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Experimental of Steel Plates Protected with Gypsum Boards Subjected to Explosion

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ABSTRACT

In research pertaining to the response of steel plates or steel structures to explosive events, most investigations tend to overlook the potential influence of fire protection systems, such as intumescent coatings, on explosion absorption capabilities. It is widely assumed that board-type passive fire protection systems, such as gypsum boards, possess the ability to absorb and mitigate explosive forces effectively. The present study aims to conduct experimental investigations in order to assess the absorption capacity of gypsum boards in mitigating the effects of explosions. In this study, four equilateral steel plates with dimensions of 500 mm × 500 mm and a thickness of 3 mm were utilised. The region of exposure to the explosion was confined to 300 mm x 300 mm. The study examined three specific cases: Case 1, which involved solely a steel plate; Case 2, which involved a steel plate protected by gypsum board; and Case 3, which involved a steel plate protected by gypsum boards with a space between them. This study is a specialised explosion test that examines the efficacy of gypsum boards in safeguarding steel plates. The test employs a range of explosive charges to evaluate the protective capabilities of the gypsum boards. The experimental findings indicate that the magnitude of deflection for Case 1, Case 2, and Case 3 is 5 mm, 4 mm, and 1 mm, respectively. This observation demonstrates the capacity of gypsum boards to effectively absorb and mitigate explosive forces, thereby offering a protective barrier for steel plates in the event of an explosion. The findings indicate that Case 3, characterised by the presence of a gap between the steel plate and gypsum boards, offers the most effective protection for the steel plates.

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1. Introduction

September 11, 2001, the collapsed of World Trade Center in New York City gave the best example of the situations in which the fire is a direct consequence of an explosion that can influence the structural steel integrity. The needs to understand the behaviour and combined effects of explosion and fire which could lead to the progressive collapse of structure has been increased.

As far as author's survey, there are limited works on the combined effects of explosion and fire published in the open literature. Izzuddin et al [1, 2] proposed an integrated adaptive environment for fire and explosion analysis of steel frames. Liew and Chen [3] used fiber element approach for inelastic transient analysis of steel structures subjected to explosion loading followed by fire. Liew [4] used LS-Dyna to investigate the survivability of the steel frame structures subject to localised damage caused by blast load and fire. Additionally, Ding et al [5] proposed a new Pressure-Impulse-Exposure time diagram that can be used in evaluating the mechanical damage of steel constitutive under blast load and fire. All these methods described above vary in their applicability and degree of sophistication; however, whether the steel subjected to explosion only or combination of explosion and fire or vice versa, their analysis involved only for unprotected steel structures.

The common practice in the steel constructions is to incorporate steel beams and columns with protective systems, such as fire protection. Some of these protective systems, e.g. intumescent coating, do not have any energy absorption ability. Therefore, the effects of explosion are directly and completely imposed on the steel structures. Owing to that, most of the researcher will neglect the influence of fire protection materials to the effect of explosion. However, some systems, such as fire protection systems in which boards are used and there is some space between the fire protection and the steel structure, the protective systems may have some energy absorption capacity to reduce the effects of explosion on steel structure. The proposed research project is to carry out detail investigations through experiment.

Methodology

The aim of this study is to investigate the behavior of steel plate protected with gypsum board subjected to explosion and fire through experiment. Nines square 3 mm thickness mild steel plates S275 which is 500 mm x 500 mm in dimensions will be subjected to explosion. The exposed area is 300mm x 300mm. The gypsum board used is from brand USG BORAL Impactstop, impact resistant board with 19mm thickness as shown in Figure 1. The explosive used is Plastic Explosive (PE4).

