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Stress Components Generated in 10 mm and 20 mm Thick Steel and Concrete Pipes Buried in Dense Sand at Different Embedment Ratio Due to Underground Blast

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ABSTRACT

The stress components of the different responses were examined, and the analytical approach was employed to estimate the subsurface blast loads of regularly used explosives at different stand-off positions. Soil and pipe materials were regarded in this investigation as elastic, homogenous, and isotropic. Utilized were the material and geotechnical characteristics disclosed by a number of studies and pipe makers. Using the temporal integration technique in the finite element numerical code ABAQUS/Explicit, the responses of subsurface pipes to an underground blast were investigated. The stress components produced in subterranean steel and concrete pipes were examined when they were buried in dense sand at varying embedment ratios. The results of this study will make a local and global contribution to the body of academic literature already in existence.

1. INTRODUCTION

In material analysis, stress is usually divided into two main categories: shear stress, which is the consequence of pressures applied parallel to a material surface, and normal stress, which happens when force is applied perpendicular to a material surface. Three typical stresses make up the general stress condition of a point in a solid. Every stress or stress component that acts on the little cube of material is a force per unit area. Hoop stress, axial stress, bending stress, torsional stress, and fatigue stress are the five types of stresses in pipes. The stress that is delivered to the pipe, either internally or externally, is known as hoop stress. In this instance, the external loading wave velocity is a result of an unintentional subsurface explosion known as a blast. Primary, secondary, and peak stresses are the three main types of stress in pipes, and the limits of these stresses are connected to the different failure modes. These are listed in the following order: The main goal of the stress limits is to stop bursting and plastic deformation. Large displacement should be maintained to a minimum in order to reduce stress in pipes, and this can be accomplished if the burial depth is reasonably high (i.e., at H/D larger than 3). The effective stress operating in a radial direction perpendicular to the pipe's longitudinal axis is known as radial stress in a pipe.

Modeling, which is the simulation of a partial representation of a system, can assist in providing answers to some issues that are beyond the scope of a single empirical research. An actual engineering problem is examined using engineering models. When building the actual, full-scale object assembly or system, the findings are typically and consistently utilized. When it comes to material properties, the relative densities of loose and dense sand are respectively less than 35 percent and more than 65 percent. Shear failure typically happens in thick sand, whereas local shear failure typically happens in loose sand. The flexible resistance of a pipe to deflection, or ovalization under stress, is measured as pipe stiffness. Flexible pipe can withstand a 2 percent deflection without breaking. Modulus of elasiticity, E is a measure of a pipe's stiffness. The Young's modulus E of steel pipes is higher than that of concrete pipes. In general, thicker pipes have a higher internal pressure tolerance than thinner pipes made of the same material. The primary phenomena resulting from unintentional explosive detonations underground are craters and camouflets, deformation, shock waves, and the transmission of elastic-plastic waves in the interaction between the soil and its structure.Concrete pressure pipes come in a variety of forms, including bar-wrapped concrete pressure pipes, prestressed concrete pressure pipes, and reinforced concrete cylinder pipes. Because of their strength and longevity, reinforced concrete pipes are the most often utilized type of concrete pipe for irrigation, storm drains, culverts, drainage systems, and sewage lines.The five different forms of carbon steel pipes are flat bar stock, round, square, rectangular, and thin-walled tubing. Steel pipes are suitable for long-term installation and are used to convey goods like gas, oil, and water.

The simulation can employ an infinite number of distinct materials, and each material specification has a name. By assigning section characteristics that correspond to the material name, different sections within a model are linked to distinct material definitions. The data sets describing plastic behavior of a material's is converted into proper Abaqus input format using the nominal stress-strain curve. The plastic data is found using the points on the nominal stress-strain curve.The first step is to change the nominal and nominal strain and stress to true stress and strain by using the equations connecting the the true strain to the nominal strain and actual stress to the nominal stress and strain.

Plastic strains connected to each yield stress value can be found using the equation that links the plastic strain to the total and elastic strains once these values are known. It is crucial to give Abaqus the correct stress-strain data if the simulation's strains will be high as, although there aren't many variations between the nominal values and true values at little strains, there are at bigger strain values. Abaqus/Explicit may not use the material data precisely as specified by the user when doing an analysis; instead, all material data are automatically regularized for efficiency. Temperature, external fields, and internal state variables like plastic strain can all be functions of material data.

The state of the material must be calculated for each material point calculation through interpolation. Abaqus/Explicit fits the user-defined curves with curves made up of points that are equally spaced to maximize efficiency. The material information used in the analysis is represented by these regularized material curves. Any discrepancies between the specified curves and the regularized material curves utilized in the analysis should be understood. the elastic stress; the viscous stress; the energy dissipated by viscous effects; the residual energy, also referred to as the internal energy; and the stress derived from the user-specified constitutive equation, excluding viscous dissipation effects.

