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The study of energy absorber in strengthening of steel plates against explosion wave and impact

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ABSTRACT : *Impact strength of engineering structures against impact and explosion, is an attractive subject for researchers. Sometimes in explosion, maximum pressure induced due to explosion wave is bigger than structural static collapse pressure. Therefore Structures undergo a big plastic deformation and absorb the energy. Steel plates will experience big deformations against explosive loads. So using methods for reducing these plastic deformations seems necessary. In this paper, it is tried to minimize the plastic deformations using energy dissipaters. For this reason, the effect of energy absorbers with metal yield mechanism is studied. Also, failure load of various range of models are studied and in some cases, 89 percent increase in failure load has been observed.*

KEYWORDS: *impact and explosion, strengthening, dissipaters, steel structures*

I. INTRODUCTION

Explosions in important structures around the world have caused concerns about explosive loads. In explosion, the maximum pressure induced from explosion wave is much bigger than static structural failure pressure and structures usually experience big deformation under blast loads. So using methods to reduce these plastic deformations seems necessary. In recent years, many efforts in investigation and development of structural control systems with emphasis on reduction of seismic and wind effects in buildings and bridges have been done. Many devices have been invented so far to increase performance and structural safety against natural and artificial hazards that are in different levels of investigation and development. In these devices, phenomena such as frictional sliding, steel metal yields, solid deformation, visco–elastic liquid deformation or moving liquid through holes are used. One of the most effective mechanisms for dissipating of the internal energy of structures is to make non–elastic deformation in the metals, which is used in energy absorbers with metal–yield mechanisms. For this reason, the effects of energy dissipaters with metal–failure mechanism in plates are studied in this paper in various conditions.

II. BLAST EFFECT ON STRUCTURE

There are three loading conditions for explosion impacts on structures.[1] In the first one, rather a big impact wave collides to a rather small structure, but structure resists against movement.

The second kind incorporates a big wave and smaller structure than previous one. In this condition, the object is small enough and moves under drag dynamic force. In the last one, explosion wave is small and the structure is very big. Instead of simultaneous loading of members, each member is loaded individually.

Reflection pressure occurs when an explosive wave collides to the materials with bigger density than environment. In this case, air molecules are stopped by these materials and are pressed by backward wave front. This reflection pressure dissipated as time pasts. The roof and side corners of building are loaded with the pressure of collision wave (not reflective). After passing of wave through roof and sides, the pressure reaches to the back of building. For this side reflection effects should be considered. In addition to this additional pressure, drag force is applied to the structure (Figure 1).

