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A REVIEW OF THE BLAST EFFECTS ON SANDWICH PANELS WITH SUPPRESSIVE CORES

By

Laissy * M.Y   Abdel-Latif ** W.M   Abdel-Wahab *** M.M

Abstract

In recent years, explosives became the weapon of choice for the majority of terrorist attacks therefore the response of structures to impact loads have gained a significant interest. An explosion within or immediately nearby a building can cause catastrophic damage of both external and internal structural buildings' frames, collapsing the walls, blowing out of large expanses of windows and shutting down critical life-safety systems. The events of ninth of September (9/11) continue to have a lasting effect on the world. The implications of the vulnerability of the infrastructure to terrorist attack became a major concern that should be shared by all engineers whereas the design and construction of new structures so as to resist such loads possess not so much technical as economical challenge, this is even clearer in the case of strengthening of existing structures.

This paper describes different experimental and numerical techniques used for different sandwich panels with suppressive cores to reduce the effect of blast loads on the buildings and/or protective structures. The results from FEM simulations of these sandwich panels subjected to explosion were discussed and the results obtained from these methods were compared, the simulations were performed using AUTODYN-3D software [1].

Keywords: Sandwich Panels, Suppressive Cores, Blast load.

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* Ph. D. Applicant, Cairo University, Egypt.

** Associate Professor of Construction Engineering, Department of Civil Engineering, Faculty of Engineering, Cairo University, Egypt.

*** Brig. D, Military Technical College, Egyptian Armed Forces, Egypt.

Abbreviations

TNT : Trinitrotoluene
FEM : Finite Element Method
RHT : Strength Model for the Concrete

1. Objective

The primary objective of this paper is to study the resistance and ability of different sandwich panels with suppressive cores to withstand different levels of blast loads.

2. Introduction

Today, the impact resistance of engineering structures subjected to blast loads is of great interest to engineering communities and governmental agencies against possible terrorist threats. In explosion, the peak pressure produced by shock wave is much greater than the static collapse pressure of the structures. The structures usually undergo large plastic deformation and absorb energy before collapsing to a more stable configuration or fracture. The aim of using sandwich panels with suppressive cores is to contribute in increasing the resistance of the structures against the blast load effects. Since massive concrete structures withstand blast waves and fragment impacts effectively, they are often used as protective structures according to Swedish Shelter Regulations [2].
This paper studies the effect of blast loads on different sandwich panels. The experiment investigations were performed using explosions of 10 and 20 kg of TNT on concrete, concrete-steel as well as steel sandwich panels.

3. FEM Analysis

FEM provides detailed understanding of the interaction between model parts. Computer-based methods can provide the researcher or designer with a great deal of valuable information about the explosion loads. Such methods are very useful when dealing with the explosion effects which will be a combination of blast waves and stress waves.
In this paper, for ensuring and verification that the model can predict the blast loads from the explosion, the results obtained from FEM simulation of a 10kg TNT explosion at a distance of 1.0 m from the model have been compared to experimental results made for the same model with the same boundary conditions.
Analysis with AUTODYN [1] by using the RHT model for the concrete part of the model and Johnson & Cook strength model for the steel angles part of the model have been used, and the data listed in Tables (1) and (2), respectively.

4. Models Description

In this study six models were tested to evaluate the effect of the blast loads on the buildings or protective structures. Each model has been meshed into same type of elements and same numbers of nodes to resemble the geometries to produce accurate results. The dimensions for general model (6000mm×1000mm×1000mm), as shown in (Figure 1), the boundary conditions for the concrete and steel angles were fixed from two sides and the air boundary condition is set to be flow-out to allow for the pressure wave to simulate the reality. The details of construction for each model are shown in Figures 2 to 12.

Model 1: This model was formed of a concrete block with the dimension of (0.2 m×1.0 m×1.0 m) exposed to an explosion of 20 kg of TNT, the details are illustrated in Figure 2.

Model 2: This model was formed of four rows of angels (0.7m×0.7m×0.007m) block and was exposed to an explosion of a 20 kg of TNT, the details are illustrated in (Figure 4).

Model 3: This model was formed of four rows of angels (0.7m×0.7m×0.007m) block and a concrete block with the dimension of (0.2 m×1.0 m×1.0 m) and was exposed to an explosion of a 20 kg TNT facing the steel block, the details are illustrated in (Figures 5 and 6).

Model 4: This model was formed of four rows of angels (0.7m×0.7m×0.007m) block and a concrete block with the dimension of (0.2 m×1.0 m×1.0 m) and was exposed to an explosion of 20 kg TNT facing the concrete block, the details are illustrated in (Figures 7 and 8).

Model 5: This model was formed of four rows of angels (0.7m×0.7m×0.007m) block and in between them a concrete block with the dimension of (0.2 m×1.0 m×1.0 m) and was exposed to an explosion of a 20 kg TNT, the details are shown in (Figures 9 and 10).