2. METHODOLOGY

Dense sand is the ground media taken into consideration in this study, and the response of underground pipes to blast loads was studied using the geotechnical properties of this ground media as reported by multiple researchers (Das, 1994; FLAC, 2000; Coduto, 2001; Duncan, 2001; UFC, 2008; Kameswara, 1998; etc.). The Young modulus, E, Poisson's ratio, and material density are the material parameters employed since the two elastic constants are sufficient to examine the mechanics of an elastic body (Kameawara, 1998). Figures 1 depict a cross-section of an underground pipe and the types of blasts that are appropriate for underground pipes.

An underground blast occurs below the surface of the earth and is referred to as subterranean. The uppermost and bottommost parts of an underground pipe are referred to as the crown and invert, respectively. The two sides of an underground pipe are called spring-line. Conditions for boundaries were established in relation to the global Cartesian coordinate.

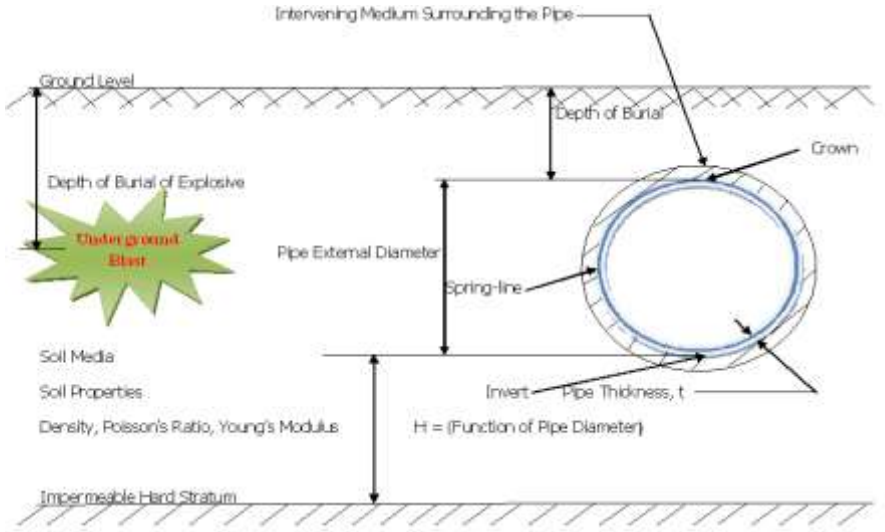

Figure 1: Underground blast

Analyses were performed on simulated models using the time integration technique of the finite different scheme in ABAQUS/Explicit to solve the equation of motion of the system as shown in Equation below, in accordance with ABAQUS Analysis Users' Manual (2009) and with different parameters.

$$[m][\ddot{U}]+[c'][\dot{U}]+[k][U]=[P]$$

where dot denotes their time derivatives and m, c',k, U, and P stand for the global mass matrix, global stiffness matrix, global displacement vector, and global stiffness matrix, respectively (Kameswara, 1998; ABAQUS Analysis User's Manual, 2009). The external work, energy, and viscous dissipation buried in the loose, dense, and undrained clay are the measured parameters.

3. DISCUSSION OF FINDINGS

Figure 2 depicts the boundary condition and loading wave velocity on an underground pipe in dense sand, while Figures 3 to 22 show the stress components produced in 10 mm and 20 mm concrete and steel pipes buried in dense sand at varying embedment ratios as a result of the loading wave velocity from an underground accidental explosion. Dense sand reduces the stress components in pipes caused by subsurface unintentional explosions, regardless of the pipes' thickness at deeper burial levels.

The stress components created are minimized to the point that they are completely unnoticeable at the embedment ratio of 5 that was taken into consideration for this study. In essence, pipeline embedment establishes the size of the pipe-soil contact area, which influences the potential mobilization of soil resistance during the pipeline's axial and lateral movement. Internal loads are created in subterranean pipes when they encounter resistance from temperature changes. Thermal expansion or contraction stresses are produced by these internal loads, which also include axial, shear, and bending moments.

The three main stresses in a cylindrical pipe are the longitudinal stress, which is the stress that runs parallel to the pipe's axis; the tangential stress, which is the stress that runs circumferentially; and the radial stress, which is the stress that runs radially and varies with the pipe wall's thickness. Energy dissipation increases noticeably with explosives that have higher TNT weights. Because of the strong horizontal stresses that form in the upper parts of the piles closest to the explosive charge, foundations exposed to surface accidental blast loads might not be suitable for supporting superstructure following the blast.

Similar to this, stress and deformation will happen if subterranean pipeline is exposed to an external explosion load, such as an unintentional subsurface explosion. The subterranean pipeline's regular use will be impacted when the stress and deformation values rise above a predetermined threshold.

