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Dynamic and damage response of steel rods reinforced concrete slab subjected to air blast load

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ABSTRACT: The primary material used in nuclear power plant containment and military engineering is reinforced concrete. But collisions and explosions have the potential to demolish such buildings entirely, resulting in a great deal of death and destruction of property. Thus, the propagation law of a blast pressure wave and the dynamic response of reinforced concrete buildings against the effects of explosive pressure waves are analyzed in this paper. This work conducts a numerical simulation of a free-field explosion model using correct state material parameters and equations, followed using the nonlinear finite element analysis software ABAQUS. Two damage models for concrete were considered in this research which are concrete damage plasticity (CDP) and the famous Johnson Holmquist (JHQ) model. The Johnson Cook (JC) damage model was utilized for the steel rods. Following validation of the numerical analysis model's dependability through comparison with the calculated results from empirical equations, the destruction and impacting variables on reinforced concrete slabs under blast pressure wave effects are examined. The outcomes can be used as a guide for analysis and design for the future.

KEYWORDS: Blast pressure wave, Reinforced concrete slab, Numerical simulation, CONWEP, TNT charge

1. Introduction

The primary material utilized in nuclear power plant containment and military engineering is reinforced concrete. It has complex mechanical reactions when dynamic loads are applied.

The structural mechanics theory can be used to analyze a load acting slowly on a large plane. Due to inertia and short-duration effects, if the load acts quickly on the concrete structure, the response creates a localized area of high temperature and pressure. An outbound shock wave forms inside the concrete as a result of the response, which is focused on the load point. Spalling results from the interaction between the tensile wave and the compressive wave reflected from the target's rear sides. Additionally, the behavior of concrete differs from that caused by a quasi-static load.

Due to the material's difficult to regulate behavior and the mechanical behaviors' variability under various stress circumstances, this problem is complex. The approaches used to research this topic include analytical methods, experimental method and numerical approach [1,2].

The modelling implications of impulsive stresses on reinforced concrete slabs were examined in the study in [3]. The elastic–plastic dynamic response of steel columns exposed to the pressure wave from an underground explosion was numerically analyzed by authors [4]. An analysis of explosive damage to columns made of reinforced concrete was done in [3,4]. Regarding walls' resilience to explosions.

An abrupt explosion in the atmosphere causes a high-temperature, high-pressure detonation wave due to the quick release of energy. The surrounding gases rapidly expand and spread due to this pressure wave. The blast pressure wave, or high-pressure air at the front of these gases, is where most of the explosive energy is found. As the propagation time and distance grow, the energy carried by the blast pressure wave will decrease. In a moment, the pressure behind the shock wave front can drop to levels lower than the ambient air pressure. The air is removed to form a vacuum during the negative pressure phase, after which the temperature and pressure equalize with the surrounding air. A typical explosion pressure time history curve is shown in Fig. 1. This research investigates the effect of a blast load effect of 10 kg TNT charge on a reinforced concrete described above.

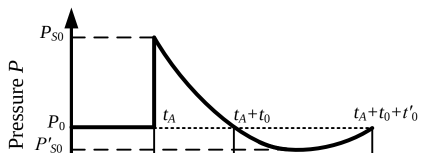


Fig. 1. Typical pressure time history for air blast [2].

2. Materials and methods

The concrete slab is made up of concrete class B50. Concrete B 50 is a three component, high strength epoxy grout specially designed to withstand static and dynamic loads. B 50 is a blend of epoxy resin, curing agent and inert aggregates. For this research, a concrete with dimension 1000×1000×50 mm. During the computing process, the explicit time integration method was employed to compute the time integration. Since it is a conditional stable integration method, and the integration time step size is a function of the characteristic mesh length. The steel reinforcement in form of rods with 10 mm diameter and 1000 mm was embedded in the concrete as shown in the concrete as shown in Fig. 2. 10 kg charge of TNT was detonated at a standoff distance (SoD) of 250 mm from the center of the slab. The model was done using Conventional Weapon approach (CONWEP). The concrete was modelled using CDP and JHQ damage model, while JC damage model was used for the steel rods. The whole calculation time lasted for 0.005 s.