Figure 1: USG BORAL Impactstop gypsum board

Figure 2 shows the setup for the explosion test. It consists of a test jig made from steel angle section; the test plate is placed at it face position and fixed with clamp plate at 1.5 m height. The exposed area of the plate is 300 mm x 300 mm. One PE4 charges are used in the explosion tests which is 100g for each cases. The minimum amount of charges chosen was to make sure the charges will not totally damage the steel plates or gypsum boards, however it is able to make small deflection to the steel plates. The stand-off distance is 1 m from the center of the steel plate. Three cases are analyzed in the present study: Case 1- steel plate only, Case 2 - steel plate with gypsum board and Case 3 - steel plate with gap and gypsum board. The gap distance is 19 mm. Example of the case 3 is shown in Figure

3. The explosive charge is suspended in the air in front of the steel plate. Blast parameters (overpressure and impulses) will be calculated using Kingery's equation (Kingery, 1984). Dynamics response is observed by means of high speed camera. Mid-span deflection and vibration frequency are measured by means of strain sensor type PCB Piezotronics recorded at the back of the steel plate. After each test, damage and crack patterns of the gypsum boards are carefully observed.

Figure. 2: Experimental setup for explosion test Case 1 –Steel Plate only

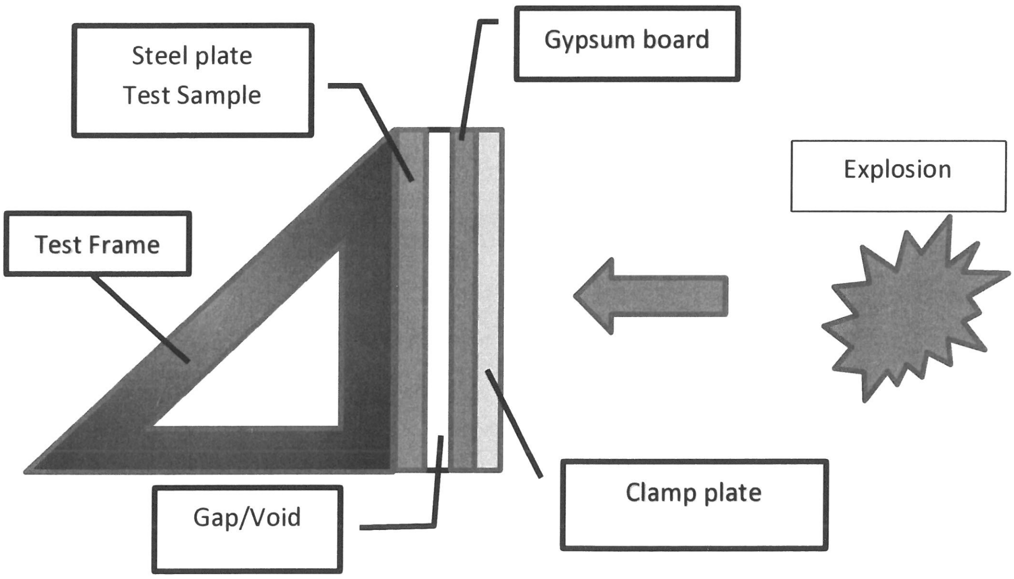

Figure 3: Case 3 -Plate + Gap + Gypsum

Result and Discussion

Figure 4 shows steel plate after explosion test. The strain sensor should measure the deflection of mid plate, however, it did not gave good reading. Both sensor gave unrealistic result. These due to the strain sensors detached from position resulted from explosion test as shown in Figure 5. Therefore, direct measurement is taken to measure final deflection of the steel plate. Even though this technique will not give accurate result, still it can give some overview on the data available. The deflection of each cases can be seen in Figure 6 to Figure 8.

