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Coupled Explosive/Structure Computational Techniques at Sandia National Laboratories

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Dale S. Preece
Stephen W. Attaway
Jeffrey W. Swegle
J. Richard Koteras
Rudolph V. Matalucci

Sandia National Laboratories
Albuquerque, NM

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Introduction

Simulation of the effects of explosives on structures is a challenge because the explosive response can best be simulated using Eulerian computational techniques and structural behavior is best modeled using Lagrangian methods. Due to the different methodology of the two computational techniques and code architecture requirements, they are usually implemented in different computer programs. Explosive and structure modeling in two different codes make it difficult or next to impossible to do coupled explosive/structure interaction simulations.

Sandia National Laboratories has developed two techniques for solving this problem. The first is called Smoothed Particle Hydrodynamics (SPH), a relatively new gridless method comparable to Eulerian, that is especially suited for treating liquids and gases such as those produced by an explosive (Swegle et al, 1994). The SPH capability has been fully implemented into the transient dynamics finite element (Lagrangian) codes PRONTO-2D and -3D (Attaway, 1992). A PRONTO-3D/SPH simulation of the effect of a blast on a protective-wall barrier is presented in this paper.

The second technique employed at Sandia uses a new code called Zapotec (Prentice, Fuka, and Peterson, 1997) that combines the 3-D Eulerian code CTH and the Lagrangian code PRONTO-3D with minimal changes to either code. CTH and PRONTO-3D are currently executing on the Sandia Terraflops machine (9000 Pentium Pro processors). Eulerian simulations with 100 million cells have been completed on the current configuration of the machine (4500 Pentium Pro processors). The CTH and PRONTO-3D combination will soon be executing in a coupled fashion on this machine.

Wall Blast Simulation Using Smoothed Particle Hydrodynamics

Figure 1 illustrates a 3-D finite element model of a wall that will be subjected to an explosive loading. The wall is 1 ft. thick and 13 ft. high with the base unattached to the ground beneath. Elastic concrete material properties are used for the wall and the ground with no allowance, in this calculation, for damage or breakage. SPH elements, represented by spheres, are shown in Figure 2 with the inner block being used to model the explosive detonation and the outer block serving as a buffer/transition zone between the explosive and the air. A JWL equation-of-state is employed to model the explosive which is assumed to be 15352 lb of ANFO, separated from the wall by a six foot gap. The air is modeled as an ideal gas. Figure 3 illustrates the SPH elements used to

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model the air between the explosive and the wall. Detonation of the explosive is modeled with a controlled burn based on the detonation velocity and point of initiation. Figure 4 shows the detonation of the explosive with its resulting pressure (psi) expansion and impact on the wall. Contact resolution between the SPH and finite elements results in a calculated explosive loading of the ground and wall. This loading results in the pressure (psi) pulse in the ground and wall as shown in Figure 5. The pressure applied to the wall causes the velocity (in/s) distribution illustrated in Figure 6. The pressure also produces a displacement (in) of the wall at 3 ms as displayed in Figure 7. The displacement of the closest corner of the wall (Figure 7) from the top to the bottom is given in Figure 8 for a number of different times, up to 3 ms. It is obvious from Figures 5 through 8 that the loading on this wall is concentrated on the lower right corner and that this corner will brake off and move at high velocity. The remaining portion of the wall will move with significant velocity.

Conclusions

A significant capability exists at Sandia for performing coupled explosive/structure interactions. These capabilities are now available on the Sandia Terraflops machine which is capable of running simulations with 100's of millions of finite difference cells or finite elements.

An important national problem that will be addressed using this capability is the effect of explosives on multi-story civilian/government structures. The objective of this work is an understanding of structural response under these conditions and the development of guidelines for building safer new structures and protecting both old and new structures from this type of threat.

References:

Swegle, J. W., Attaway, S. W., Heinstein, M. W., Mello, F. J. and Hicks, D. L., 1994, *An Analysis of Smoothed Particle Hydrodynamics,* Sandia National Laboratories, SAND93-2513.

Attaway, S. W., 1992, *Update of PRONTO 2D and PRONTO 3D Transient Solid Dynamics Program,* Sandia National Laboratories, SAND90-0102.