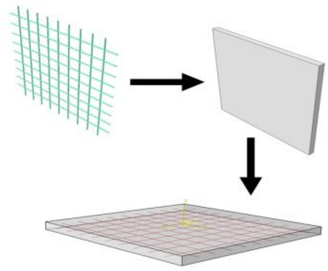


Fig. 2. Assembly of the reinforcing phase and the concrete.

3. Results and discussion

We performed a free-field explosion simulation and compared the blast pressure wave characteristics and the stresses in order to verify the veracity of the assessed results. A von Mises stresses-time contour map of the model with JHQ compared to CDP is displayed in Fig. 3. It is evident that the overall loads on the target following the blast were entirely different, despite the fact that the parameters were maintained constant. The blast pressure wave period was discovered to be quite brief when the time history comparison was carried out 250 mm from the explosion's center point.

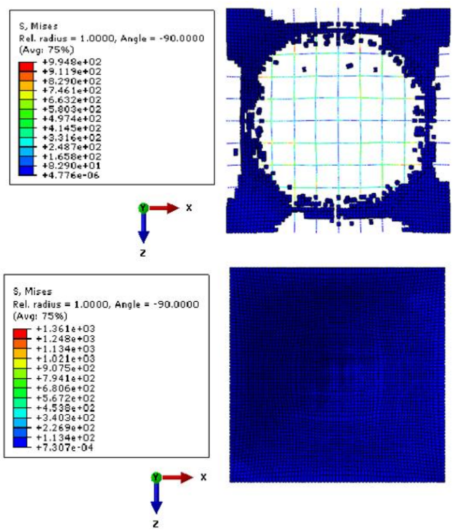


Fig. 3. Final failure of the sample after blast.

Once the blast pressure wave reaches its apex, it rapidly begins to diminish. The blast pressure wave curves that this study's simulations produced show the same pattern as an ideal blast pressure wave, as seen in Fig. 4. The peak pressure did, however, peak at various values. The difference could also be observed on the damage steel rods in Fig. 5.

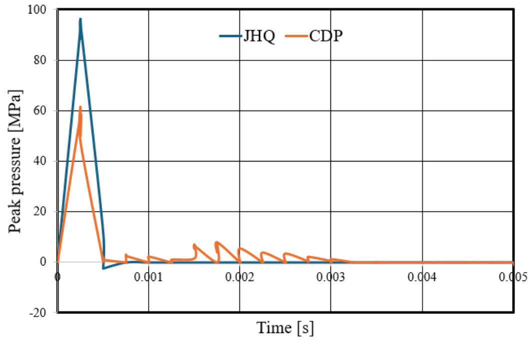
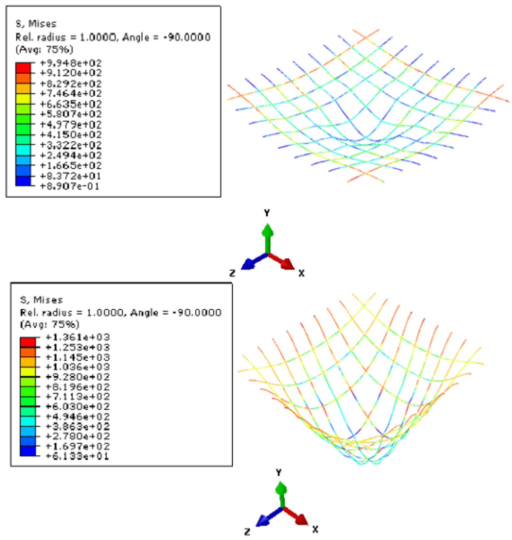


Fig. 4. Peak pressure plots for different models.



Rys. 5. Von Mises stress on the reinforcement.

4. Conclusion

After the numerical calculation investing the effect of blast wave on a concrete structure, the following conclusions were made:

1) Modelling parameters has great influence on the overall results.
2) The concrete structure couldn't withstand 10 kg TNT as the peak pressure was sufficient to damage it.

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