A case study of the effect of cladding panels on the response of reinforced concrete frames subjected to distant blast loadings

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A B S T R A C T

The turbine building is a vital structure within nuclear power plants that houses turbines, moisture separators and electric generators among other important equipment. Turbine buildings are typically frame structures that in most cases have not been designed to resist blast loadings. The authors to determine the dynamic responses of reinforced concrete (RC) frame structures when subjected to distant intense surface loadings caused by explosions carried out a numerical study. The study was extended further to investigate the influence of claddings on frame structures when exposed to blast loadings. A three-dimensional (3D) nonlinear dynamic finite element model was created and utilized to determine the dynamic responses of frame structures from both local and global perspectives. It was observed from the results obtained from the finite element (FE) simulations carried out that the dynamic responses of frame structures with claddings were more severe. This is due to the variations in blast forces received by the structure.

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1. Introduction and background

Security in nuclear power plants has to take an additional heightened level with the recent surge in the occurrence of worldwide explosive events caused by terrorism. In nuclear power plants, boiling water reactors present unique challenges since the water going through the turbines are radioactive. This means that the turbine hall has to be slightly contained and may require unique maintenance routines. The focus of this study is to investigate the behavior of these turbine buildings, which are typically frame structures, when subjected to distant blast loadings.

After the trigger of a blast, a blast wave including a high-pressure shock front is formed and expands outward from the center of detonation (ASCE, 1985; Biggs, 1964; Baker et al., 1983; Forbes, 1999; Smith and Hetherington, 1994). As the blast wave strikes a building, explosive detonations may cause extensive damage to both the target structure and nearby buildings. The analysis of overpressure and drag force of the blast wave on a structure, and the interaction between them is extremely complicated. However, considering the relative distance of the detonation center with the target structure as well as the size of the structure itself, two classes of blast wave-structure interaction can be generally identified and is shown in Fig. 1 (Smith and Hetherington, 1994). The first class is the interaction of a blast wave produced by the detonation of a smaller charge loading a target structure at a short standoff distance, which is typical for most terrorist attacks such as car bombings (Corley et al., 1998; Longinow and Mniszewski, 1996; Luccioni et al., 2003). The second class is the interaction of a blast wave on a relatively distant structure as might be present due to an accidental severe surface explosion of petroleum refineries, chemical plants, ammunition storage areas (Glasstone and Dolan, 1977; Kletz, 1975) and turbine buildings.

The profile of blast loadings on a structure tends to be different within these two classes of blast wave-structure interaction. In the first class, the blast pressures are produced locally to individual structural members and the members are likely to be loaded sequentially. In contrast, during the second class of blast wave-structure interaction, the target structure is engulfed due to the diffraction of the blast wave and a normal squashing force will be applied to all of the exposed surfaces. There is also a translational drag force, which tends to move the body of the structure laterally. Many explosion tests and numerical analyses have been carried out to determine the behaviors of structures in the first class of blast wave-structure interaction where the blast pressures are applied locally to individual structural members. This results in the possibility of an excessive local failure of several critical structural members that could lead to a progressive collapse noticeably in a non-redundant structure (Corley et al., 1998; Longinow and Mniszewski, 1996; Luccioni et al., 2003). However, little literature is available due to the limited research that has been devoted towards the behavior of structures and their possible failure mechanisms in the second class of blast wave-structure interaction.

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