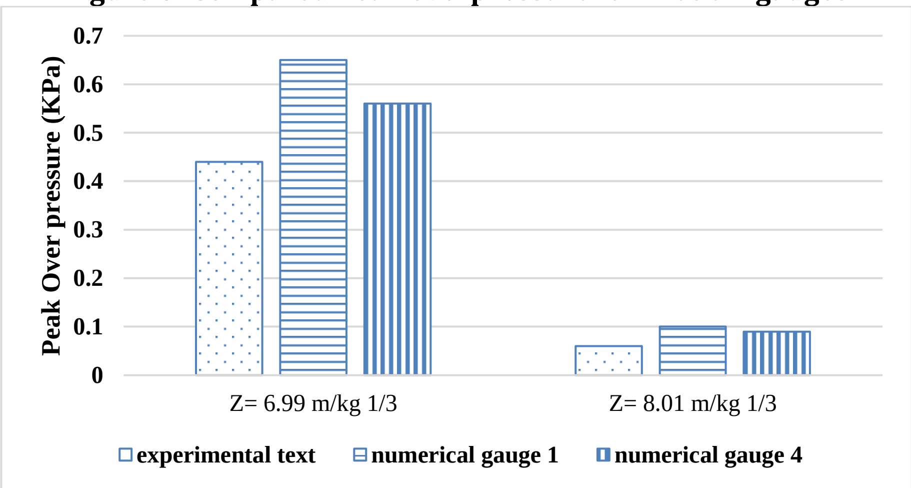

Figure 9: Compared Peak overpressure for protected gauges

It is obvious from the results that the numerical model gives slightly higher results than the experimental model, however, the comparison shows that the numerical model can be validated as the difference in results can be insignificant.

5. Conclusion

In this paper, the usage of environment friendly material such as the OSB (Oriented Strand Board) was investigated to withstand the blast wave effect. According to previous researches the OSB showed good results with respect to its cost, availability and sustainability. A validation is conducted by numerical modelling of a blast wall made of Wood-Sand-Wood.

A comparison is conducted between the results of an experimental published work, and the results obtained from the numerical model done with Autodyn, the validated model showed good agreement with the experimental work in terms of peak over pressure calculation for free air and protected gauges, where the difference in results between gauges recorded results does not exceed 0.21KPa for protected gauges and 1.7 KPa for unprotected (free air) gauges.

As conclusion, the numerical model is successfully validated and can be used for future work recommendations.

6. Future work

The numerical model, presented and validated by the current paper, will be effectively used to study the effect of higher TNT charges on the Wood- Sand –Wood panel system using higher OSB thicknesses and higher overall wall thicknesses to reach a practical blast wall system that can withstand blast wall pressure, protect structures and people behind it, and fabricated with low cost and sustainable materials.

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