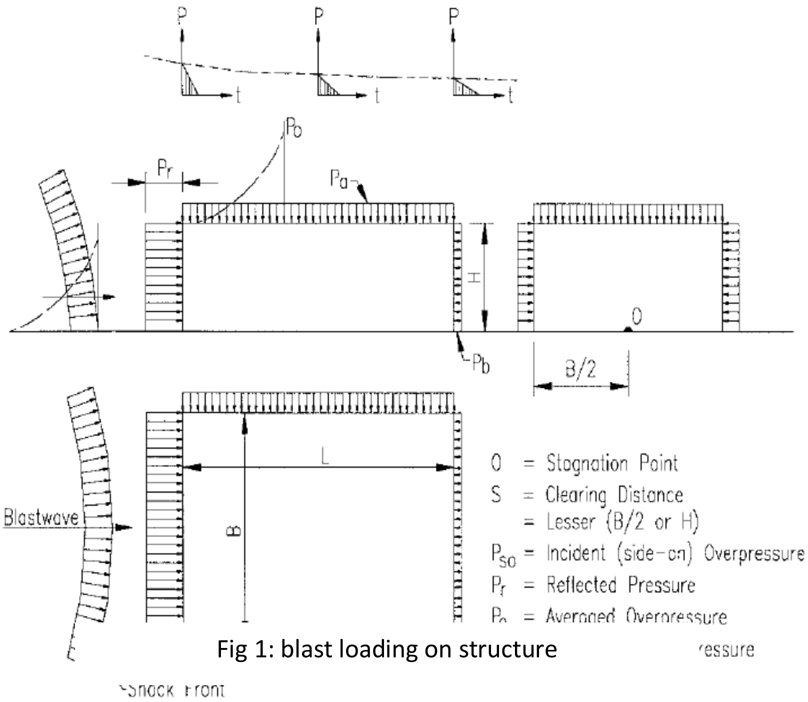

Fig 1: blast loading on structure

III. FAILURE MODES OF STRUCTURAL MEMBERS

Various failure modes in structures under different load conditions have been observed [2]. Usually two kinds of loading are used in experimental and theoretical studies: impact loading and dynamic loading (velocity loading). Mekes & opat performed experimental studies on the dynamic plastic response of the fixed end steel beams under uniform dynamic loading along the span fig. 2(a). Their studies revealed that the beams have deformation response with still a specified loading velocity (fig. 2(b)). If this velocity exceeds a specified range, the beams will have failure due to material tearing in supports (fig. 2(c)). If this velocity increases more, the plastic deformations of beams will be around the supports until a shear failure happens in a critical velocity in supports (fig. 2(d)). Based on these experiments, menkes & opat concluded three failure modes under impact loading in a fully restraint beams:

1) inelastic deformation (mode I)
2) tensions tearing (mode II)
3) transverse shear failure in supports (mode III)

It must be noted that failure modes II and III occurs in two beam sections not along the beam.[3] Similarly, three main failure modes have been observed in restrained circular and square plates under impact loading. Nurick *et al* have divided failure mode I in two groups: failure with relative necking around the supports (mode I_a) and full necking around the supports (mode I_b) [4]. Nurick & shave have observed more failure conditions in square plates for mode II [5]:

Mode II: relative necking in supports
Mode II^a: full necking with center displacement increasing
Mode II^b: full necking with center displacement decreasing

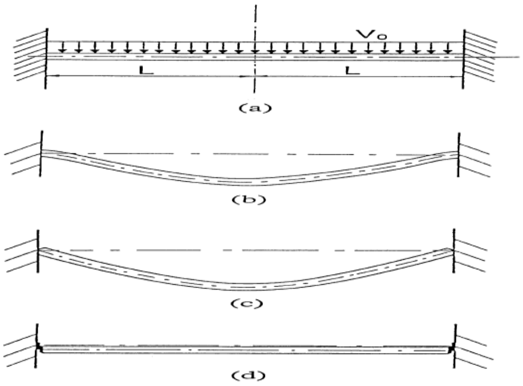

Fig 2: a) the fixed end steel beam under uniform dynamic loading b) failure mode I c) failure mode II d)) failure mode III

Failure modes I & II have been observed for concentrated explosive load. Failure mode III doesn't happen in thinner plates but shear failure have been observed in thick plates. In concentrated central load, failure occurs in central region. By increasing the impact value, the central part necking (mode II_c), relative tearing (II*c) and full tearing (II_c) happen [6]. As shown in Figure 3, by more increasing of impact, more tearing occurs in the rosette mode. In square plates, mode III is used only for shear tearing at four corners of the plate. It must be noted that in plates with high velocity impact, a complicated failure mode with combination of total structural and local penetration or local hole occurs [7].

IV. MATERIALS AND METHODS

In this study, two kinds of models are used for energy dissipation in steel plates. As it can be seen in Figures 4 and 5, because of symmetry, only a 1.4 steel plate is modeled and symmetric boundary conditions are applied to the surface edges. For dissipating energy through material yielding, two models are used. In model A, energy dissipates through plastic deformations. For this model, the effect of thickness of offside part on energy dissipation, maximum displacement and equivalent plastic strain are studied. In model B the plate at its edges has bent part and in these models the effect of curvature radius on the rate of energy dissipation, maximum displacement and equivalent plastic strain has been studied.