Model 6: This model was formed of four rows of angels (0.7m×0.7m×0.007m) block between two concrete blocks with the dimension of (0.1 m×1.0 m×1.0 m) and was exposed to an explosion of a 20 kg TNT, the details are illustrated in (Figures 11 and 12).

5. Experimental Study

An experimental model for the sandwich panels was made and exposed to an explosion of 10 kg TNT and the same model was simulated analytically in the ANSYS - AUTODYN and the results from these two models are compared.

5.1. Experimental Model

This model is formed of a steel angles block of four rows with the block dimensions of (0.3 m×1.0 m×1.0 m) as shown in Figure 13. The steel angels block boundary condition was simply supported on the ground: the model is exposed to as explosion of 10kg of TNT at a distance of 1m from the steel angles block and 1.4 m from the pressure sensor; the details are illustrated in Figures 13 and 14.

The results gained were as follows; the sensor reading = 7.3 volt, as illustrated in (Figure 16), by using the sensor sensitivity = 4.969 mV/PSI, then the output mill volts (mV) = (7.3/4.969) x 1000 = 1469.12

Using the calibration certificate chart we get the INPUT-PSI =307 PSI = 21.17 bar

5.2. Numerical Model

This model is formed of block of steel angles consisting of four rows; the block dimensions were (0.3 m×1.0 m×1.0 m) as shown in Figure 15. The steel angels block boundary condition was simply supported and rest on sand to simulate the ground in experimental model; this model is exposed to as explosion of 10Kg of TNT with a distance of 1m from the steel angles block and 1.4 m from the pressure sensor, the details are illustrated in Figure 15.

The ANSYS pressure reading "P_{so}" after the angles = 2169 kPa = 314.587 Psi = 21.69 bar

This indicates that the experimental and numerical models results are almost the same with a 0.98% error factor "less than 1%".

The ANSYS pressure reading "P_{so}" before angels = 4478 kPa = 649.479 Psi = 44.78 bar

From which we can find that the use of the steel angels as suppressive cores will reduce the explosion pressure by 48.4% as illustrated in Figure 17.

6. Main Achievements

1. Establishing a construction model with low cost and weight that can resist blast loads and can be applied for either old or new structures.
2. Developing an assertion about the effectiveness of using AUTODYN-3D in evaluation and examination of the performance of the structures under the blast load effects.
3. Investigating a 3-D finite element model of a different construction sandwich panels with suppressive cores utilizing the AUTDYN and ANSYS software.

4. Verifying the results from an ANSYS AUTODYN simulation models with those obtained from experimental ones.

7. Conclusions

From the previous study, the following conclusion can be drawn out:

1. Due to the time consuming and the expensive cost of experimental work, AUTODYN software can be used successfully as an alternative mean to study different parameters that can affect the behavior of different sandwich panels with suppressive cores.
2. Sandwich panels with suppressive cores are highly recommended for protective structures due to their high energy dissipation by steel angles as well as energy absorption by concrete.
3. The use of steel angles in the suppressive cores rather than a block of steel with the same weight is the main factor affecting the reduction of both penetration distances, cost and model establishment i.e. it gives better results in the protection.
4. The AUTODYN code satisfactory simulates the blast experimental tests.
5. The main advantage of dynamic simulation analysis is that it is of relative simplicity compared to a full FEM of sandwich panels, combined with preserved accuracy. Another advantage of this type of analysis is to verify the intactness of the sandwich panels and to determine the action necessary for the suggested core. This simplicity allows rapid construction of the model in addition to reduction in required computation time.
6. The response of sandwich panel under the blast load will be significantly higher compared to the use of the common individual steel and concrete cores.
7. The analysis of sandwich panel can be simulated under the blast load using ANSYS software and it will give a higher analysis precision compared to the common analysis method used.
8. A steel angles core reduces the blast load effects on the buildings or protective structures by 48.4 %.

6. References

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Table-1 Input Data for Concrete Target with P-Alpha Equation of State and RHT Strength Model