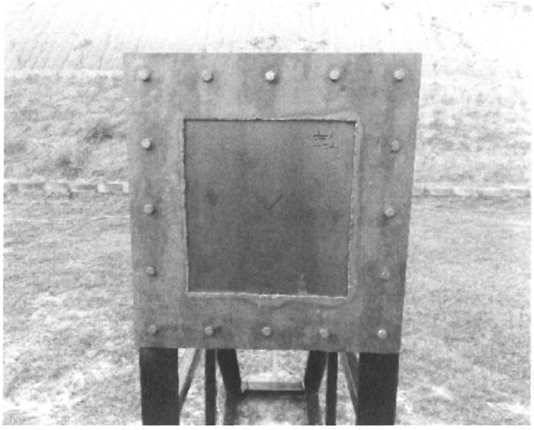

Figure 4: Case 1 – Steel Plate after explosion

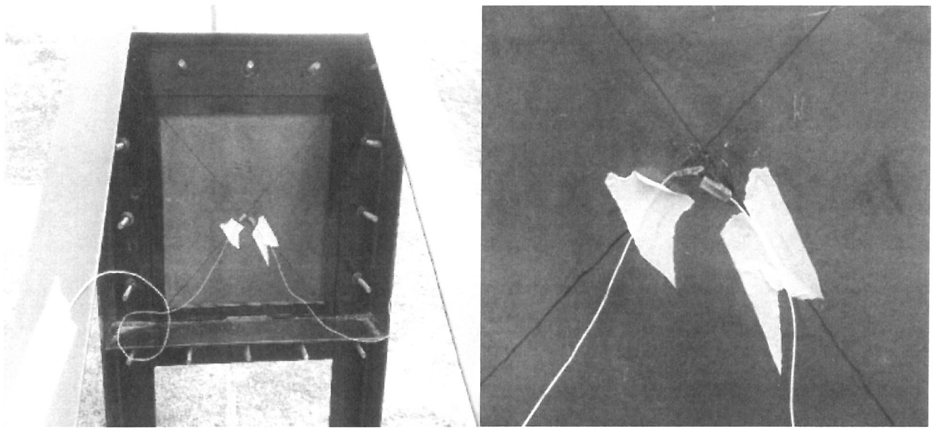

Figure 5: Detailed view of strain sensor at the back of steel plate before and after explosion test

Table 1 shows the final deflection of steel plate for each cases. As can be seen, the deflection decreased when the steel plate was protected with gypsum board. The deflection was further reduced when there is gap between the steel plate and gypsum boards. The results indicate that the board type of fire protection system do have some energy absorption capacity to reduce the effect of explosion to the structures.

Table 1 Deflection of steel plate subjected to explosion

Test	Average Deflection (mm)	Observation of gypsum board
Case 1 – Plate only	4	-
Case 2 - Plate+gypsum	2	No damage
Case 3 - Plate+gap+gypsum	1	Cracked