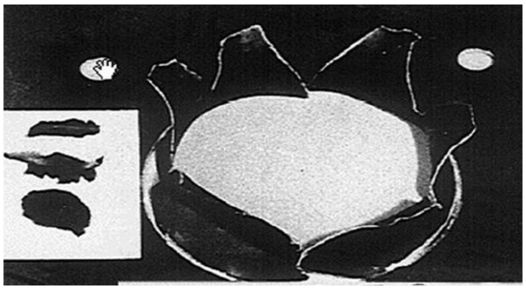

Fig 3: the rosette mode in plate

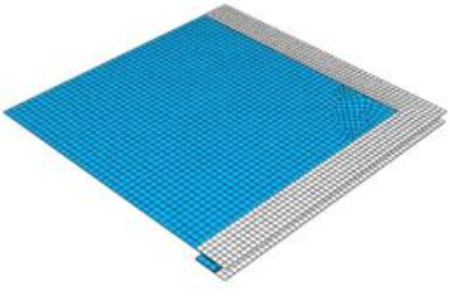

Fig 5: model B

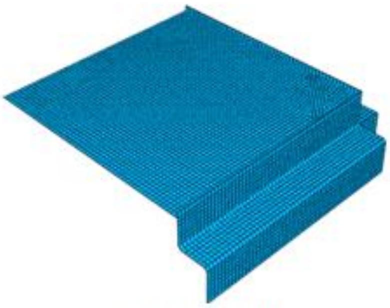

Fig 4: model A

In all models, triangular explosive loads [8] as shown in fig. 6, are used. Its positive duration face t ^{d} is 10 Ms. In all models, except the models of failure load estimations, maximum pressure P $_{max}$ is assumed to be 2*105 Pa.

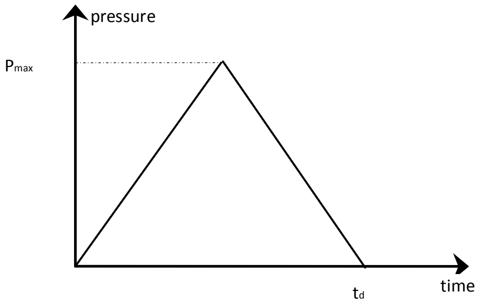

Fig. 6: triangular explosive load

V. ENERGY DISSIPATION IN MODEL C

The thickness of edge part of the plate is one of the main parameters in energy dissipation so in the following, the effect of this thickness is studied. The proposed thicknesses are 3, 5, 7 and 10 mm. In fig. 7, the displacement of central part of steel plate for various thicknesses of edge parts, is shown. It can be seen that by the increasing thickness from 7 mm to 10 mm, there is no considerable variation in maximum displacement.
The thickness of 3mm has the optimum application, but in the view of dissipated energy, the most important matter is that the dissipated energy in the panel must be minimum (fig. 8). For this reason, the dissipated energy for different thicknesses is shown in fig. 9. The minimum dissipated energy is in the panel with 7 mm edge thickness. Fig. 10 shows the panel with 3 mm edge thickness that has the maximum amount.

VI. ENERGY DISSIPATION IN MODEL B

As mentioned in model B, energy dissipation happens through plastic deformations. In this model, one of the main variants is the radius of the curvature of edge segment of the plate. So in this section, the effect of curvature radius on maximum displacement, dissipated energy and equivalent plastic strain is studied. In Figure 11, the displacements of the centre of steel plate for curvature radius 5, 7, 10, 12.5 mm are shown.