Porous density (g/cm^3)	2.39	Shear Modulus (MPa)	18000
Porous sound speed (m/s)	3000	Compressive Strength f´c (MPa)	92
Initial compaction pressure (MPa)	80	Tensile Strength ft	0.057 fc
Solid compaction pressure (MPa)	1800	Shear Strength fs	0.3 fc
Compaction exponent n	5	Failure Surface Parameter A	1.9
EOS Solid	Polynomial	Failure Surface Parameter N	0.6
Compaction curve	Standard	Tens./Compr. Meridian Ration	0.6805
Reference density (g/cm^3)	2.54	Brittle to Ductile Transit.	0.0105
Parameter A_1 (MPa)	40000	G(elas.)/G(elas-plas.)	2
Parameter B_0	1.22	Elastic Strength	0.8 ft
Parameter B_1	1.22	Elastic Strength	0.75 f´c
Parameter T_1 (MPa)	40000	Residual Strength Const.B	1.6
Reference Temperature (k)	300	Residual Strength Exponent M	0.61
Specific heat (j/kgk)	640	Comp. Strain Rate Exponent α	0.01
Strength model	RHT CONCRETE	Tens. Strain Rate Exponent. δ	0.013
Failure model	RHT CONCRETE	Tensile Failure model	Hydro Tens.
Damage constant D_1	0.08	Min. Strain to Failure	0.05
Damage constant D_2	1	Residual Shear Modulus Frac.	0.13

Table-2 Input Data for Steel Projectile with Shock Equation of State and Johnson-Cook Strength Model

Equation of state	Shock	Strength Model	Johnson -Cook
Reference density (g/cm^3)	7.75	Shear Modulus (MPa)	81800
Gruneisen coefficient	2.17	Yield Stress (MPa)	1539
Parameter C_1 (m/s)	4569	Hardening Constant (MPa)	477
Parameter C_2 (m/s)	1.49	Hardening Exponent	0.18
Bulk Modulus (MPa)	159000	Strain Rate Constant	0.012
Reference Temperature (K)	300	Thermal Softening Exponent	1
Specific Heat (J/kgK)	477	Melting Temperature (K)	1763

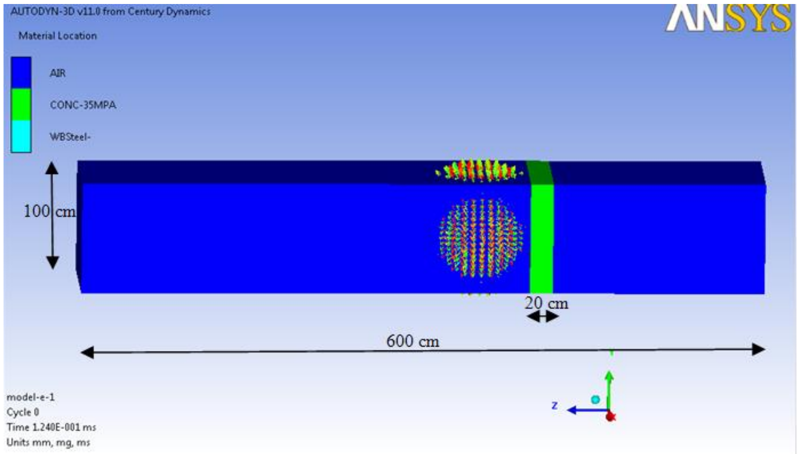
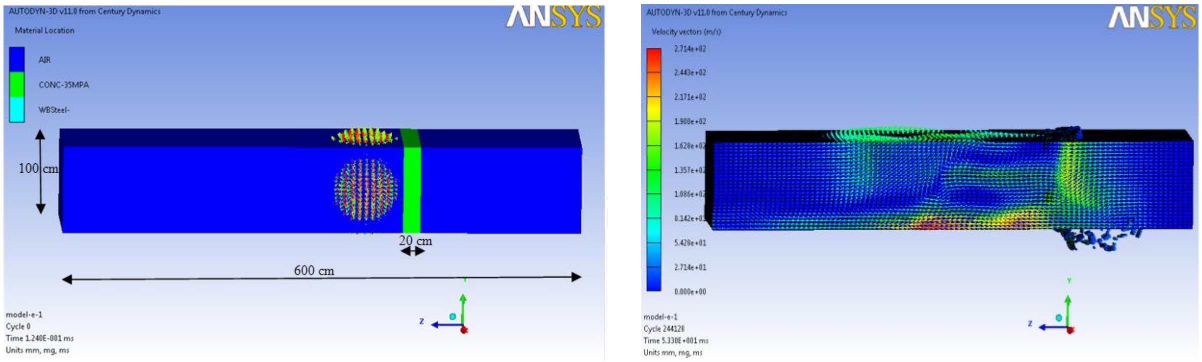


Figure (1): Dimension of the general model.



Model "1" Details Explosion Effect on model "1"

Figure (2): Explosion of 20 kg TNT for Model "1".