Prentice, J. K., Fuka, D. R., and Peterson, D. P., 1997, *Zapotec Users Manual (DRAFT)*

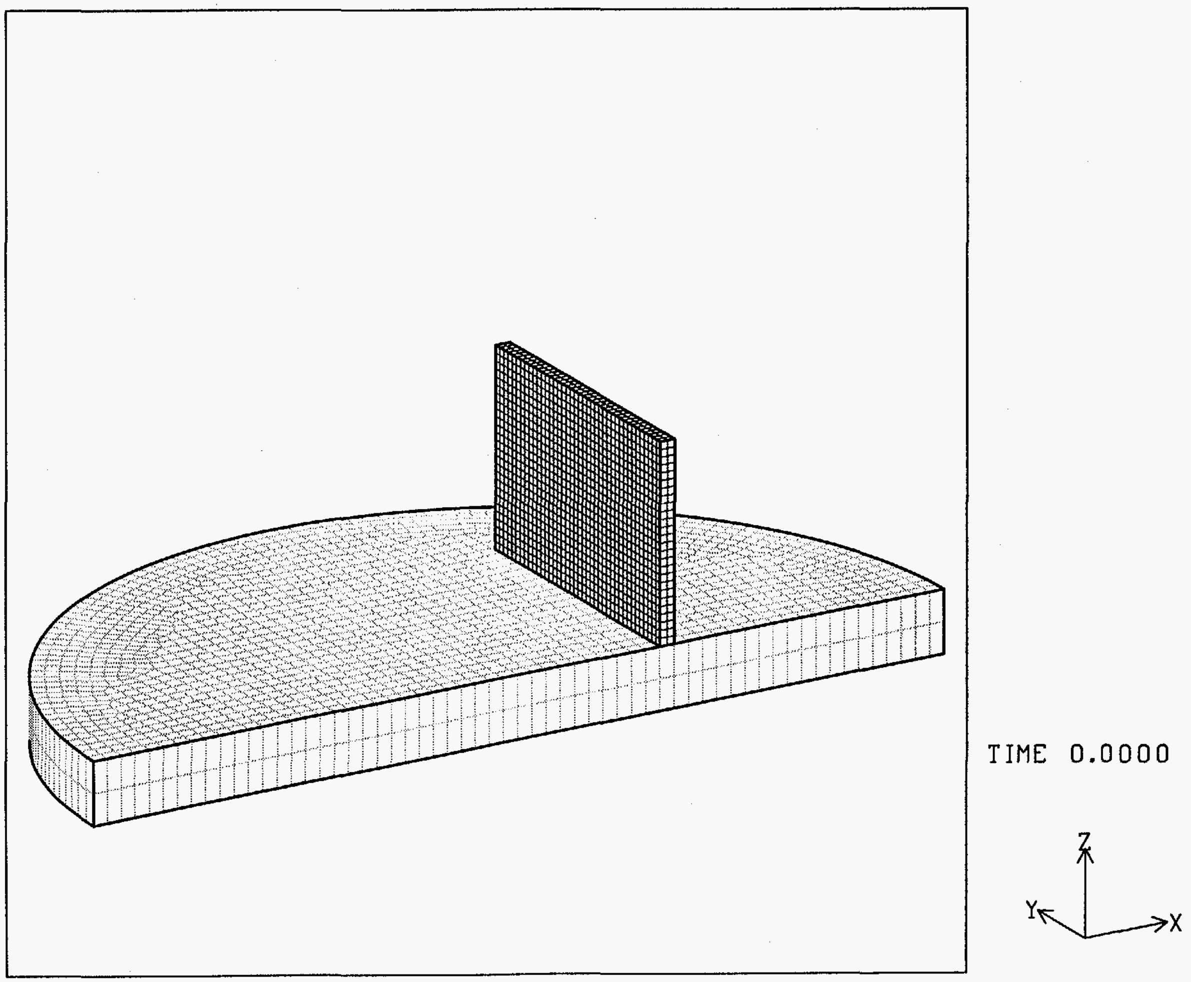

Figure 1: Wall and ground to be subjected to blast loading.

