

New frontiers in the management of explosion hazard

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Abstract

Recent project engineering have permitted to find technical solutions wich using in an original way consolidated building technologies and introducing others more innovative, have pointed out solutions to several problems. That solutions aim at solving a wide and expandable range of problems connected with bunkering existing buildings and newly constructed buildings. The parameters wich can be determined through the risk analysis are sufficient to define the requisites of resistant capacity wich the construction is to sustain and therefore to plan the necessary adjustment interventions. The article illustrates some project solutions which have been adopted and which in that case had to make the building resistant to an overpressure wave of 0,1bar and to a 180minute fire. Project solutions refer to: the system of fixed glass windows, the system used for blind or grid doors, both fire-proof and explosion-proof; how to determine the size and the characteristics of a 16cm thick concrete wall and the criteria used for steel reinforcement.

1 Introduction

The factory protection from a shock wave due to an explosion may be succesfully controlled using informations normally pointed out by the risk analysis, e.g. the entity of the overpressure and the duration of positive phase.

The article suggest to detect the effects of shock waves in a deterministic way, decomposing the buildings into mechanical subsystems. Mechanical subsystem may be characterized examining the constraints of each part with the others: normally can be considered mechanical subsystems outside doors and windows, exterior walls,

prefabricated panels and frames of structures. For each mechanical subsystem equivalent static forces are determined that depend mainly on the form of the overpressure diagram, on periods of vibration, on type of materials that compose the subsystems and on its ductility.

As will be seen, furthermore, timing delay necessary to the shock wave to reach variously exposed faces moving at nearly the sound speed, give rise to a net load on a structure as a whole. These net load is quite different from the one that is shown on each face: the first (net load) should be used in global stability analysis, while the second concern for the local checks of mechanical subsystems.

In keeping with this kind of structural analysis is a form of design, that the authors like to define "shield bunkering". Shield bunkering means to provide an exterior shield that may be backed up at existing frame or stand by itself; this shield is made with parts specialized to carry out the designed functions such as shock-resistance, fire-resistance, earthquake-resistance, transparency (presence of windows), presence of doors and ventilations and so on. We emphasize that exterior shield could be intended to protect the exterior surfaces only (without interfere with the global stability) or also that to avoid the collapse of building.

Specific solutions are proposed to solve the problem of doors and windows that will be blast-resistant and fire-resistant also in case of they must allow the natural aeration.

2 Load diagram

A good deal has been written on physical phenomena that are shown during the positive phase of an explosion; in the following we remind main ideas.

The explosion takes place in an initial narrow space and then spreads pressing the adjacent air shell that in its turn transfers the compression at the following and so on. So it is generated a shock wave that moves nearly at the sound speed (fig. 1).

When the shock approaches a building take place a phenomenon of reflection, that is the first waves of compression that collide with the building are reflected against the other arriving compressive waves. So the initial overpressure rise up to even more than 5 times the overpressure in open spaces! When the building is crossed, the action and reaction principle teaches us that the shock wave impart a force equal but in the opposite direction of that of propagation. Subsequently, after a stagnation phase representing the combined effect of blast wind and shock overpressure, occurs the phenomenon of aerodynamic drag (or wind phase) and then the overpressure decays. The above phenomena are in reference with the upwind and the leeward faces of the building. On roofs and side walls, instead, overpressure is obtained computing the mean value of upwind and leeward faces and considering shrewdnesses that allow to esteem the effects of time delay. In the examining case the diagrams are those of fig. 2.