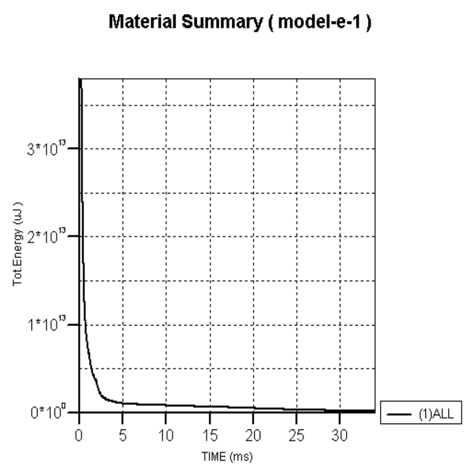
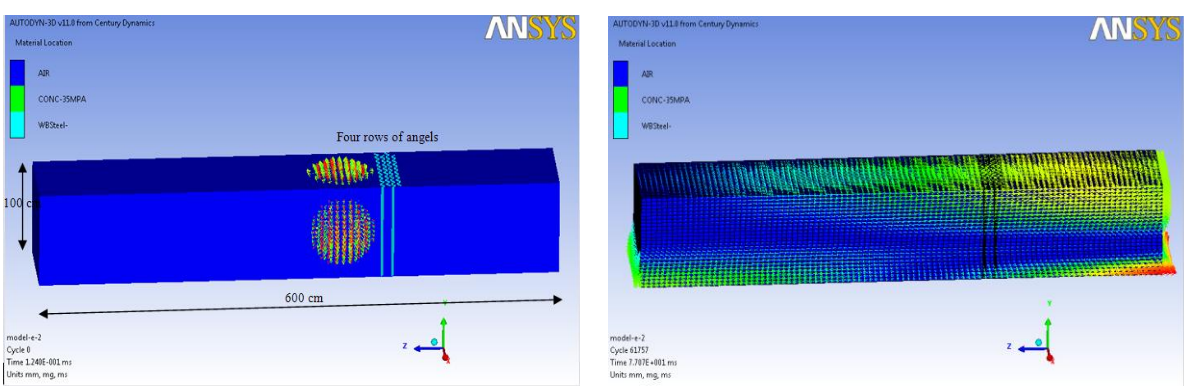
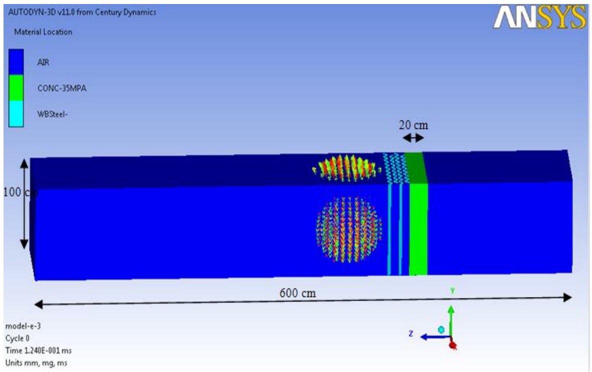


Figure (3): Total Energy Profile For Model "1".

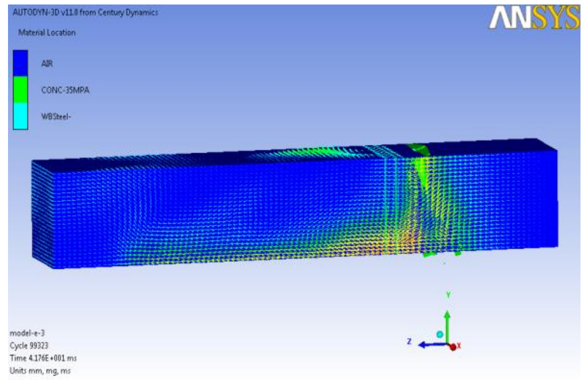


Model "2" Details Explosion Effect on model "2"

Figure (4): Explosion of 20 kg TNT for Model "2".

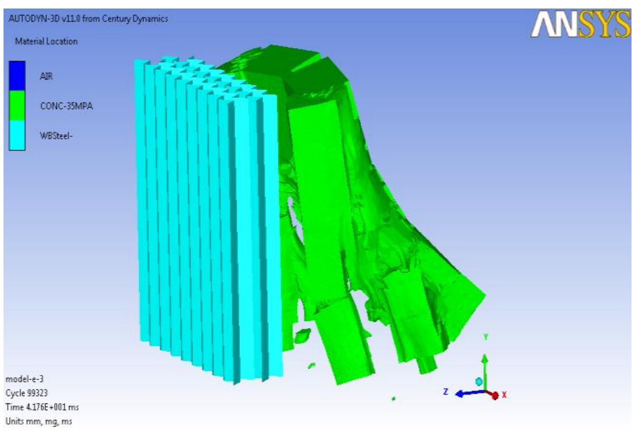


Model "3" Details

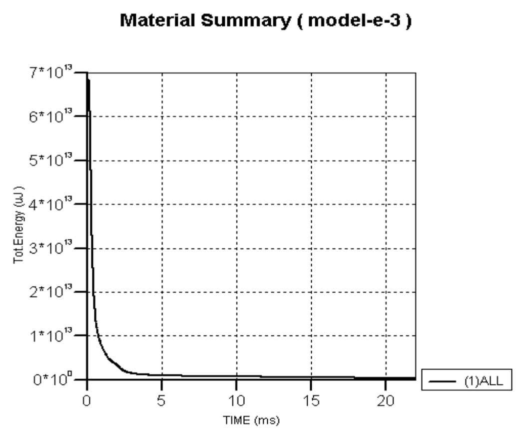


Explosion Effect on model "3"

Figure (5): Explosion of 20 kg TNT for Model "3".

