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The use of sandwich-panels as a safety and easily thrown off designs for internal explosions

Vyacheslav Gorev[1] and *Evgeniya* Salymova[1*]

[1]Moscow State University of Civil Engineering, 129337, Yaroslavskoye Shosse 26, Moscow, Russia

Abstract. New method of explosion-proof ensuring for industrial buildings by usage of sandwich-panels as enclosures and easily thrown off designs by inside combustions is examined in this work.

Possibility of dumping of an overpressure at internal explosion indoors - the obligatory requirement at projection and operation of explosive rooms [7]. The acceptable results are achieved by two options:1) use of the weak protecting designs (glass, membranes); 2) use of loose couplings when fastening of the protecting designs to a building framework. In case of the former the protecting designs collapse, in the second communications collapse and the released protecting designs start moving, opening the aperture blocked by them. Through the opened apertures from the room gases expire that leads to pressure decrease. The best results are achieved at the quasistatic nature of explosion when wave processes are insignificant.

The protecting designs serving for an explosion depressurization are often called the safety designs (SD) [4] or easily thrown off designs (ETD). [9].

Now most the energy industries enterprises are built with use triplex a sandwich panels which at the corresponding fastening can apply, owing to their small weight, to use as ETD.

Full success is achieved, if the area does not allow the rise of the burst pressure to allowable values ΔP_d , which is determined by the carrying capacity of protected structures. This success is possible, if the area of openings, covers easy detachable more than the required minimum, and easily thrown off designs are opened fast enough to provide the required area expires during the development of the explosion.

It is necessary that the time development of the explosion was more than time for the opening of openings. Internal quasi-static explosion devoted many works [1, 2, 3, 4]. Most of the required area is determined by the expiration. Question - how do you ensure this area remains on the sidelines with the exception of destructible structures: glass and membrane [4, 5].

In industrial hazardous locations more convenient to use light panels that have loose connections. The explosion destroyed the first, and the panels fly off under the action of pressure and release they overlap the square. In this paper the process of opening the light panels and the change in pressure directly after the destruction of relationships, retaining panel. The analysis is performed using the equations describing the pressure changes with increasing square of the expiration of the [4] and the equations of motion of the panel.

This assumes that:

[*] Corresponding author: Kiara_lion@mail.ru

1. The movement of the panel is described by the equation:

$$M\frac{d^2x}{dt^2} = \Delta Pab$$

Where **x-** distance last the panel by the time of time **t**

2. Expire cold gases.
3. The average pressure acting on the panel:

$$\Delta P = \frac{\Delta P_1 + \Delta P_V}{2},$$

where $\mathbf{\Delta P_1}$ – corresponds to the first maximum pressure immediately after opening, $\mathbf{\Delta P_V}$ – pressure opening. From experiments and numerical solutions performed in [6] shows that $\mathbf{\Delta P_1}$ depends on $\mathbf{\Delta P_V}$ and the speed of combustion. And may exceed $\mathbf{\Delta P_d}$.

4. Dealt with the pressure at which the velocity is described by the expression

$$\sqrt{\frac{2\Delta P}{\rho_0}}$$

that overrides the carrying capacity of many buildings. However, this limitation does not matter.

Note the experimental fact that the maximum $\mathbf{\Delta P_1}$occurs at the opening of sandwich panels with incomplete opening of the opening, i.e.

$$x < \frac{ab}{2(a+b)}$$

a and **b** – sides aperture.

Using assumptions 1-4 and condition of maximum pressure

$$\frac{dP}{dt} = 0$$

is the value of this maximum:

$$\frac{\Delta P_1 - \Delta P_V}{\Delta P_V} = \frac{2F^{1/2} - 1}{\left(F^{1/2} - 1\right)^2} \tag{1}$$

$$F = \frac{\nu_1 (a+b) ab \Delta P_V^{3/2} N}{2^{3/2} \pi M \rho_0^{1/2} U_g (\sigma - 1)\sigma^2}$$

$\mathbf{U_g}$ - the rate of combustion at the time of opening of easily thrown off designs, $\boldsymbol{\nu_1}$ – flow coefficient, **N** - is the number of opened panels, **M** – mass of the panel, $\boldsymbol{\sigma}$ - the rate of expansion during combustion, $\boldsymbol{\rho_0}$ - is the initial density of the gaseous medium.

The number of panels is determined from the condition that the area is completely uncovered openings provided for reducing the pressure of the explosion to $\mathbf{\Delta P_d}$, at the time of the maximum speed of energy release, i.e. at the moment when there $\mathbf{U_g}$ and $\mathbf{F_f}$ are maximum (where $\mathbf{F_f}$ - is the area of burning).

Thus, (**N*a*b**) has the necessary space required fully opened openings. This area is defined by the expression [4,6]:

$$S_{treb} = \left(\frac{2\rho_0}{\nu_2 \Delta P_d}\right)^{1/2} \frac{\sigma^2 (\sigma - 1) U_g K_f V_0^{2/3}}{\left(1 + \sigma^{1/2}\right)} \tag{2}$$

Substituting this expression into the previous one and requiring that would $\mathbf{\Delta P_1 < \Delta P_d}$, after simple transformations, we obtain the condition:

$$\Delta P_d\left[1-\left(\frac{\Delta P_V}{\Delta P_d}\right)^{1/2}\right]^2 > \frac{2\pi M U_g^{\ 2}\left(1+\sigma^{1/2}\right)}{(a+b)K_f V_0^{\ 2/3}} \tag{3}$$

Here $\mathbf{K_f}$ is the shape factor of the premises, determined from:

$$(F)_{\max} = K_f V_0^{\ 2/3} \tag{4}$$

F – surface area of the flame when deflagration internal explosion.