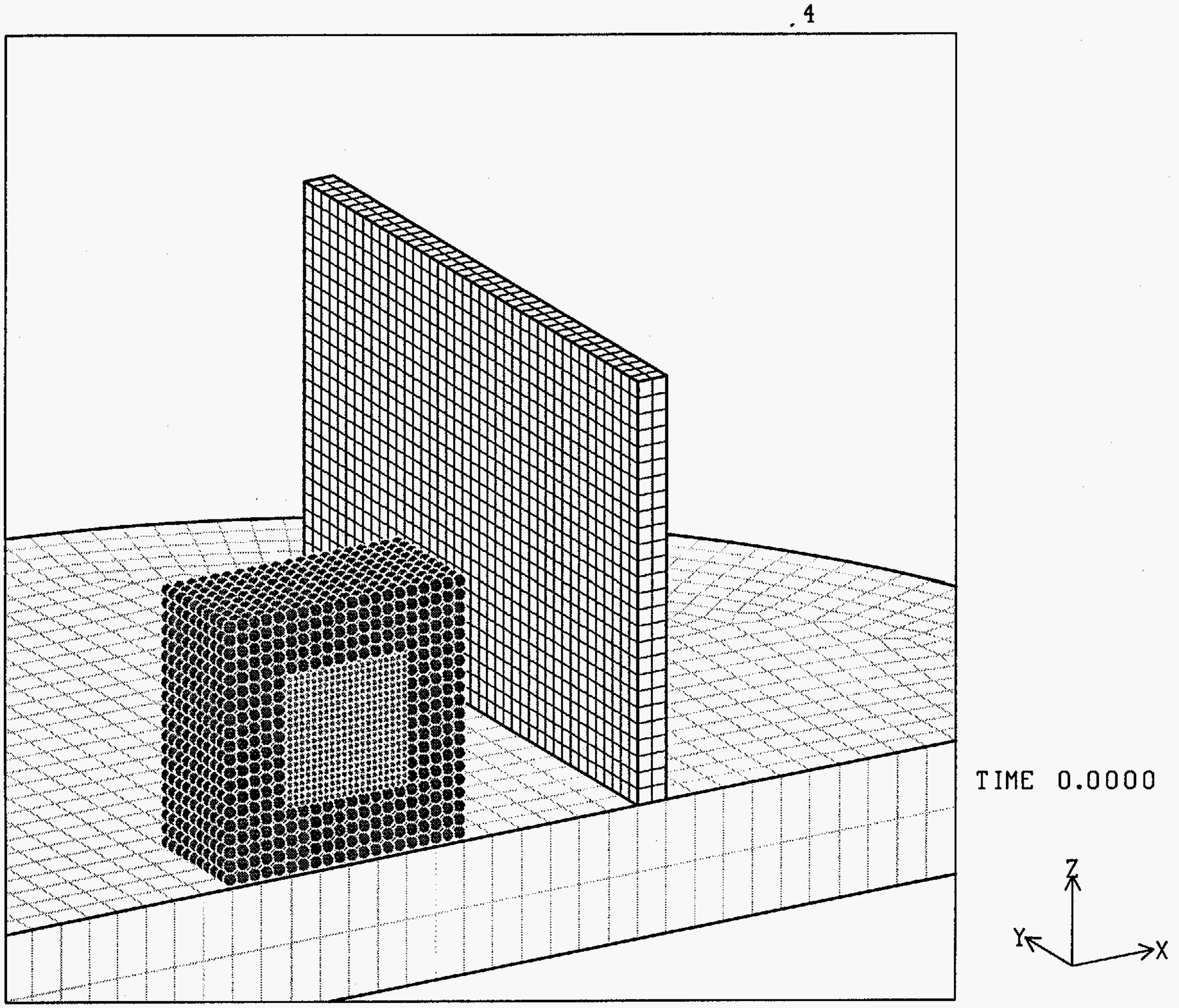

Figure 2: Explosive and buffer zone SPH elements with wall and ground.

