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EXTENDED ABSTRACT

Vulnerability Assessment of Blast-Resistant RC Control Room In Refinery Facilities by Eulerian-Lagrangian Coupling Method

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1. Introduction

A control room is a place where, as a center of operations in the petrochemical industry, production processes are monitored and controlled. Two main factors must be considered in the design of control rooms. The first factor is the protection of the control room building against possible hazards and the second factor is the location of the control room and the arrangement of the panels, to ensure the effective and ergonomic operation of the control room in normal and emergency conditions, which must be designed in such a way that the danger to the residents of the control room is acceptable and be suitable for the maintenance and protection of the unit (ASCE, 2010; Association, 2014). One of the regulations for the design of blast-resistant structures is the Swedish shelter regulations, which are derived from the examination of structures destroyed in the second world war (Ekengren and räddningsverk, 1994). The Swedish Shelter Regulations regulate the design of civil defense shelters in Sweden and include the requirements specified for these protection structures. Civilian defense shelters are designed not only to withstand the effects of conventional weapons, but also to withstand radioactive radiation, chemical and biological warfare, and gases explosion. By considering these requirements, shelters should be designed with minimal risk of death or injury to those in need of shelter, and be able to withstand the effects of the shockwave generated by a 250-kg bomb at a distance of 10 meters. Also, the requirements of proper design and retrofitting of existing structures against explosion can significantly reduce costs. In view of the above, the analysis and design of refinery structures against explosion loads and the strengthening of their members has great importance. Long-distance explosions and loading of structural elements also include phenomena that are not yet well understood. In order to increase knowledge in this field, a numerical study is currently presented. For this purpose, in this study, four types of concrete columns and four models of exterior wall for the control room were designed according to Swedish regulations to withstand the pressure of an explosion of a 250kg TNT at a distance of 10 meters and then against explosions of 6000, 4000 and 8000 kilograms at a safety distance of 40 meters is evaluated by the Eulerian-Lagrangian coupling method in Autodyn software. Response limit-state are selected according to the ASCE standard (ASCE, 2010).

2. Methodology

2.1. Material Model

Numerical analyzes require material strength-models to describe the response of structural members. The response of structures under blast loading is a very complex phenomenon due to the high strain rate, the effects of geometric and materials nonlinearities. In any hydro code, for solving three equations of conservation of mass, momentum and energy, Equation of State and strength model should be considered (Woodruff, 1976).

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In this study the Jones-Walkins-Lee (JWL) equation of state and ideal gas EOS (Equation of state) have been used for explosion and air (ANSYS, 2019). Also to solve the effect of strain rate on material strength, two solutions are proposed: using dynamic increase coefficient or using strength-models considering the strain rate. The Johnson-Cook strength model with strain rate sensitive behavior used for longitudinal and transverse reinforcements in this study. The Johnson-Cook strength model accurately predicts the behavior of reinforcing steel in concrete under blast loading. Johnson-Cook equations constant parameters are obtained based on the Hopkinson bar test. Also for considering the effect of high strain-rate for concrete model, in this study, the RHT material strength model is considered (Li et al., 2020; Riedel, 2009; Wu et al., 2020). In Autodyn software, the properties of GFRP materials are included in the compliance matrix using engineering constants.

2.2. Model Parts

In this study four column types and for different exterior wall are considered. In all stages, the flexural stiffness of the frame located behind the column and the wall is modeled as a spring. For columns and walls, solid element (eight-node element) is used for concrete and beam element (two-node element) is used for rebars. Also, in order to apply the boundary conditions and create a rigid support at the bottom of the column, all nodes are fixed at bottom. Shell element (6 degrees of freedom) used to model the GFRP sheet in ANSYS Composite pre-post software, the resistance model for orthotropic materials. The orthotropic strength model is defined for GFRP materials.

3. Results and discussion

The results show that the design of a blast-resistant structure based on a specific blast pressure or a certain amount of explosive at a given distance is not conservative. For example, the pressure and impact obtained for an explosion of 250kg TNT at a distance of 10 meters are equal to 2.1MPa and 3MPa, respectively. This is while for an explosion of 8000kg TNT at a distance of 40meters, despite the lower explosion pressure (1MPa), due to the longer duration, the area under the pressure-time diagram increases and more impact is applied to the structure. Therefore, for designing members of structures such as control rooms, it is recommended that the response of structural members to explosions with different amounts of explosives at different distances be investigated during design. The results show that increasing the rebar has a small effect on reducing the response of the column compared to increasing the column dimension in the direction of the blast wave. Also, by retrofitting columns and walls with GFRP sheets, damage is significantly reduced.

4. Conclusions

In this study using the Eulerian-Lagrangian method and parallel processing in the cloud space, four types of concrete columns and four models of exterior wall designed for 250 kg TNT at a distance of 10 meters for explosions of 4,000, 6,000 and 8,000 at a safe distance of 40 meters were evaluated the result show that:

- The design should be based on the overall performance of the structure against a series of different explosions at near and far distances and the effects of explosion impact along with explosion pressure should be considered in the design.
- The type of failure for reinforced concrete members is different for contact and far field explosions. For example, for blasts at far distances, shear and bending fractures occur, but for contact explosion, failure due to spall damage occurs.
- Using the Eulerian-Lagrangian coupling method has advantages such as:
    1. Positive and negative pressure is applied to the structure member and the effects of reflection are well observed.
    2. Blast load is dynamically applied to the structure and the nonlinear effects of materials such as the effect of strain rate are well investigated.

5. References

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