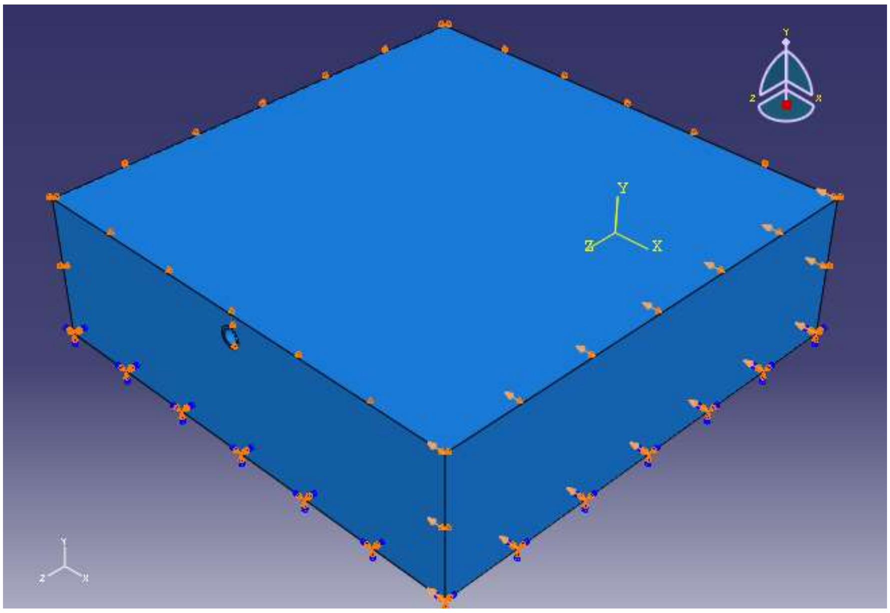

Figure 2: Boundary conditions and loading wave velocity on underground pipe in dense sand

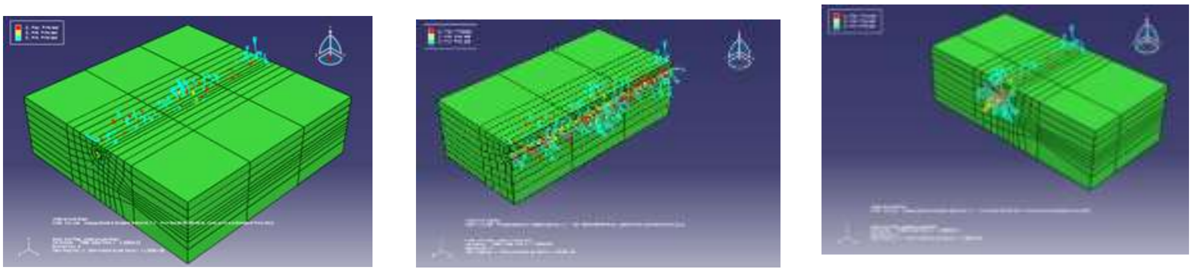

Figure 3: Stress components generated in concrete pipe buried in dense sand due to loading wave velocity (ldv from underground accidental explosion (20mm concrete pipe, H/D=1)

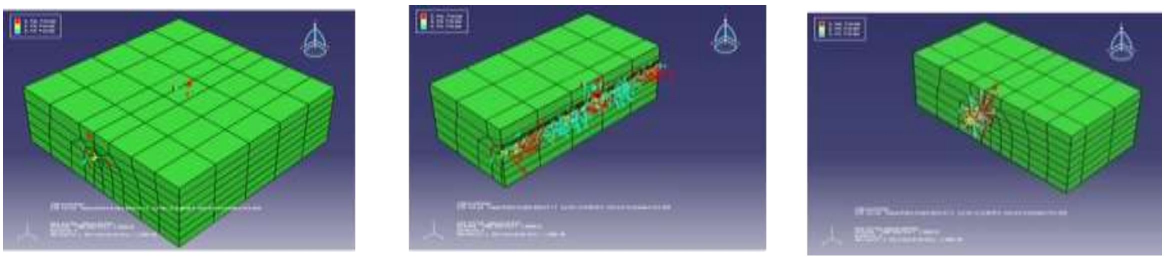

Figure 4: Stress components generated in concrete pipe buried in dense sand due to (ldv) from underground accidental explosion (20mm concrete pipe, H/D=2)

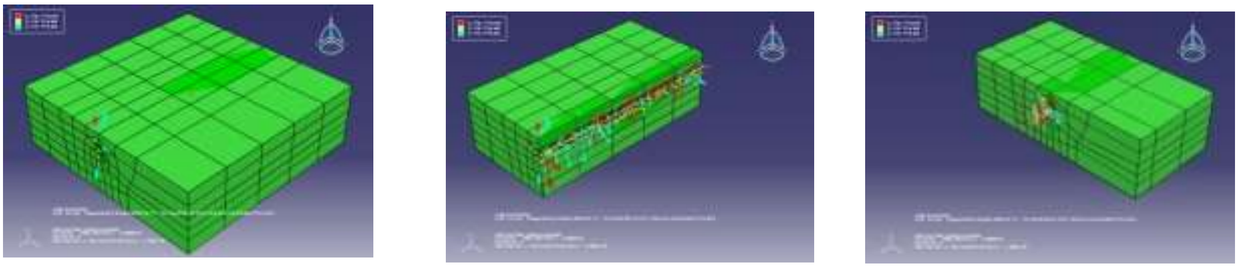

Figure 5: Stress components generated in concrete pipe buried in dense sand due to ldv from underground accidental explosion (20mm concrete pipe, H/D=3)