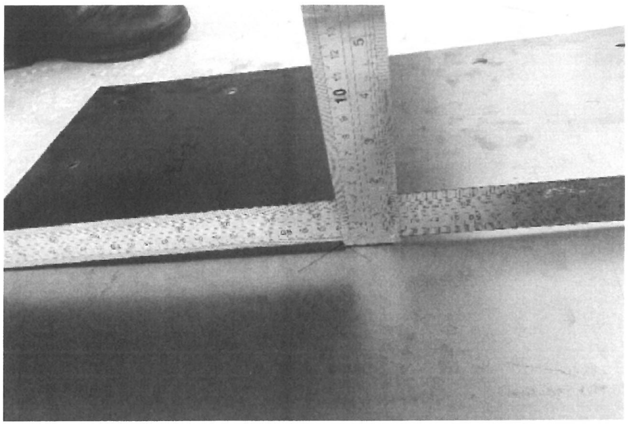

Figure 6: Deflection of steel plate subjected to explosion

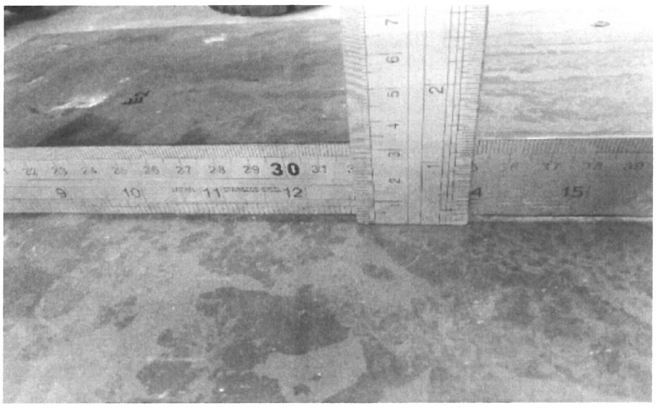

Figure 7: Deflection of steel plate + gypsum

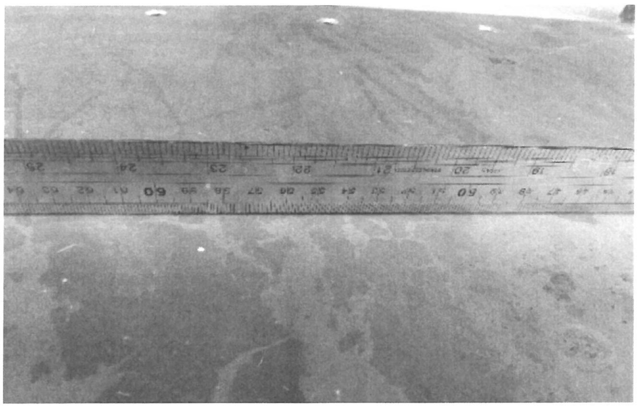

Figure 8: Deflection of steel plate + gap + gypsum

From observation, as shown in Figure 9, no visible damage can be seen with naked eyes to gypsum board in case 2 after exposed to explosion. This is thought to be due to the characteristic of gypsum board which it can resist extreme compression pressure but very weak in tension. The tension area where usually resisted by a layer of paper that covered both side of the gypsum board. The manufacturer strengthen the paper with fiber reinforced. For Case 2, the extra tensile resistant is provided by the steel plate and gypsum boards resist only compression pressure. Compare with case 2, gypsum board in Case 3 totally damaged after subjected to explosion. This can be seen clearly in Figure 10. As discussed earlier, gypsum board failed due to the bending at the center of the board.

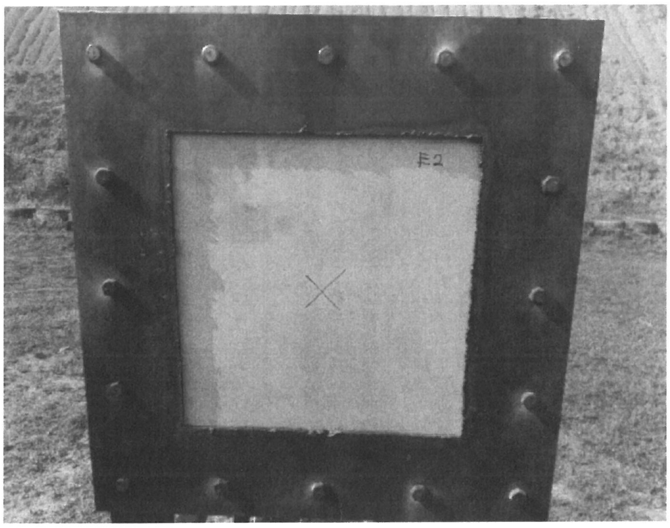

Figure 9: No damage to gypsum board protecting steel plate (Case 2)

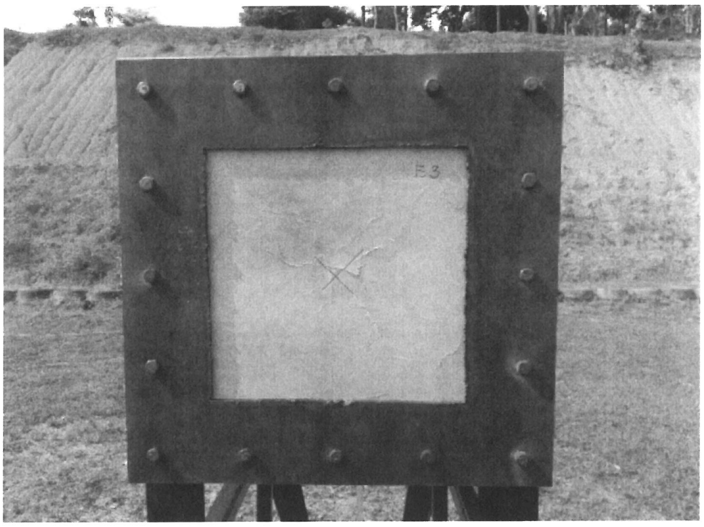

Figure 10: Crack pattern after explosion to steel plate with gypsum board with gap (Case 3)

Conclusion

This work was devoted to assess the behavior of steel plates protected with gypsum boards when subjected to explosion. It was found that board types of fire protection such as gypsum boards does have energy absorption capacity to reduce the explosion effect to steel plate. More detailed work need to be carried out so that more accurate result can be obtained.

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