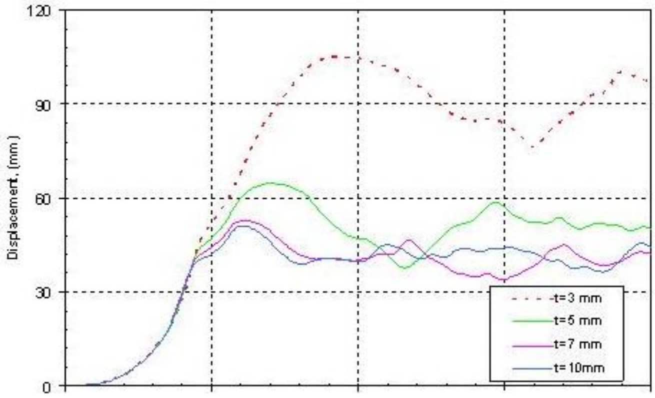

Fig 7: displacement of central part of steel plate

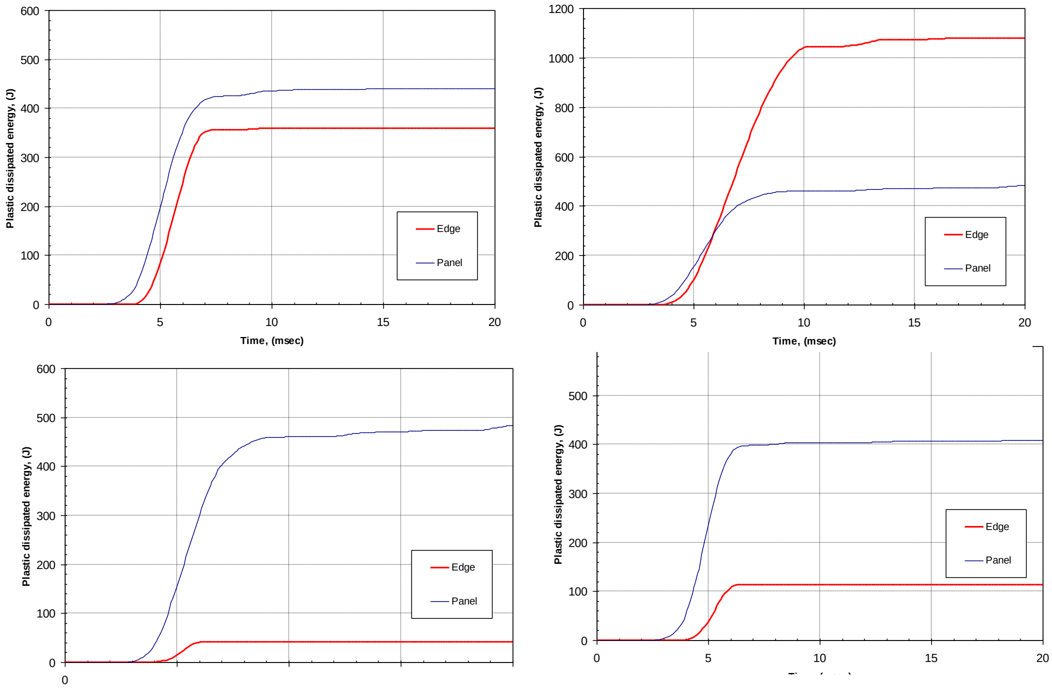

Fig 8: dissipated plastic energy in the panel for different thicknesses

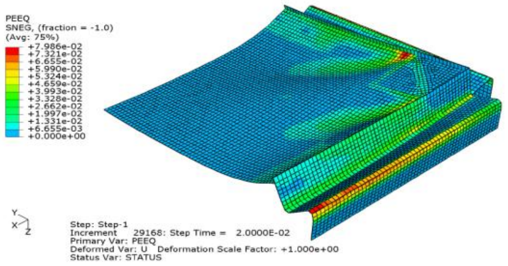

Fig 10: equivalent plastic strain for 7

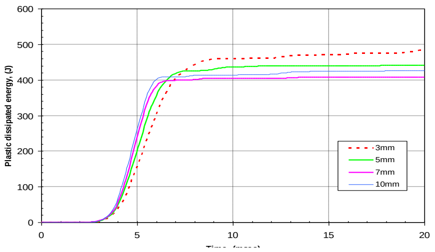

Fig 9: dissipated energy for panel apart edge for different

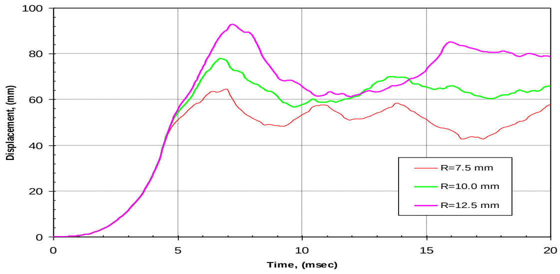

Fig 11: displacement of central part of steel

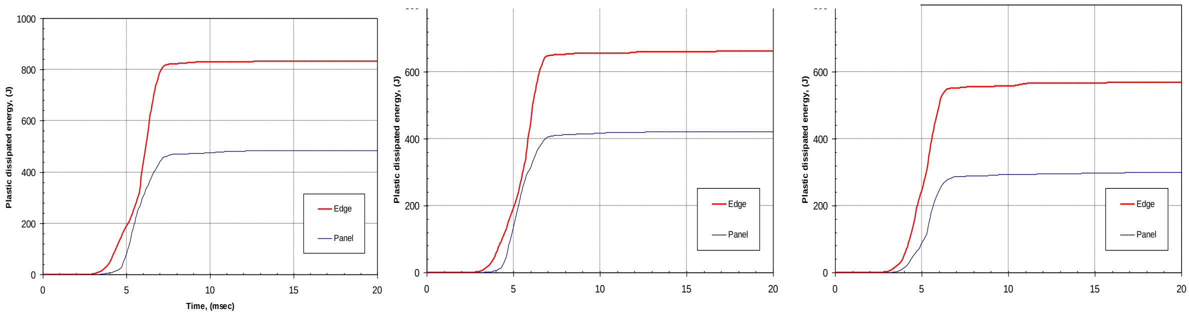

Fig 12: energy dissipated for model with different curvature radius

It can be seen from figure 12 that the minimum displacement belongs to minimum curvature radios. It can be seen that although the dissipated energy at edge segment increases with the increasing of curvature radios, but the dissipated energy in panel increases. So to select the best condition, the dissipated energy inside the panel for various curvature radiuses must be compared with each other.

This comparison, has been shown in figure 13. It can be seen that in the view of dissipated energy in the panel, the curvature radios of 7.5 mm is the best choose. (figure14).

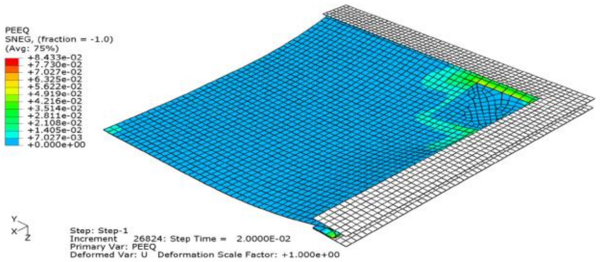

Fig 14: equivalent plastic strain for 7 mm curvature radius

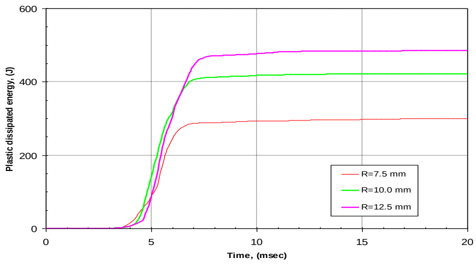

Fig 13: dissipated energy for panel apart edge for different curvature radius

VII. CONCLUSION AND RESULTS