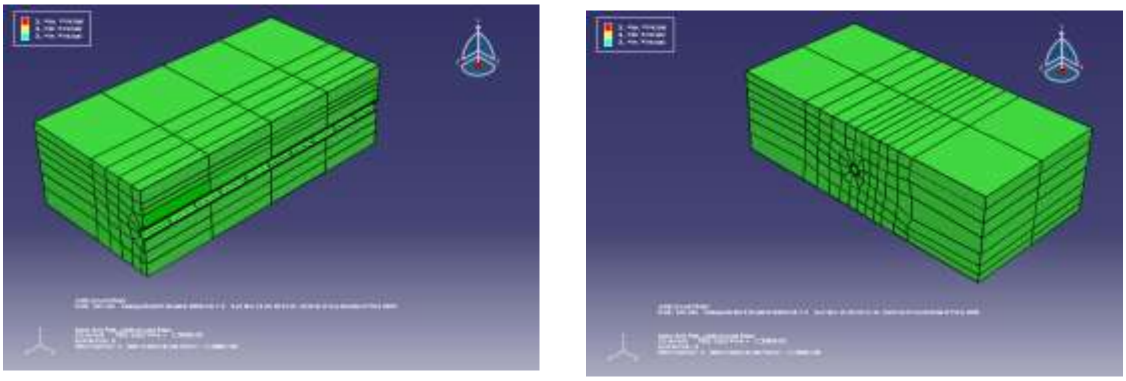

Figure 6: Stress components generated in concrete pipe buried in dense sand due to ldv from underground accidental explosion (20mm concrete pipe, H/D=4)

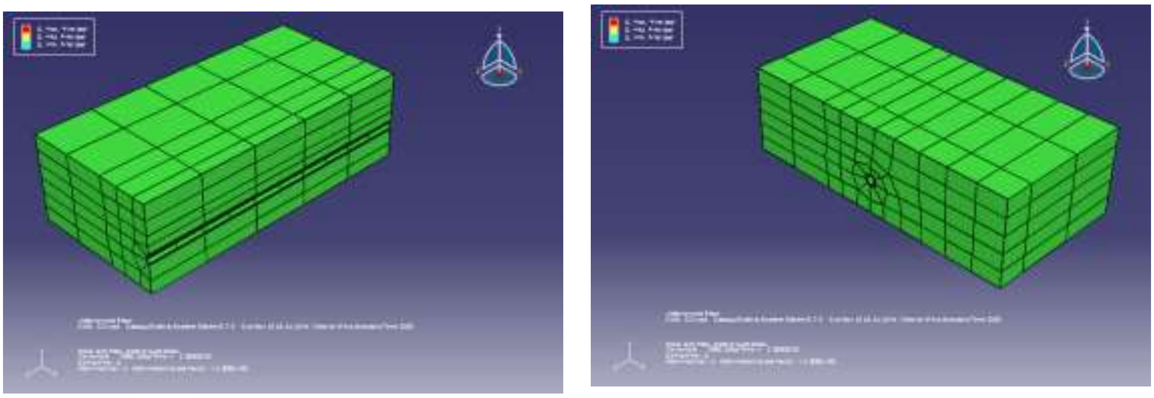

Figure 7: Stress components generated in concrete pipe buried in dense sand due to ldv from underground accidental explosion (20mm concrete pipe, H/D=5)

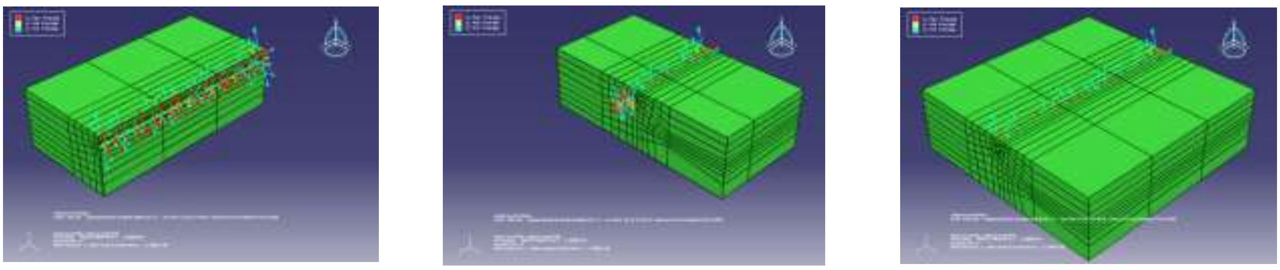

Figure 8: Stress components generated in concrete pipe buried in dense sand due to ldv from underground accidental explosion (10mm concrete pipe, H/D=1)