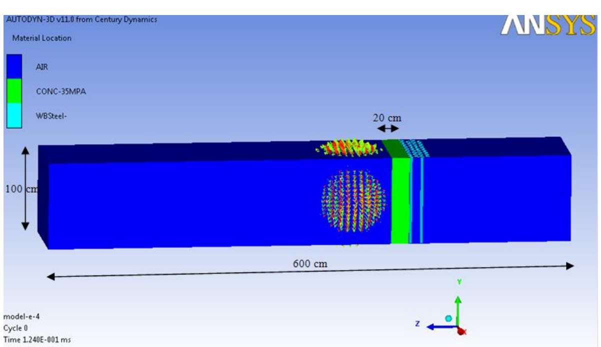


Explosion Effect on model "3"

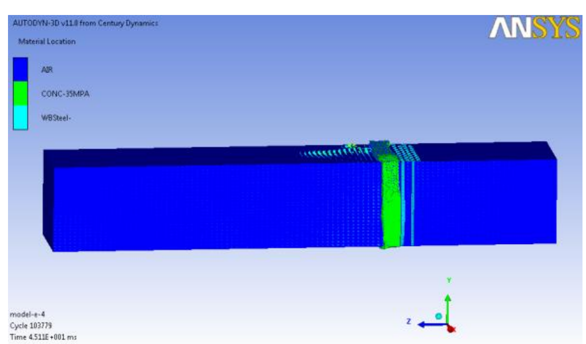


Total Energy Profile For Model "3".

Figure (6): Explosion of 20 kg TNT for Model "3".

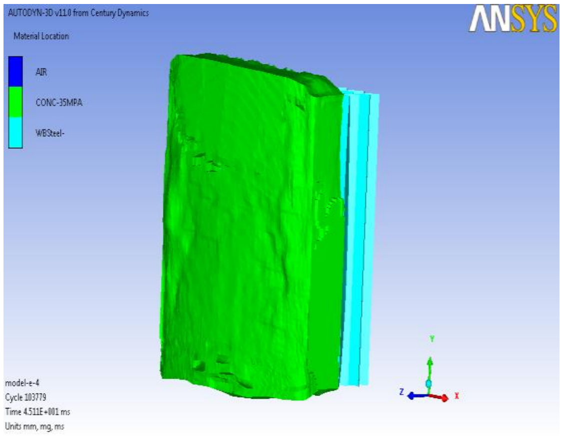


Model "4" Details

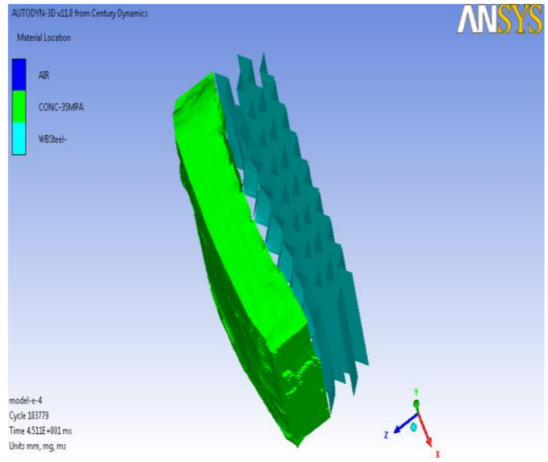


Explosion Effect on model "4"

Figure (7): Explosion of 20 kg TNT for Model "4".

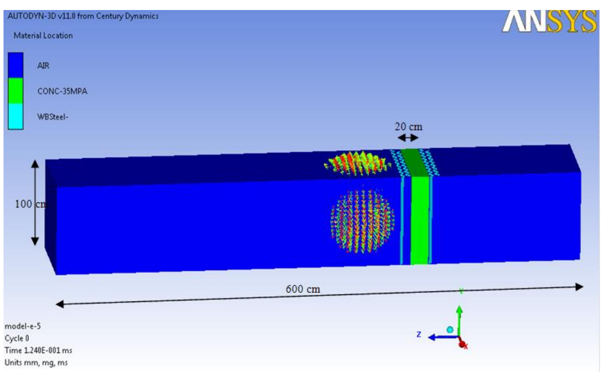


Explosion Effect on model "4"

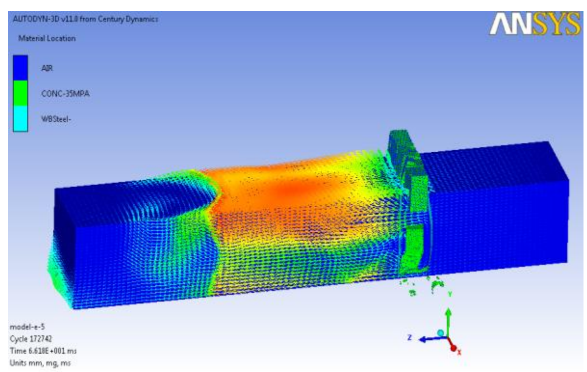


Explosion Effect on model "4"

Figure (8): Explosion of 20 kg TNT for Model "4".

