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Assessing the Effects of Explosion Waves on Office and Residential Buildings

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***Abstract*—**Explosions may cause intensive damage to buildings and sometimes lead to total and progressive destruction. Pressures induced by explosions are one of the most destructive loads a structure may experience. While designing structures for great explosions may be expensive and impractical, engineers are looking for methods for preventing destructions resulted from explosions. A favorable structural system is a system which does not disrupt totally due to local explosion, since such structures sustain less loss in comparison with structural ones which really bear the load and suddenly disrupt. Designing and establishing vital and necessary installations in a way that it is resistant against direct hit of bomb and rocket is not practical, economical, or expedient in many cases, because the cost of construction and installation with such specifications is several times more than the total cost of the related equipment.

***Keywords*—**Explosion Waves, explosion load, Office, Residential Buildings

I. Introduction

THE resistance of a building against explosion wave first depends on the power of the building and the materials used in it and then on its shape and the number of its openings. The strongest types of structure is the square and rectangular ones with steel and concrete frames, and the weakest ones are the factories' inclined frames with light and long beams and ceilings without braces. In case of explosion, the building's shape is not that much important, because almost all buildings are quadrangular. A narrow and long building if hit by explosion wave on its narrow part sustains less damage than when it is hit on its wide part. The matter of shape is effective only in some parts of a building such as chimneys and piles. Since explosion wave surrounds them immediately from all directions and press the entire round with a same pressure, they show high resistance. The explosion load on the parts of a structure may have two local and general effects. Type of the structure's response usually depends on the rate and direction of loading as regards the building, and the bearing conditions. The general shape of the building failure depends on the explosion loading and may be in form of bending or punch cut. Local reactions to explosion include bursting and scrunching of the parts near to explosion waves. General reactions, also, include bending failure of the system parts [1]- [3] .

II. General Response of Structure under Effect of Explosion

General response of system to transitional loads out of the plate takes a long range of time and is usually depended on bending or shearing resistance of the structure. With this explanation, the resistance of superstructure of reinforced concrete depends on bending resistance of the components. The second type of general failure is shear failure. According to Woodson's studies in 2003 [4], four types of shear failure may be sustained by a building under the effect of static and dynamic loading: 1- diagonal pressure shear2- diagonal gravitational shear3- punch shear4- direct shear (dynamic).

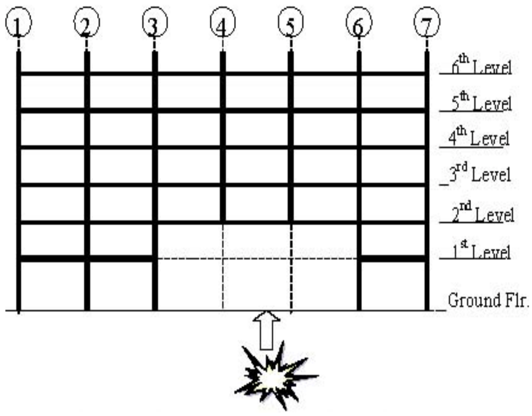

Fig. 1 explosion loading on the structure [5]

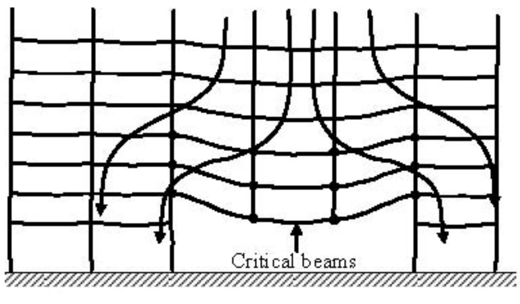

Fig. 2 results of failure analysis & the route of the structure's general failure to explosion load [5]

The first two types may occur in ordinary buildings under general static loads, too. The third one, also, depends on local shear like the one made in the slab by its holder column.

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These three types have a little influence on explosion loading. But the fourth type occurs with high intensity in a short time and depends on high pressure of the wave. The shear occurred due to a sudden pressure is very stronger than the one occurred due to bending. The stress induced by the wave may cause direct shear in a very short range of time equal to millisecond. In fig.1 an example of structure analysis has been shown for studying the structure behavior against general failure resulted from explosion.

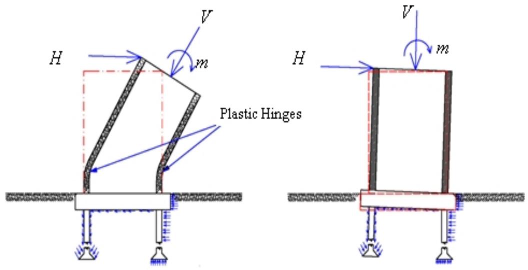
III. The Structure's Local Effect under Explosion

Adjacency of explosion to elements of the structure may cause shearing or bending failure of those elements that such failures have a great effect on the speed of the structure's failure. This type of structure effect appears in the form of bursting and making holes in the structure's parts. In the below figure, an instance of it has been shown on a wall near to which a explosion has happened.