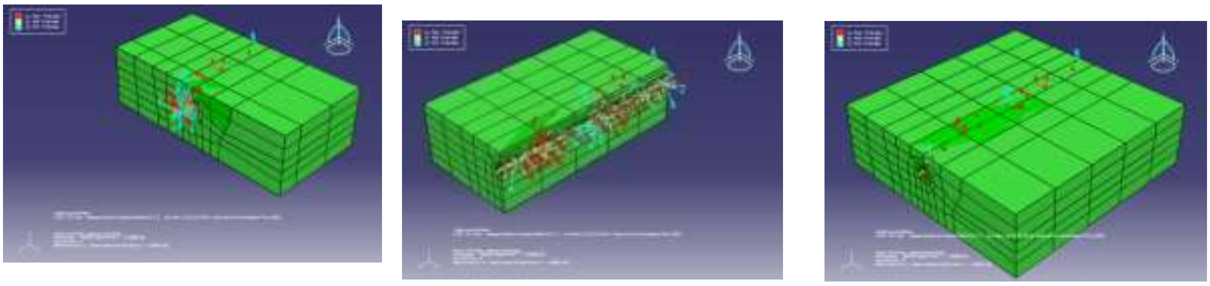

Figure 9: Stress components generated in concrete pipe buried in dense sand due to ldv from underground accidental explosion (10mm concrete pipe, H/D=2)

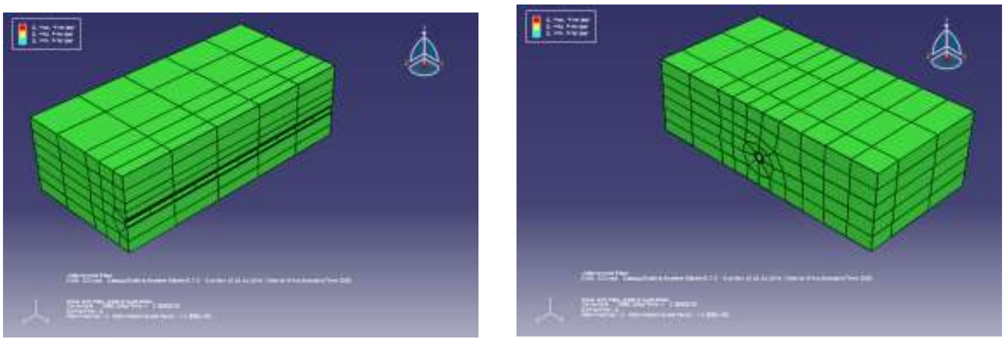

Figure 10: Stress components generated in concrete pipe buried in dense sand due to ldv from underground accidental explosion (10mm concrete pipe, H/D=3)

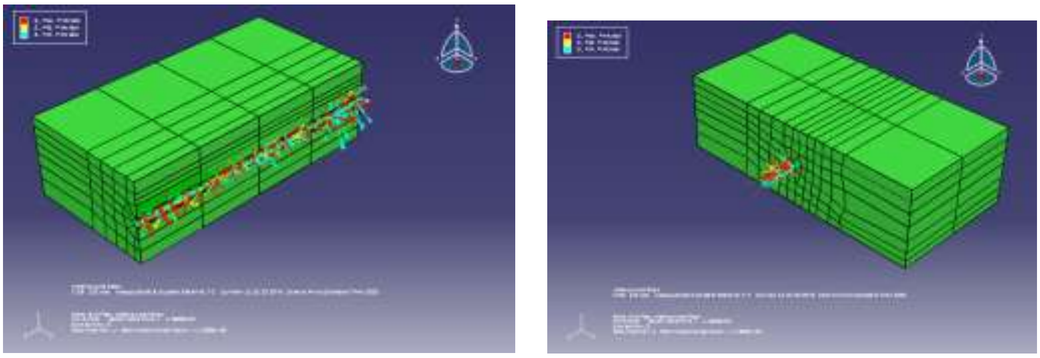

Figure 11: Stress components generated in concrete pipe buried in dense sand due to ldv from underground accidental explosion (10mm concrete pipe, H/D=4)

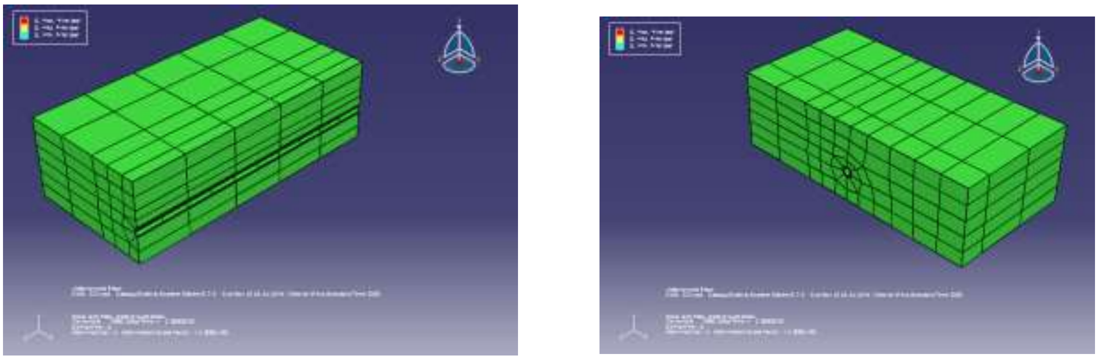

Figure 12: Stress components generated in concrete pipe buried in dense sand due to ldv from underground accidental explosion (10mm concrete pipe, H/D=5)