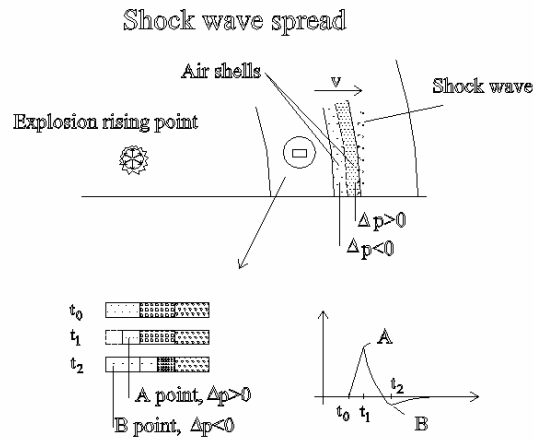


Figure 1. Blast wave spread

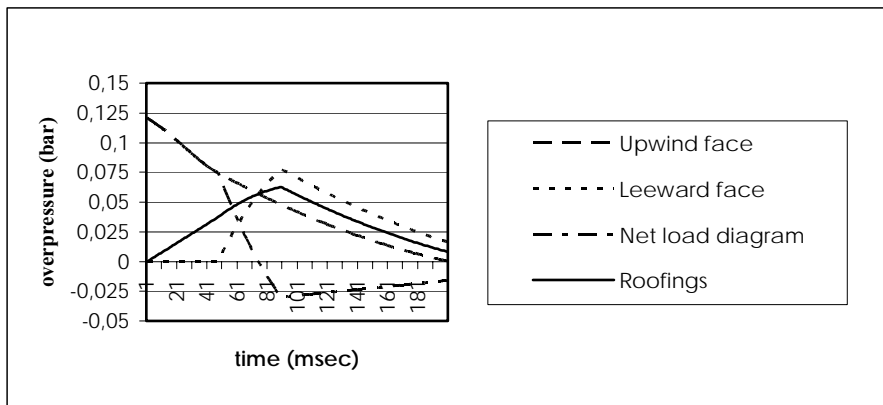


Figure 2. Load diagrams for examined building

3 Reinforced concrete wall

In this particular case the main bearing frame, designed with earthquake-proof standards, is qualified to tolerate the horizontal force generated by a blast and consequently to assure the global stability of the building. The outside prefabricated panels (vertical walls and roofings), instead, in case of an accident would be seriously damaged. The designers' choice was to place a baffle-plate against the existing building supported by mechanically independent foundations (fig. 3). In

case of explosion this baffle-plate can swallow up stresses due to the shock wave, transferring stresses to the main frame of the building. Besides, the thickness of plate (16cm) and the arrangement of reinforcements were determined also regarding the necessity of assuring appropriate fire resistance and earthquake resistance. Particularly, reinforcements have been designed in an interior position so to ensure mechanical resistance for all fire duration (fig. 4).

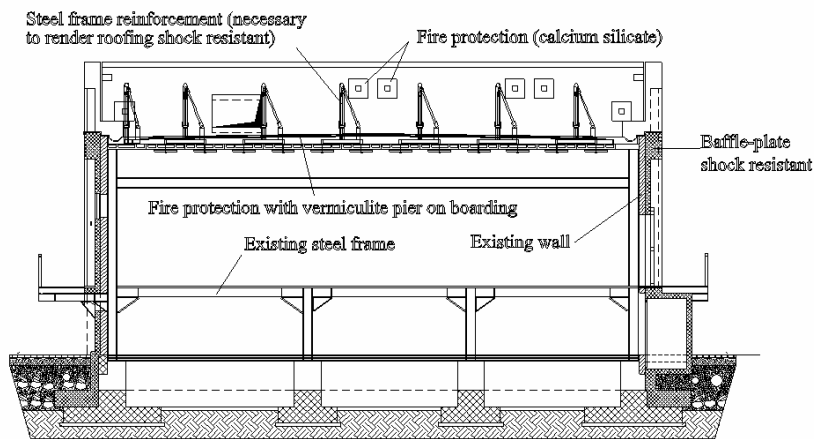


Figure 3. Designed baffle-plate against existing building supported by mechanically independent foundations

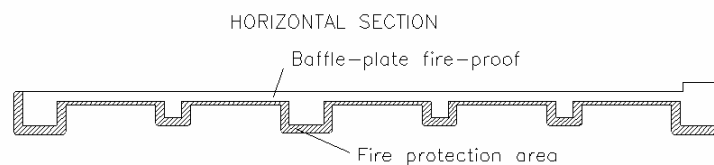


Figure 4. Arrangement of reinforcements assuring appropriate fire resistance

4 Opening devices

The designed opening devices are made up of two doors: the outside one is normally closed and explosion-proof; the inside is fire-proof and is ordinarily kept open by electromagnets (fig. 5). When a fire occurs a centralized device control opens the outside sash driving a cylinder actuator and renders inactive the electromagnets so that the inside sash, pushed by a spring, closes. A couple of probes surveys external fire and explosions; they are placed near every door. This device assures the highest working flexibility because it is run by a software that allows to

programme the sequence and the duration of the actions to be done in case of emergency. The aims to be reached are:

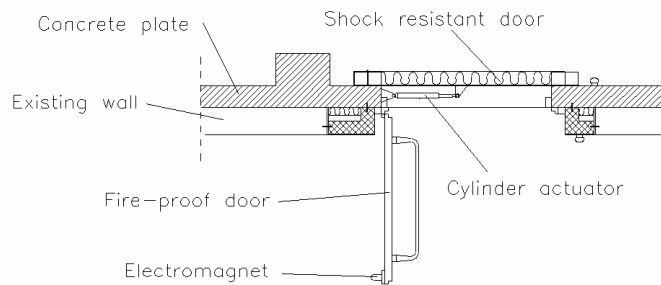


Figure 5. Double door devices

- the security outside doors will have to resist to a possible shock wave
- the safety place in case of explosion or fire is inside the building, and it must be accessible from the outside in the course of an emergency
- the admittance across these doors must be allowed during ordinarily working conditions too
- these device constantly surveys during ordinarily working conditions and can be operated by hand in case of malfunctioning or deterioration

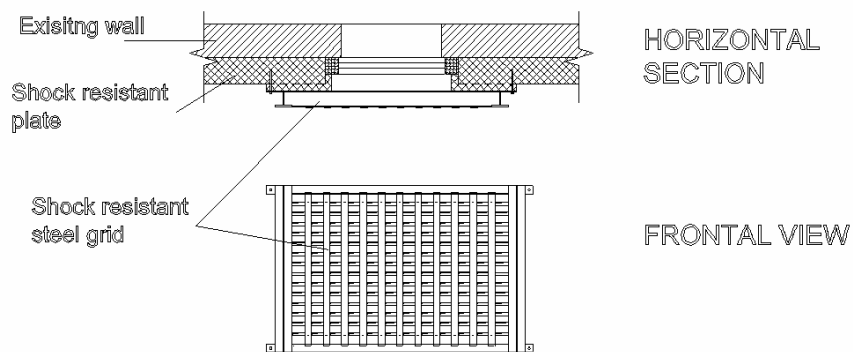


Figure 6. Shock resistant ventilation

The blast resistance is obtained using a 3mm thick sheet steel, welded on a frame of draw pieces; never mind, in fact, possibly great or plastic deformations due to

shock wave. If ventilation is needed, it is possible to just make little holes in the sheet steel so that shock wave can't pass through because it will appear like a blind surface (fig. 6).

5 Windows

The bunker has windows too fixed to the concrete wall (fig. 7). The glass is about 8cm thick and is made of several tempered crystall sheets with interposed intumescent gel between each other. The glass is fixed to the wall by means of two steel frames, one of them being outside, the other inside. The interior frame is fixed to the wall, while the exterior one is locked with bolts and is protected with calcium silicate to render it fire-proof. Inserts of ceramic fiber are placed to guarantee insulating properties and to make the windows smoke-proof. When fire heats ceramic fiber, chemical reactions increase strongly its volume and so overflow interstices left by slacks.

Glass assembly is 120minutes fire-proof and is designed for an equivalent static load determined considering it a mechanical subsystem; in particular for strength analysis has been adopted a safety factor of 2.5 compared to collapse. Analogously to what stated about the doors, mechanical strength is entrusted to the exterior sheet, the interior ones being fire-proof.

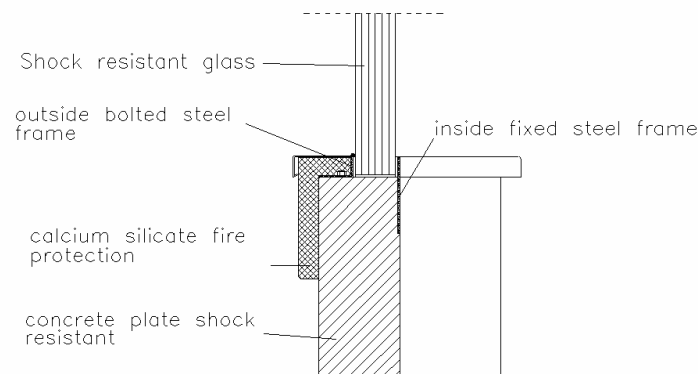


Figure 7. Shock resistant and fire-proof windows

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