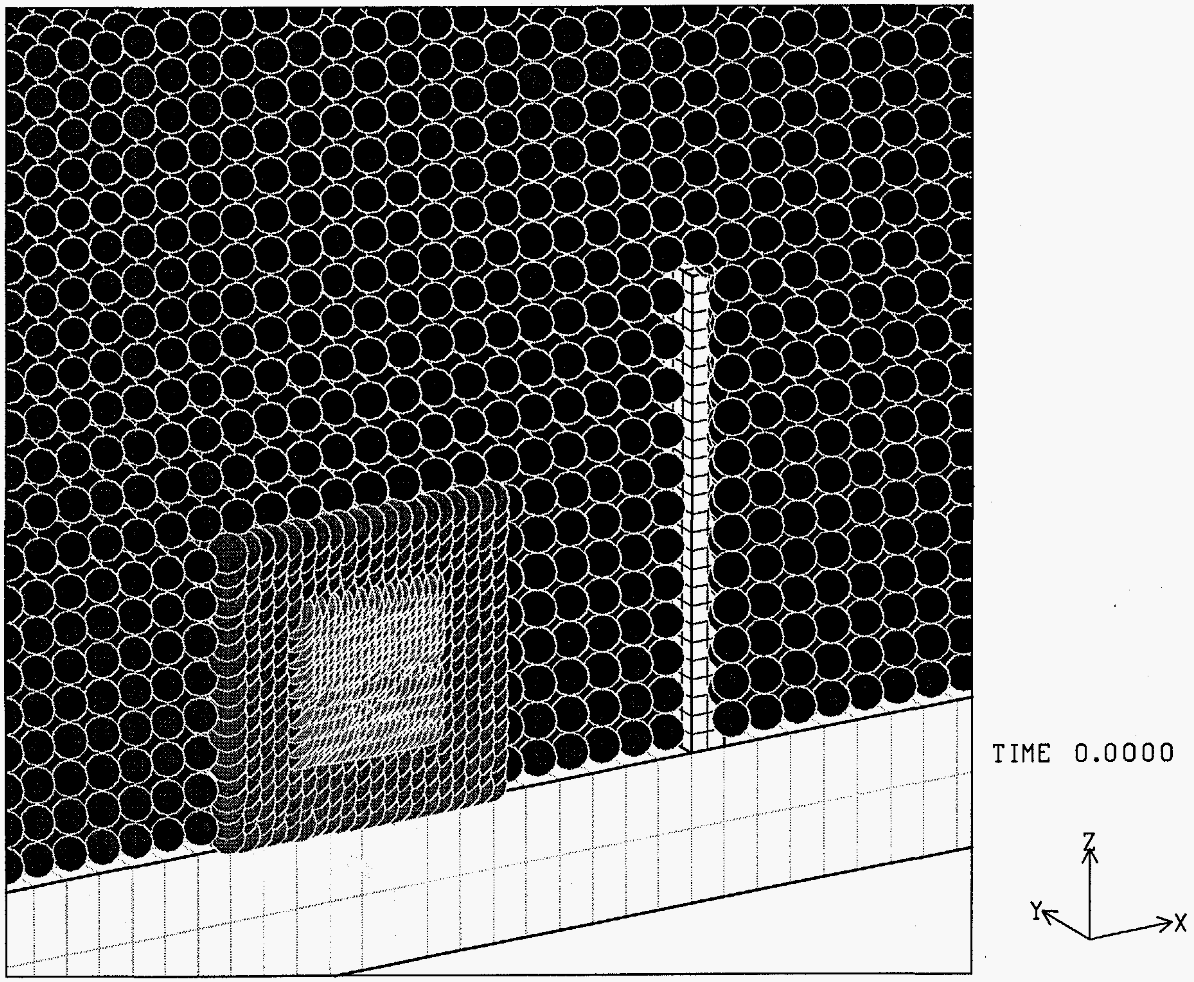

Figure 3: Explosive, buffer zone and air SPH particles with wall and ground.