Using data on the known parameters of an internal explosion and properties of easily thrown off designs, you can pick up $\mathbf{\Delta P_V}$ to $\mathbf{\Delta P_1}$ does not exceed $\mathbf{\Delta P_d}$**.** Table 1 presents data on $\mathbf{\Delta P_d}$ for different values of $\mathbf{\Delta P_V/\Delta P_d}$.

Table 1. Data on ΔPd for different values of ΔPV/ΔPd.

$\mathbf{\Delta P_V/\Delta P_1}$	0.5	0.6	0.7	0.8	0.9
$\mathbf{\Delta P_V}$**, kPa**	1.17	1.5	2.25	4.4	5.6

The calculations were performed for data: $\mathbf{V_0}$ = 1000 m^3, $\mathbf{K_f}$ = 3, σ = 7, $\mathbf{U_g}$ = 2.4 m/sec, (**M/ab**)=25 kg/m.

The table shows that the magnitude of the pressure opening has a significant influence on the resulting blast load. In [6] experimentally studied the autopsy sandwich panels for some cases of attachment. The opening pressure depends on the thickness of the sheet, the thickness of the structure in which twists of «tapping» and the number of attachment points.

Pressure of opening depends on the leaf thickness from design thickness in which «self-tapping screw» and from number of points of fastening twists and in each case is defined experimentally.

Experiments were made on two explosive cameras 1 of m^3 and 10 m^3. The technique of carrying out an experiment is described in [6,7,8]. The generalized results of experiments are presented in the table 2.

Table 2. Results of experiments.

Series of experiments	**The tested design**	**Thickness of a metal profile, mm**	**Number of self-tapping screws**	**Nature of destruction**	**Pressure of opening, kPa.**	**Load of one self-tapping screw, kN**	**Note.**
1	Sandwich panel, 1200x2000x 50mm	5	4	The «self-tapping screw» in a metal profile	3.2 3.38 3.45	1.92 2.03 2.07	-
2	Sandwich panel, 1200x2000x 50mm	5	4	The «self-tapping screw» in a metal profile	2.4 2.03 2.2	1.44 1.20 1.32	Without washer
3	Sandwich panel, 1200x2000x 50mm	5	4	The «self-tapping screw» in a metal profile	1.2 1.55 1.1	0.72 0.93 0.66	Cut of a metal leaf
4	Part of the sandwich panel, 400x400x50 mm	2	2	The «self-tapping screw» in the panel	11.28 18.8 15.40	0.90 1.50 1.23	-

Experiments were made with use of nominal «self-tapping screws» – for fastening a sandwich panels. The aperture was blocked by a unity element a sandwich panel, results of experiments testify about:

– the nature of opening of the panel depends on thickness of a design to which it to fasten. At a thickness of design of 5 mm - with break of sheets of the panel, at 2 mm – with to pull out «self-tapping screw» from it;

– decrease of the size of washers under a head of «self-tapping screw» reduced opening pressure. In the absence of a washer pressure of opening decreased by 1.5 times;

– the cruciform cut of the panel under a washer, with a cut length to edge of a washer, was reduced by opening pressure by 2.5-3 times;

– at decrease of pressure of opening the maximal pressure immediately after opening according to (3) and table 1 decreased;

– pressure of opening can be estimated on a ratio:

$$\Delta P_{в} = \frac{f * n}{S}$$

– where **f** – effort to a simple point of fastening during the opening, it is defined experimentally at a leaf thickness a sandwich panel, **δ**=0.5mm, **n** – number of points of fastening, **S** - the area a sandwich panels.

Application a sandwich panels of the big size increases load of simple knot of fastening, therefore, more rational is use a sandwich panels of perhaps larger size. In this case there is a possibility of protection not only bearing, but also protecting a sandwich panels of the smaller size.

In the conclusion it is necessary to make two remarks:

1) at installation a sandwich panels they are adjusted to each other by means of the «groove in a groove» lock along the lengthiest party. Carrying out experiments with the block a sandwich panels was impossible. It is possible to consider this effect gathering the block from a sandwich panels so that cross sectional dimension of the block (**n*b**) was common more than length one sandwich panel or to use panels without latch fastening.

2) the second remark arises because opening of an aperture begins not at the time of a start of motion, as in an experiment, and at the moment when ETD passes distance **x =δ** to panel thickness. This circumstance is considered by the amendment to opening pressure to a look:

$$\Delta P_{V1} = \Delta P_{V0}\left[1 - 8.3\frac{\sigma^2(\sigma-1)U_g^3}{V_0}\left(\frac{\delta M}{abP_{V0}^3}\right)^{1/2}\right]^3$$

This amendment is rather small. For typical values $\mathbf{\Delta P_V}$=3*10^3 Pa, **σ**=7, $\mathbf{U_g}$ = 1.5 m/sec,**δ**=10^{-1}m, $\mathbf{V_0}$ = 600 m^3,($\mathbf{\Delta P_V/\Delta P_1}$)=1.004, (**M/ab**)=25 kg/m^2.

Conclusions

1. Triplex a sandwich panel can be efficient easily thrown off designs.
2. Comparison a sandwich panels with a glazing shows advantages of panels before a deaf double glazing so their application as ETD is preferable.
3. Effectiveness of sandwich-panels as easily thrown off designs considerably is defined by opening pressure, that is effort to simple knot of fastening. The opening pressure in relation to the allowed pressure is less, the less robust constructions can be protected.

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