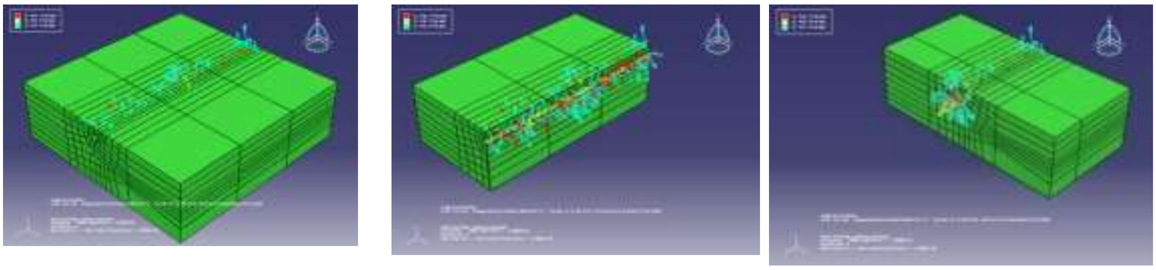

Figure 13: Stress components generated in steel pipe buried in dense sand due to ldv from underground accidental explosion (20mm steel pipe, H/D=1)

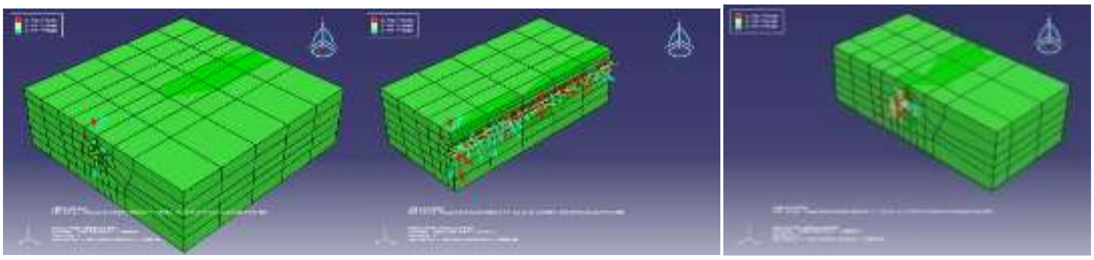

Figure 14: Stress components generated in steel pipe buried in dense sand due to ldv from underground accidental explosion (20mm steel pipe, H/D=2)

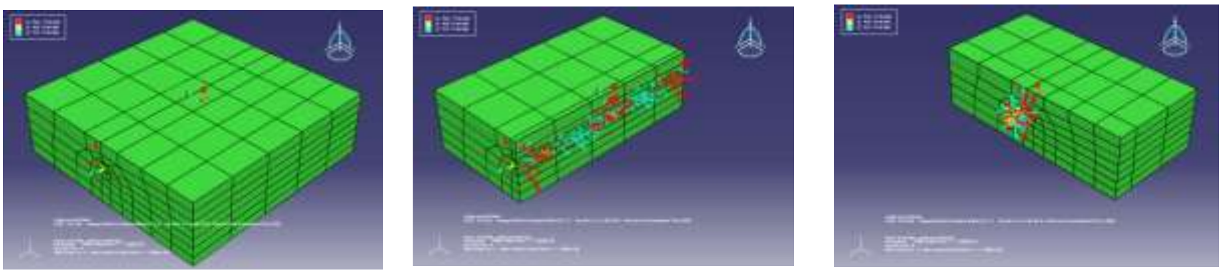

Figure 15: Stress components generated in steel pipe buried in dense sand due to ldv from underground accidental explosion (20mm steel pipe, H/D=3)