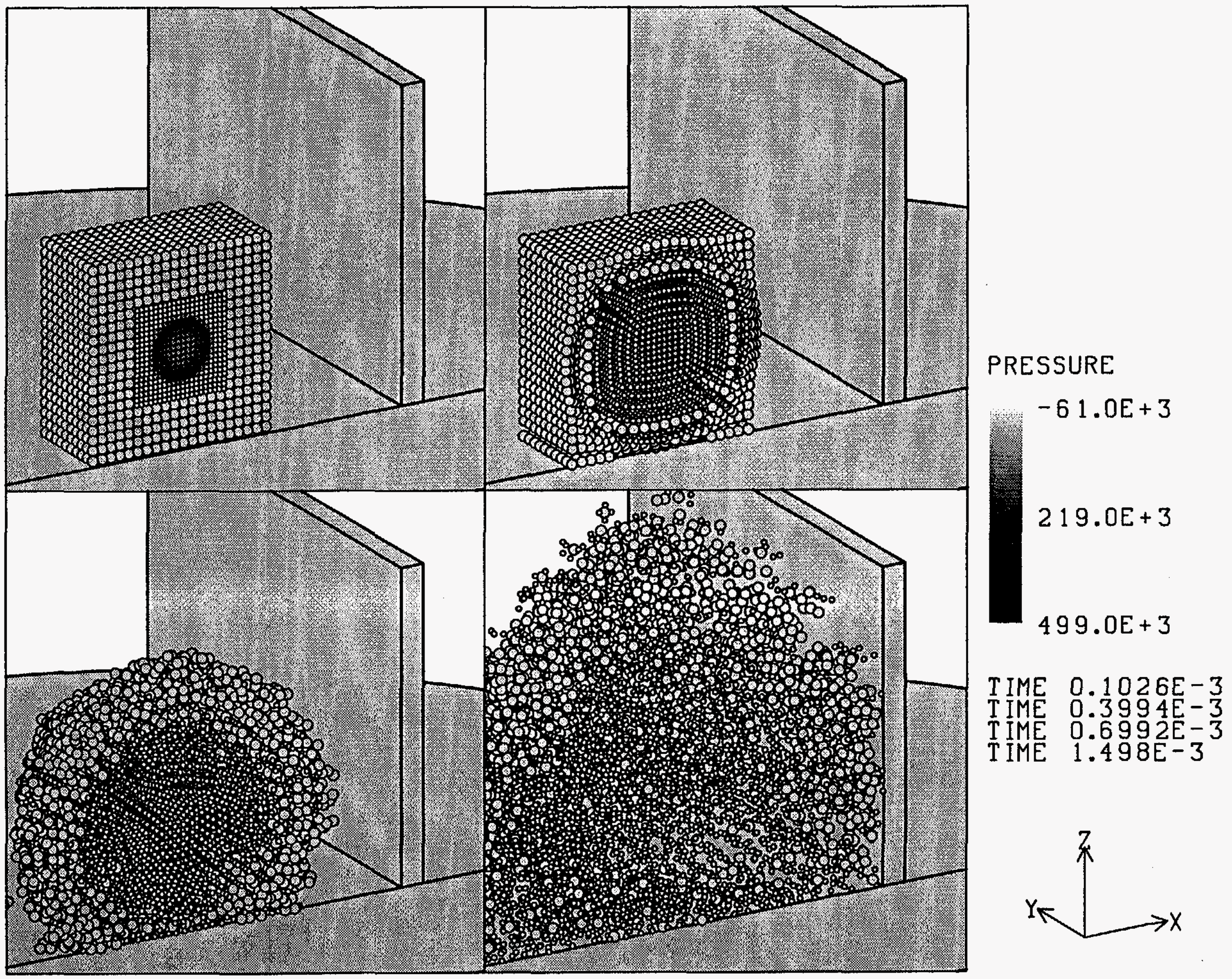

Figure 4: Pressure in SPH elements along with expamsion and contact with wall. Air SPH elements withheld from display.