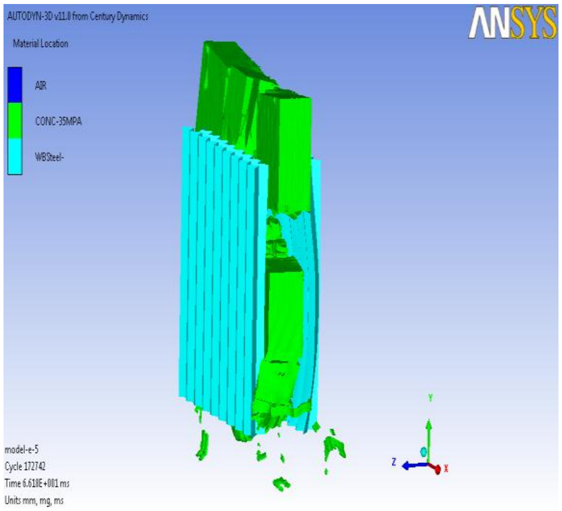


Model "5" Details

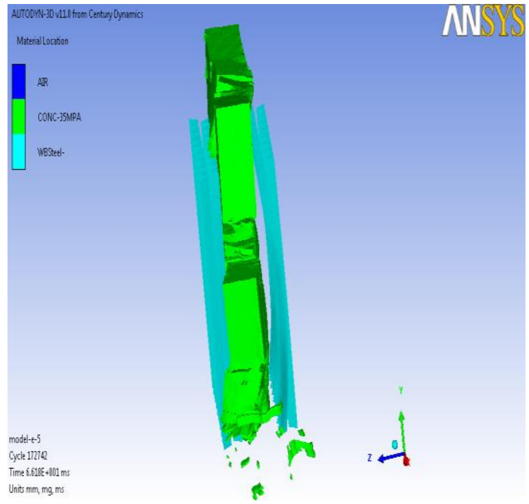


Explosion Effect on model "5"

Figure (9): Explosion of 20 kg TNT for Model "5".

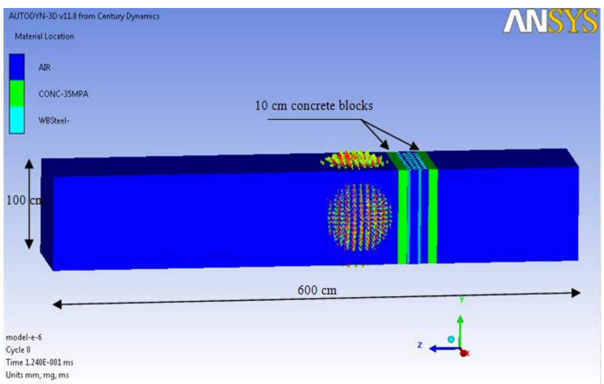


Explosion Effect on model "5"

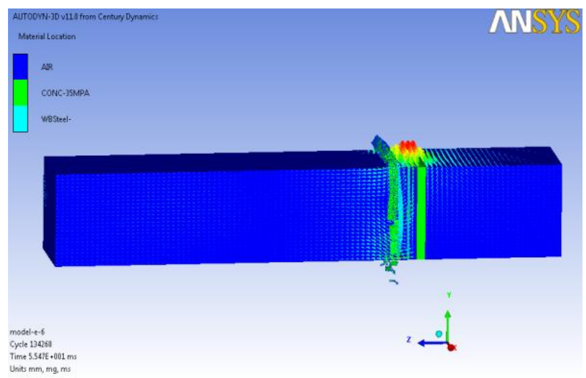


Explosion Effect on model "5"

Figure (10): Explosion of 20 kg TNT for Model "5".