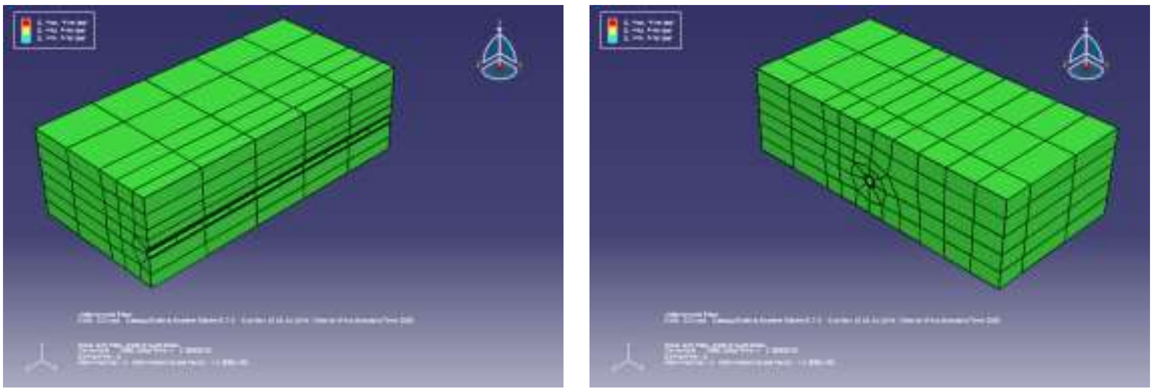

Figure 16: Stress components generated in steel pipe buried in dense sand due to ldv from underground accidental explosion (20mm steel pipe, H/D=4)

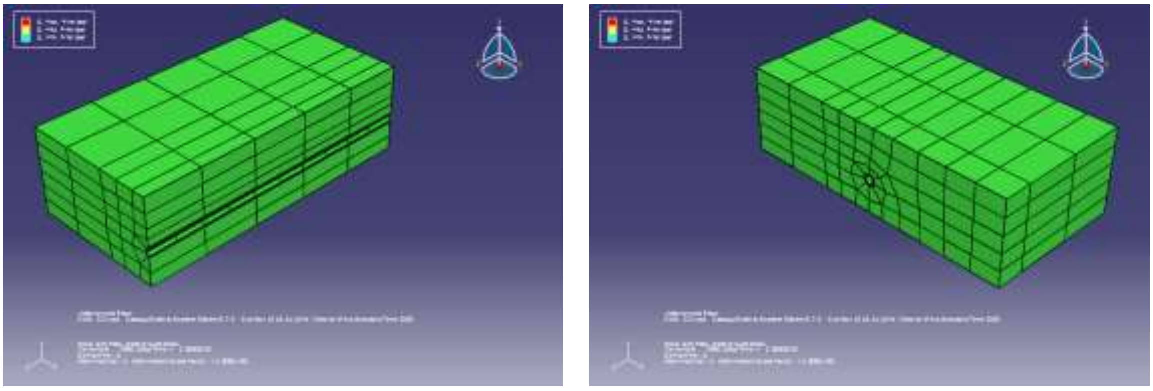

Figure 17: Stress components generated in steel pipe buried in dense sand due to ldv from underground accidental explosion (20mm steel pipe, H/D=5)

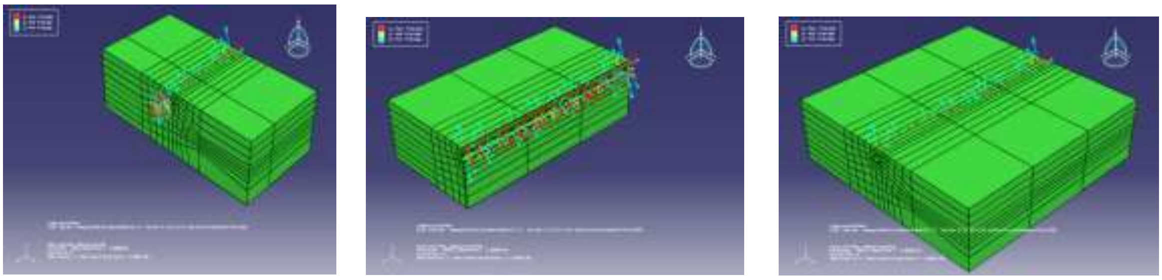

Figure 18: Stress components generated in steel pipe buried in dense sand due to ldv from underground accidental explosion (10mm steel pipe, H/D=1)

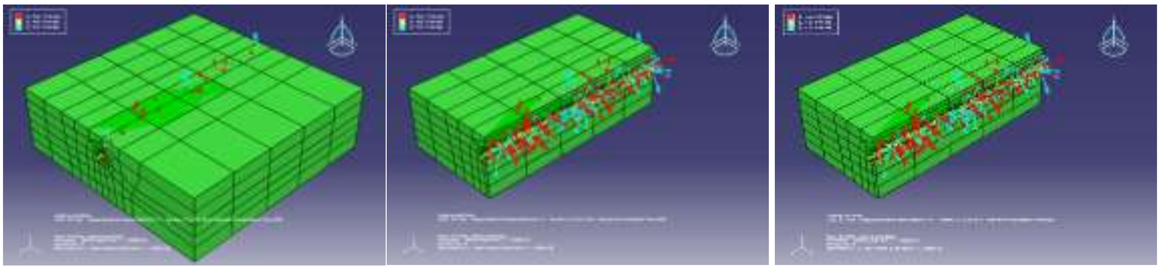

Figure 19: Stress components generated in steel pipe buried in dense sand due to ldv from underground accidental explosion (10mm steel pipe, H/D=2)