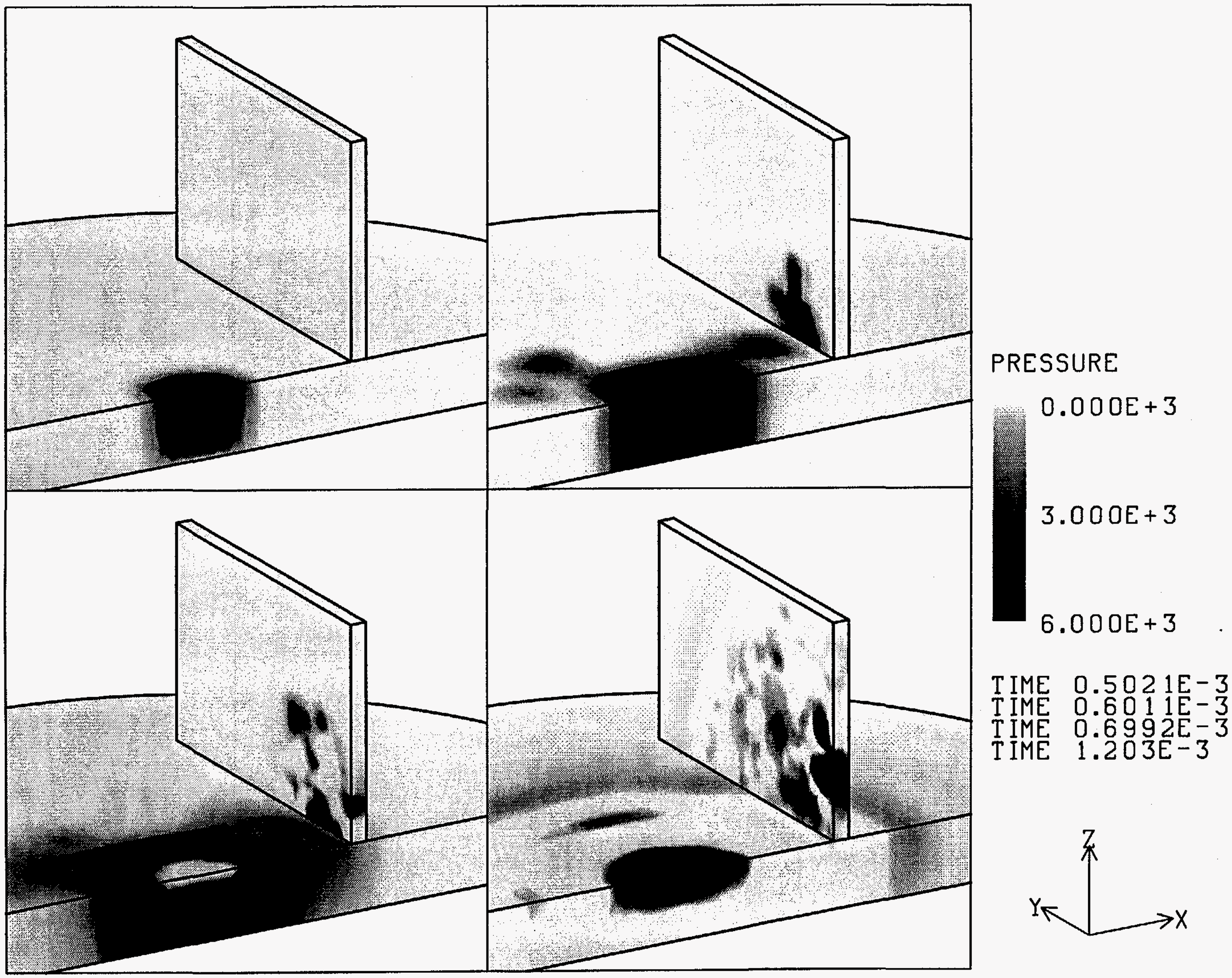

Figure 5: Pressure in the ground and wall induced by the explosive and air SPH particles

