Structural elements and personnel safety after explosion*

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Abstract

Complex scenarios like explosion generate the loading pressure that first reach and then damage the structural elements in buildings. There are of course seriously dangerous for personnel safety. Usually, this possible event is not considered by designers. The work reports a research on blast pressure influence after outside explosion with assessment of structural failure in principal elements i.e. columns and solid slab floors. The material behaviour bases on well-known standards [3, 4]. The calculations are carried out in the environment of finite element code ABAQUS/Explicit employing in addition VUMAT coding [1].

Keywords: blast loading, structure failure, public safety

1. Introduction

Current design style is improved by some government agencies which deals with missing parts (i.e. columns, walls etc.) of the structure scenario. In particular, this approach makes really sense for buildings subjected to the impact and blast loadings. The headquarters like embassies, banks, skyscrapers, hotels and others are very concerned about the possibility of this kind of loading. Nowadays, the fundamental threat is connected with terrorism and it may involve a combination of thermal, impact and explosive loads. The authors present different methods of estimation of explosive pressure evolution in the surrounding air. This comparison is performed in Abaqus code including separate procedures, for prediction of explosive pressure, like: arbitrary langrangian-eulerian (ALE), coupled langrangian-eulerian (CEL), computational flow dynamics (CFD) and CONWEP [1].

The first one concept, the ALE formulation, joins the two other formulations, pure Lagrangian and pure Eulerian. In essence, it takes the best part of both reference frames and combines them in to one. The first concept assumes the mesh moving with the material and in this formulation the mesh can be distorted up to large deformation.

The second concept assumes the moving of the material through the fixing mesh. The ALE formulation assumes the mesh motion dependent on the material motion at free boundaries and in other cases the material and mesh are independent. There is a kind of meshing that allows to maintain a high-quality meshing throughout the analysis, even when large deformations or losses of material occur, by allowing the mesh to move independently of the material. This approach was presented by the authors in [2, 7].

The second approach, the CEL analysis, involves the interaction between pure Eulerian and Lagrangian parts on the same model level. Moreover, the contact can be defined between these elements in the Lagrangian part and the material boundaries in the Eulerian part. The finite element mesh degradation is neglected regardless of high speed phenomenon like explosion.

In last decades there were developed the new methods base on computational flow dynamics (CFD), there is a third one approach. The algorithms solve and analyse the problems that involve fluid flow, e.g. to simulate the rapid release and interaction of liquids and gases. The approach is also involved in new designed FE codes [1].

Among other objective is the analysis of reflection coefficient after blast wave reflection from the obstacle. This important parameter is taken into consideration, in design codes, when using verified results of the front pressure increasing. The pressure wave after reflection from the obstacle may increase several times. The FE results which represent the reflection from the rigid walls are presented for different angles of incidence. To be sure that we are in comparable range of the pressure values, we present the results of pressure distribution for different angles of incidence on the rigid surface, see Fig. 1. The coefficient of reflected pressure stays in a good agreement with unified facility criteria (UFC) principles, see Fig. 2.

2. Numerical model

2.1. Pressure evolution in the air

The numerical consideration includes three different computational problems. The first one is an evolution of the pressure loading in the air medium. For each approaches i.e. ALE, CEL and CFD are performed the same three dimensional cubic cell geometry model, with the volume equals to 1000m^3. The pressure peaks and impulses are obtained for constant distance and mass of the charge.

2.2. Reflection from the rigid obstacle

The second problem deals with the reflection of the incident pressure on the planar surface. This obstacle is really rigid and is situated in different angle range, i.e. 0-90 degree, to incident wave. In Fig. 2 the continuous line presents the reflection coefficient which is in agreement with codes [3] , and the dashed one is performed by the authors using of the FE model. In the case under consideration Fig. 1 the numerical model consists of 5M linear 8-node elements, and the calculation time lasts more than 40e3 seconds for each case.

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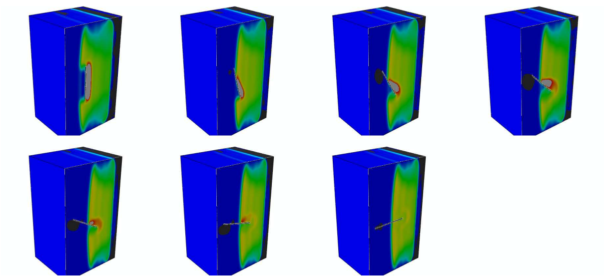

Figure 1: Incident wave after reflection from the rigid obstacle

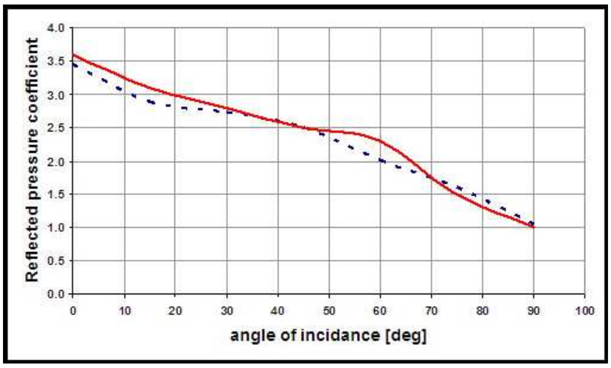

Figure 2: Pressure reflection coefficient compared with codes [3] in function of angle of incidence

2.3. *Building safety assessment*

The last one, and the crucial problem is the numerical estimation of building safety and pressure propagation for the main structural elements like columns or floor slabs after outside explosion of condensed charge. Moreover, the personnel safety is also taken into consideration by the authors e.g. for selected floor analysis Fig. 3 and with agreement with [3, 4], and for analysis of whole structure, see Fig. 4.

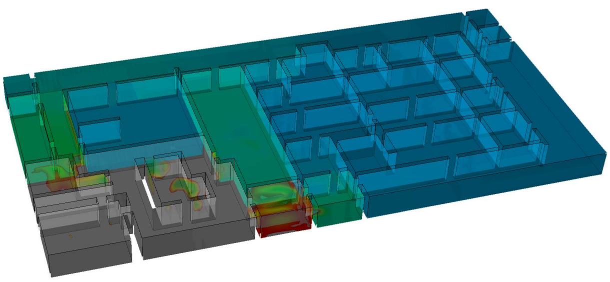

Figure 3: Blast pressure distribution 10ms after detonation

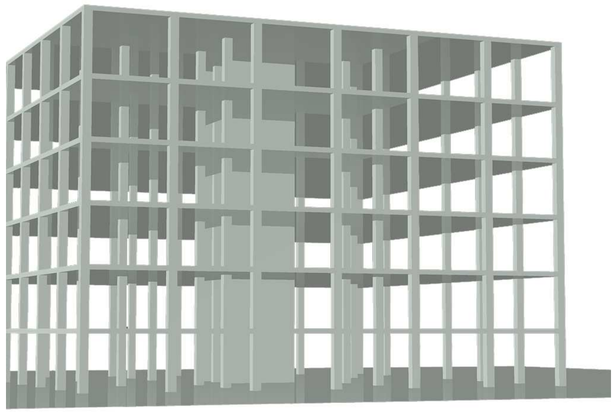

Figure 4: Geometry of RC-structure before incidental explosion

3. Conclusions

The presented research shows the wide range of existing methods in FE code (base on Abaqus code [1, 2]) which allow for analyses of blast phenomenon. These methods are applied and used for different problem with different accuracy. The authors choice prefers the CEL as a good approximation for prediction of pressure evolution outside and inside the building in booth. The consideration are performed and compared basing on results presented in UFC standards.

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