Fig. 3 Breaching Failure of the Beam in the form of Bursting [5]

IV. The Structure's Foundation System Resistant against Explosion

The most important factor in designing a foundation system for structures resistant against explosion with regards to the nature of the explosion-induced load is that the selected system not only tolerate the loads incurred into the structure, but also does not exit from the mechanism selected for dissipation of energy. To provide such conditions, all mechanisms made by dynamic loads should be defined correctly and taken into consideration in design. It is only then that the system is expected to not fall out of the design capacity due to local plasticity. The most usual and favorable design for this type of loading is to design a wall with plastic base with its pile and helmet since it resists against the excessive forces from the superstructure with an ideal resistance power. Fig.4 shows two examples of side forces to the base system and the system's resistance against the loads. According to figure (4a) it is observed that if energy dissipation is used in superstructure to provide the system's plasticity while the foundation system remains elastic, plastic hinges are made in the superstructure.



b a

a. elastic superstructure and plastic foundation
b. plastic superstructure and elastic foundation

Fig. 4 Plastic structures response to side loads [6]

Due to such hinges, great cracks are made in the superstructure; to control such cracks, many reinforcements are to be used that is not economical due to design. According to the figure (4b) if energy dissemination is used in the piles to provide plasticity while the superstructure is elastic, this design is not favorable either, because reliance on the pile's wall friction during dynamic analysis is insecure. The complete settlement of such a system in the earthquake of 1985 in Mexico proves this claim. For the same reason, a system is favorable only if its energy dissipation is distributed between the superstructure and the foundation which means that both the superstructure and the foundation system should act as plastic in dynamic analysis. According to the abovementioned facts and theory of Baker and Whitney (1992), the foundation system used in such structure would be the pile group under each of the columns [7] . After this prelude, we study the behavior of individual piles and pile groups under effect of lateral load.

V. Foundation design for Buildings Resistant against Explosion

Baker and Whitney (1992): in buildings resistant against explosion, reinforced concrete pile groups should be provided under each column [7]. The pile groups are intensively exposed to tensile and pressure loads of the columns above them. Continuity of such maximum loads is very short and makes the frame to rotate. Design of such piles is not correct only for maximum absolute axial force and effect of moment according to reaction of the pile group, since the other important factor is in design of the uplift force and the only factor of resistance against the uplift force is the foundation weight. To make the structure effectively resistant against the loads, it is necessary to make the resisting force of the piles and the main beams couple. The main beams section is to be designed so that it can balance the worst uplift force resulted from the very weight of the concrete piles and the soil column above it and secondary parts of the main beams. To estimate the damage within a scope which makes possible the new use after limited structural repair, the maximum vertical displacement should be calculated. Reinforcement of reinforced concrete beams should be designed like cantilever beams for net tensile stress. To facilitate the work, final state design method has been used for designing all the main beams.

VI. Results

A favorable structural system is a system which does not disrupt totally due to local explosion, since such structures sustain less damage in comparison with structural ones which really bear the load and suddenly disrupt.

To achieve such system, the system frame is required to additionally bear the loads resulted from failure of a member due to explosion. Steel (or concrete) flexural frames are an example of such frames. In such frames, the structural design should be performed so that the general loads are distributed from above to the bottom, and the system of the ceiling and other parts are required to be devised in a way not to be lifted under effect of the uplift force. According to the nature of explosion, in this type of loading, direction of stresses changes (it incurs to the structure in a reciprocating manner). In designing the structural parts, the joints and foundations should be accomplished so that the stresses reversibility (inversion) is restrained. For this purpose, a concrete flexural frame system may be applied. In fact, a reinforced concrete system with high plasticity and damping is as efficient as a metal frame system.

VII. Conclusion

Selection of a proper form and capacity for a building has a great effect on the rate of the total damage of the building. The windward angels and the surrounding elements of the building may capture the shock wave and intensify the explosion effect. Wide and obtuse angels have less effect than the windward or acute ones. When using curved surfaces, convex forms are prior over concave ones. The intensity of the pressure reflected on a convex and round building surface, also, is less than the pressure reflected on flat buildings. Making use of concrete structures, compound structures, retaining wall, concrete sheeting, virtual structures and the like are some of the methods to control the threats resulted from waves and the destructive power of such dynamic loads.

References

[1] W.E Baker, "A Manual for the Prediction of Blast and Fragment Loading on Structures", Report No. DOE/ TIC-I 1268, U.S. Department of, Energy , Albuqueroe Operations Office, Amarillo area office,Pantex plant, Amarillo, Texas ,1980.

[2] J.M Duncan, Evans, LT, Phillip, S.K. Ooi. , "Lateral Load Analysis of Single Piles and Drilled Shafts", ASCE Journal of Geotechnical Engineering, 1994, Vol. 120, No.6, pp. 1018-1033.

[3] M Ettouney, TRittenhouse , "Blast Resistant Design of Commercial Buildings", Practice Periodical in Structural Design and Construction; 1996 Vol. I, pp.31-39.

[4] B , Woodson Expiratory pharyngeal airway obstruction during sleep: a multiple element model. Laryn- goscope 113, 2003 , 1450–1459.

[5] P.A ,Mendis, T , Ngo, “Assessment of tall buildings under blast loading and aircraft impact”, Toward a better Built Environment, Innovation, Sustainability and Information Technology, International Association of Bridge and Structural Engineering, Australia, pp. 375-376, 2002.

[6] T , Paulay, MJ.N Pristley, "Seismic Design of Reinforced Concrete and Masonry Buildings", John Wiley and Sons, Inc, N.Y. I 992

[7] D.O ,Baker,. M.G Whitney, "Design of Blast Hardened Control Rooms", Structures under Shock and Impact, Proc. of the second International Conference, Portmouth, U.K., 16-18th June, Edited Bulson, B.S. 1992