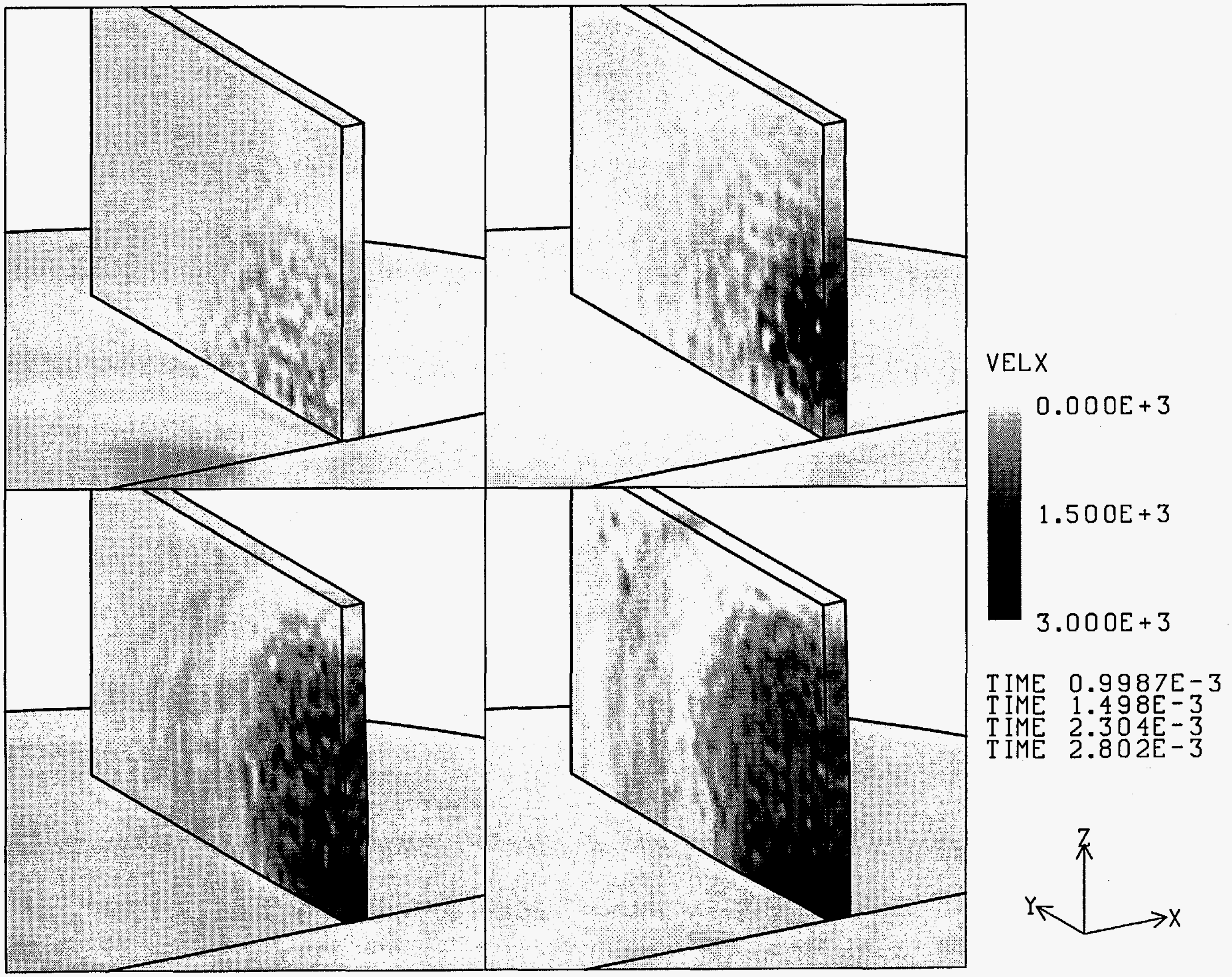

Figure 6: Velocity of wall perpendicular to wall induced by pressure loading.