Explosions in important structures around the world have caused concerns about explosive loads. One of the most effective mechanisms for dissipating of the internal energy of structures is to make non–elastic deformation in the metals, which is used in energy absorbers with metal–yield mechanisms. For this reason, two kinds of models are used for energy dissipation in steel plates, A and B. In model A, energy dissipates through plastic deformations with the effect of thickness of offside part on energy dissipation; maximum displacement and equivalent plastic strain are studied. In model B the plate at its edges has bent part and in these models the effect of curvature radius on the rate of energy dissipation, maximum displacement and equivalent plastic strain has been studied. In model A, the increase in edge segment to a defined limit, makes reduction in maximum displacement and , the increase in edge segment to a defined limit, decreases and then increases the plastic dissipated energy in panel but plastic dissipated energy in apart segment decreases and maximum equivalent plastic strain decreases. In dissipaters of in model B, by increase the curvature radius, the maximum displacement increases. In model B, not only with the increase in curvature radius, the dissipated energy in apart segment in creases, but also the dissipated energy in panel increased, so to choose the best condition the plastic dissipated energy in panel for different curvature radiuses must be compared with each other. In model B, with the increase in curvature radius, the maximum equivalent plastic strain decreases. In energy dissipater with metal yield mechanisms in model B, the energy dissipation begins from apart segments, but in model A, the energy dissipation begins from panel, that from this point of view is better than model B.

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