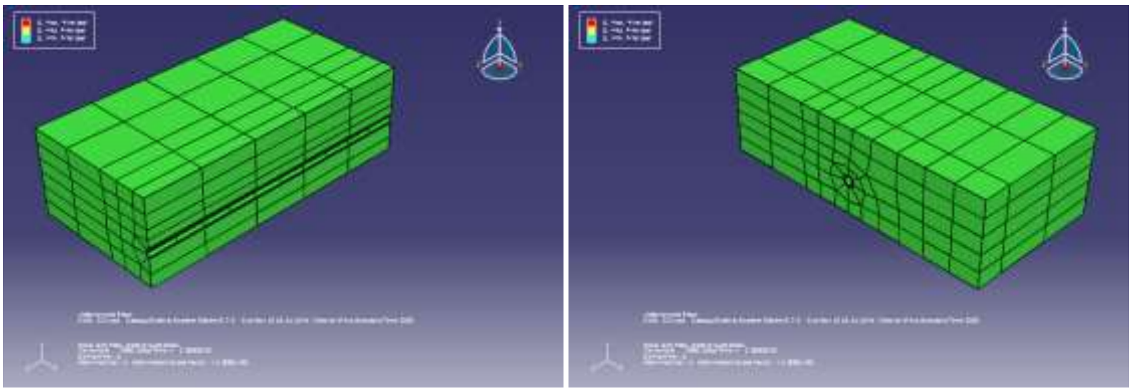

Figure 20: Stress components generated in steel pipe buried in dense sand due to ldv from underground accidental explosion (10mm steel pipe, H/D=3)

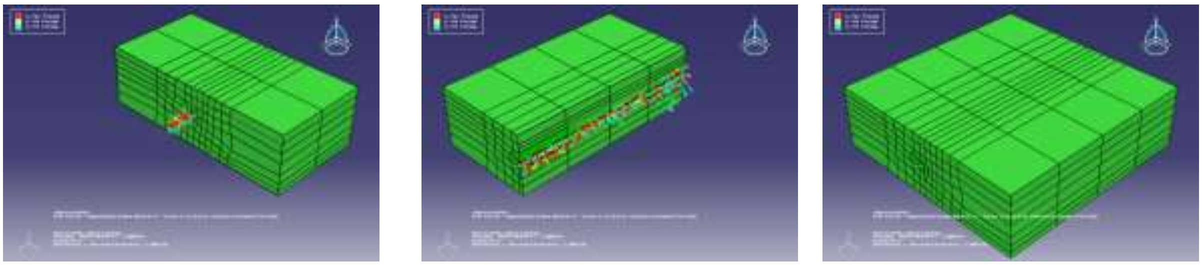

Figure 21: Stress components generated in steel pipe buried in dense sand due to ldv from underground accidental explosion (10mm steel pipe, H/D=4)

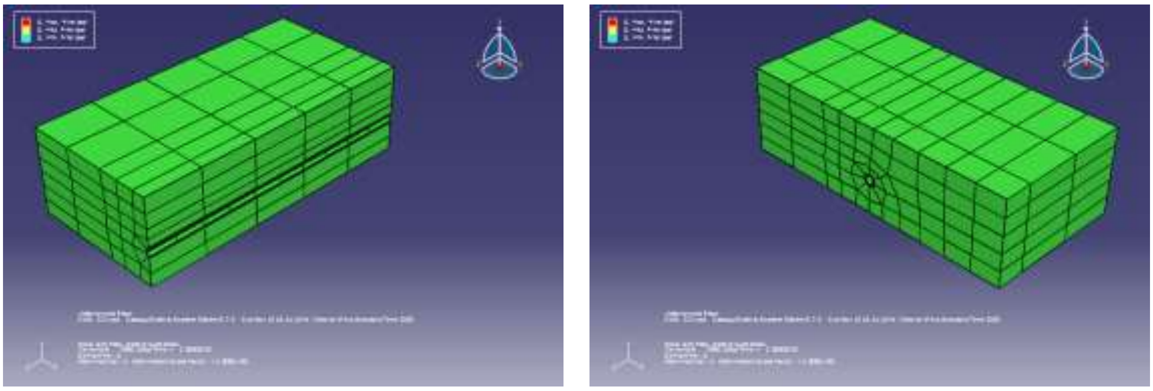

Figure 22: Stress components generated in steel pipe buried in dense sand due to ldv from underground accidental explosion (10mm steel pipe, H/D=5)

4. CONCLUSION

The results of stress components generated in 10 mm and 20 mm concrete and steel pipes buried in dense sand at different embedment ratios due to loading wave velocity from an accidental underground explosion had been presented and discussed. At low embedment ration, the stress components generated in pipes will be distinctly felt on the ground surface in comparison to higher embedment rations (H/D of 5), where the soil will effectively contain the stress components generated in pipes buried in dense sand. At the embedment ratio of 5 taken into consideration in this study, the stress components generated are reduced to the barest minimum where they will not be felt at all.

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