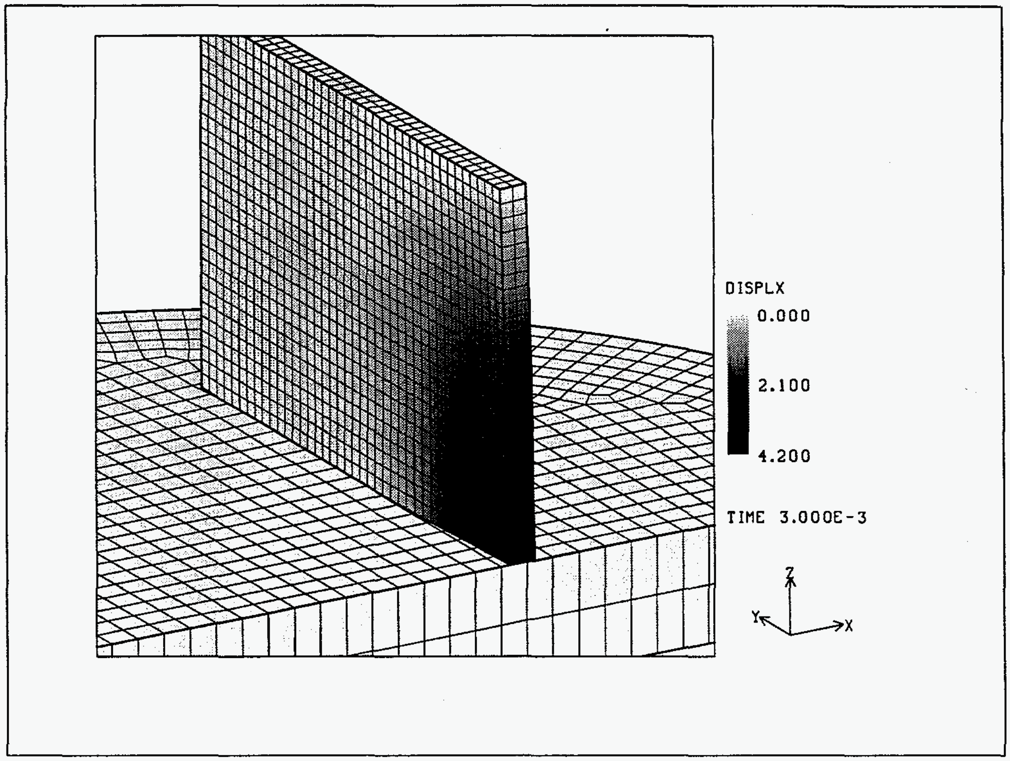

Figure 7: Wall displacement (inches) at 3.0 ms induced by pressure on wall

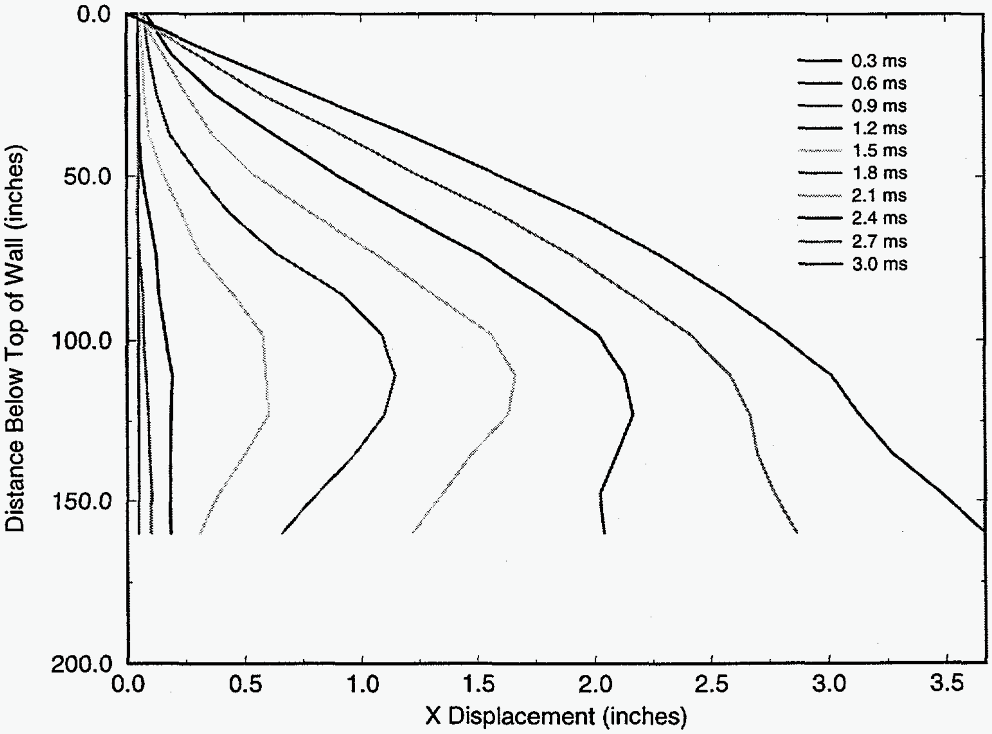

Figure 8: Displacement perpendicular to wall from the top to the bottom of the wall along the closest corner shown in Fig. 8. Lines representing increasing time, from 0 to 3 ms, start on the left.