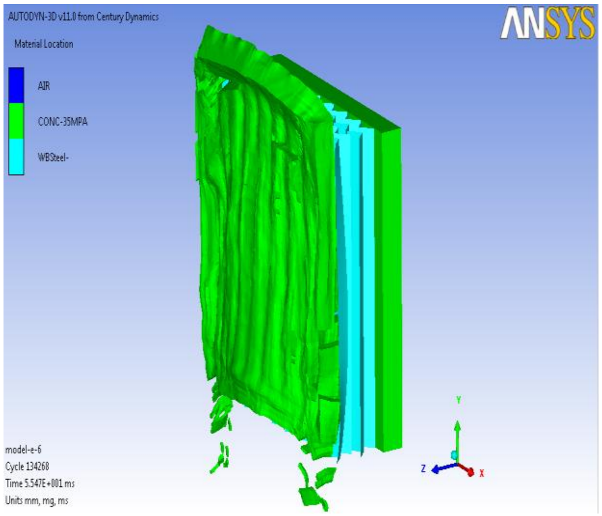


Model "6" Details

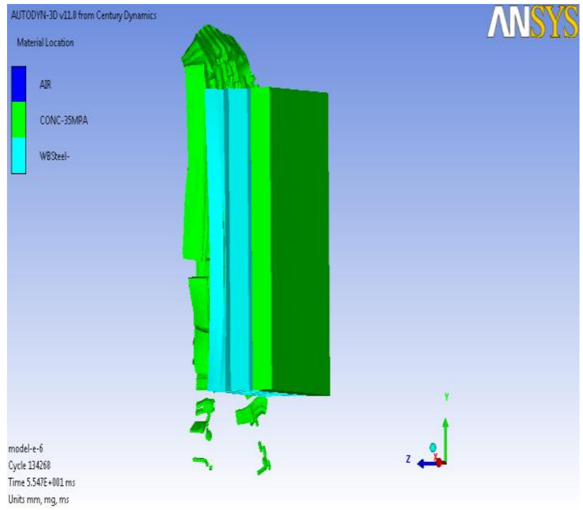


Explosion Effect on model "6"

Figure (11): Explosion of 20 kg TNT for Model "6".



Explosion Effect on model "6"



Explosion Effect on model "6"

Figure (12): Explosion of 20 kg TNT for Model "6".

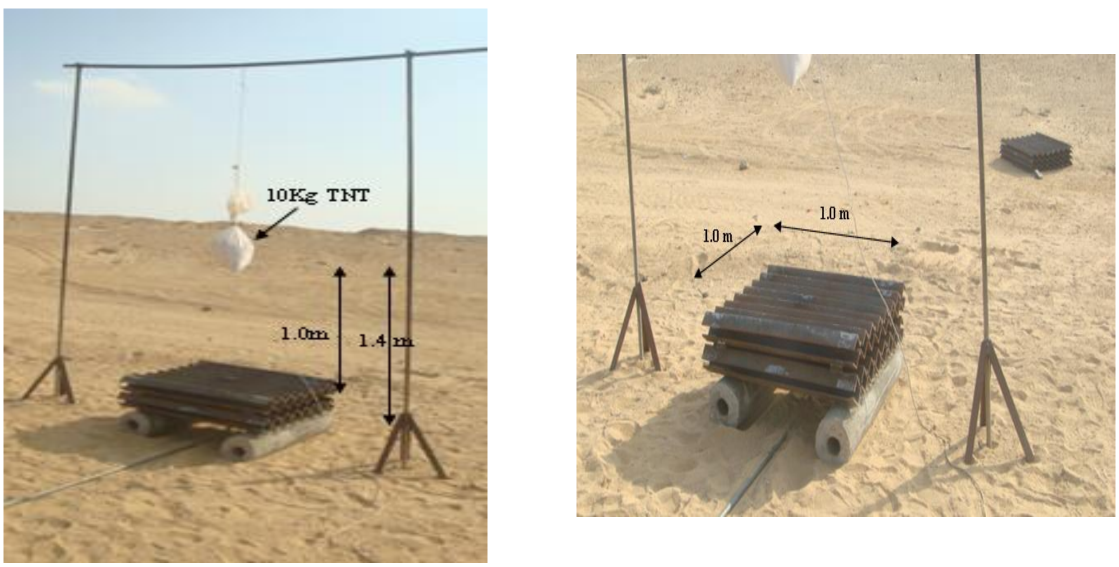


Figure (13): Explosion of 10 kg TNT for Experimental Model.

Figure (14): Explosion of 10 kg TNT for Experimental Model.

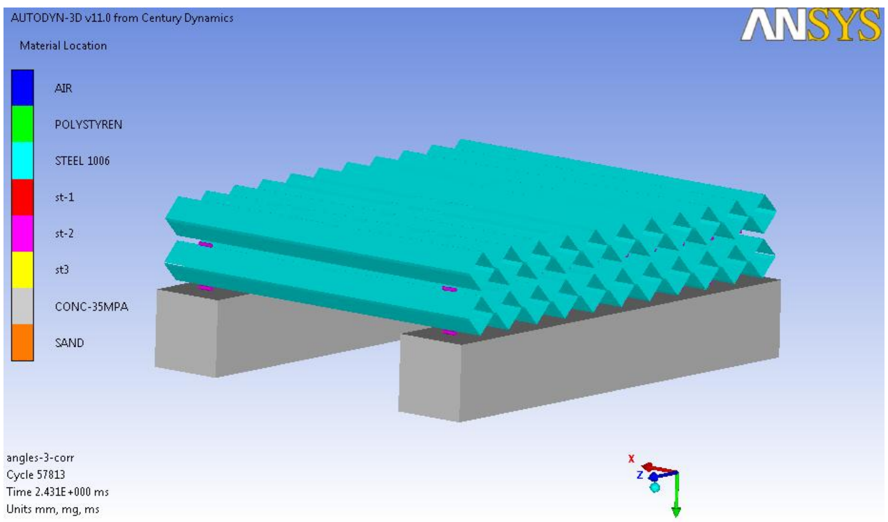


Figure (15): Explosion of 10 kg TNT for Numerical Model.

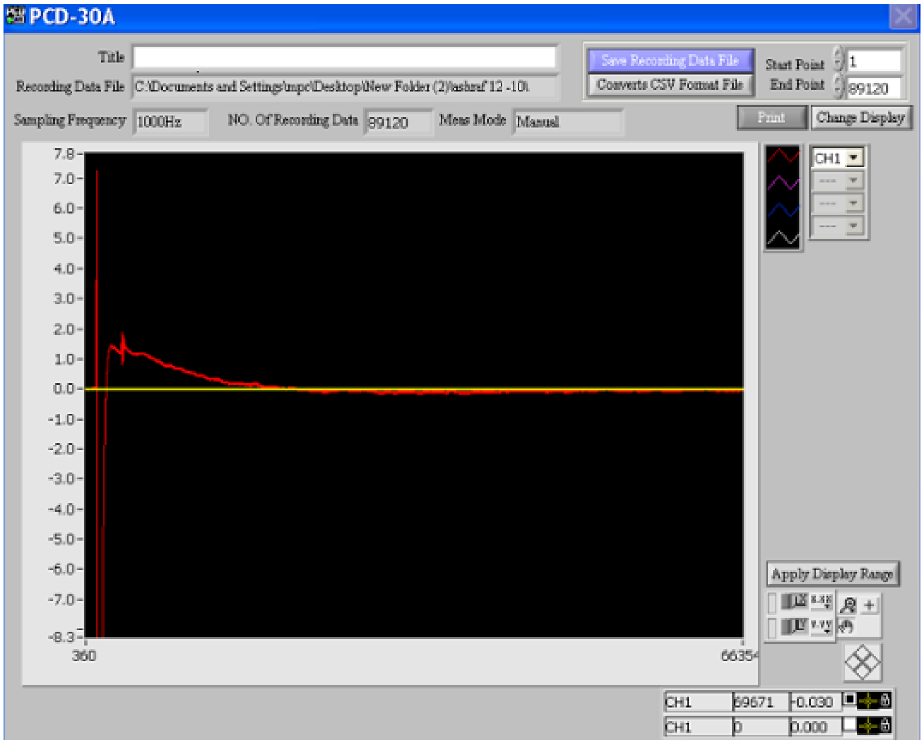


Figure (16): Detail from pressure sensor data for the experimental model.

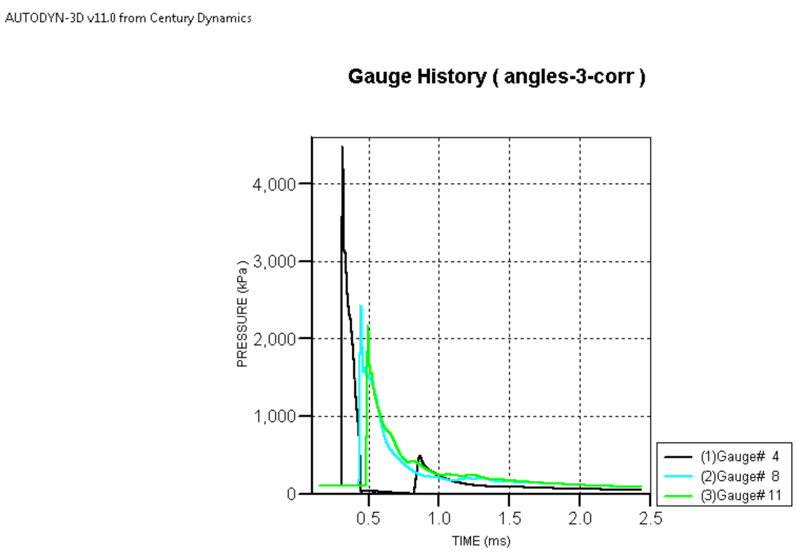


Figure (17): Pressure-Time Variation for 10 kg TNT Numerical model