APPLICATION OF NEURAL NETWORKS FOR BLAST LOADING ON STRUCTURES

A DISSERTATION

Submitted in partial fulfilment of the
requirements for the award of the degree
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(With Specialization in Structural Dynamics)

By

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CANDIDATE'S DECLARATION

I here by declare that the work presented in this dissertation entitled "**APPLICATION OF NEURAL NETWORKS FOR BLAST LOADING ON STRUCTURES**", in partial fulfillment of the requirements for the award of the degree in **Master of Engineering in Earthquake Engineering** with specialization in **Structural Dynamics**, submitted to the Department of Earthquake Engineering, University of Roorkee, Roorkee, India, is an authentic record of my own work carried out for the period from August 1999 to January 2000, under the supervision of **Mr. A. D. Pandey**, Reader, Department of Earthquake Engineering, University of Roorkee, Roorkee, India.

The matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.

Dated: 31-01-2000

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

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ABSTRACT

In dealing with problems in analysis and design of civil engineering systems, we need to carryout rigorous and complex calculations. At present, with the help of computers, various emerging analytical tools are coming up to make the laborious process easy and at the same time conforming to a greater extent of reliability when compared to hand calculations. Artificial neural networks are one step ahead of conventional programming techniques, these networks simulates the working nature of human brain. The main advantage in the use of artificial neural networks is the capability of producing acceptable solutions even for situations with imprecise, imperfect and incomplete data also.

In the present work, the application of artificial neural networks has been examined with specific reference to the Blast loading phenomenon on structures and developed four network models i.e., Pressure Net, Response Net, General Net and Height Net for evaluating the Design pressure and Response of the Structures. A comparative study has been carried out to see the variation of Design pressure and Response of structures depending on various parameters of Structure and its location from blast site. On the basis of studies conducted Neural Networks have been found to perform to a high degree of accuracy. For the more Neural Networks can be useful employed to conduct parametric studies to argument our knowledge of the blast phenomenon.

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LIST OF SYMBOLS

Q	Quantity of Blast in MT
X	Scaled ground distance
Xd	Ground zero distance from blast to structure
W	Reference yield (1 tone)
Wd	Actual yield of Blast in MT
Pa	Ambient pressure
T	Ambient pressure in °c
H	Height of structure in meters
B	Breadth of structure in meters
L	Length of structure in meters
C_d	drag coefficient
a	Velocity of sound at temperature T
P_{so}	Peak side over pressure
P_{ro}	Peak reflected pressure
qo	Peak dynamic pressure
t_o	Positive phase pressure
t_d	Duration of equivalent triangular pulse
M	Mach number
t_{od}	Scaled duration of positive phase for specific yield

U	Shock front velocity
t_{dd}	Scaled duration of equivalent triangular pulse
t_c	Stagnation or Clearance time
P_s	Shock wave over pressure
N-O	Neural Network output
P-O	Program Output

1.2 OBJECTIVES OF PRESENT STUDY

Finding the time history of pressure pulse involves various calculations based on Quantity of explosive and ground zero distance of blast or explosive from the structure along with configuration of structure such as shape, height etc., with different simplifying assumptions this leads to complex and time consuming calculations. The method of finding time history of design pressure pulse requires many inputs both from the problem point of view and from IS: 4991 for various scaled parameters.

In this present study an attempt has been made to develop neural network models for

(i) Determination of Time history of Pressure pulse based on

- Quantity of Blast or Explosive.
- Ground zero distance from Structure.
- Height of structure
- Structure configuration.
- Type of structure.

(ii) Determination of Response of Single degree of freedom for exerted pressure pulse based on

- Design force pulse
- Height of structure
- Structural Configuration
- Structural properties.

Four Neural Network models i.e., Pressure Net, Response Net, General Net and Height Net are developed and tested using the data obtained from a computer program developed for getting the data outputs conforming to design standards of IS:4991-1968. Comparative studies have been made to study the blast phenomena, depending on quantity of blast and ground zero distance from the blast to the structure, Height of Structure and Type of Structure.

Chapter 2

REVIEW OF LITERATURE

2.1 GENERAL

A shock wave will be produced when a blast occurs and it propagates released large amount of energy that too in a very short time and space. This shock wave causes sudden increase in pressure and travels like a highly compressed air in the form of a moving wall from blast site [3]. As the time passes the peak pressure and velocity decreases with time and space, but spatial extent of shock increases. The nature of blast phenomena is shown in figure 2.1 in terms of pressure Vs time [1].

The shock wave exerts positive pressure followed by suction i.e. negative pressure phase. Generally shock wave will accompany a dynamic pressure due to drag effects of any obstruction coming in its way and it clears with time depending on the extent of obstructing surface [1].

2.2 BLAST PHENOMENON

Dynamic load caused due to a blast in air striking the structure is of considerable interest in the design of structures. The shock wave is usually caused by the detonation of a conventional explosive such as TNT or a bomb. The explosion results in rapid release of a large amount of energy. A substantial portion of the energy released is expended in driving a shock wave whose front consists of highly compressed air.

Main governing factor in shock wave front is peak over pressure. Peak over pressure in the shock front decreases quite rapidly as the shock wave propagates outward from the center of explosion. So the overpressure in a shock wave arriving at a structure will thus depend on both the distance from the center of explosion and the strength of the explosive.

As the shock front passes the structure, the overpressure rapidly decreases behind the front, and at some time after the arrival of the shock wave, the pressure may infact become negative [3].

A near surface explosion creates a hemispherical shock front, which reflects from ground. The reflected shock front travels faster than the incident shock in heated air. It eventually overtakes the incident shock front and creates a Mach stem [2]. Mach stem is a certain height up to which, the moving air behind it causes a second shock to form a double shock phenomena. So the three types of wave fronts i.e., incident, reflected and air pressure behind Mach stem creates a triple intersection as shown in Figure 2.7.

The air above the contact surface continues to move downward and causes compression of air below the mach stem. The Mach shock will be at a lower pressure, but it is the second shock that quickly raises the pressure above the ambient pressure, called as overpressure [2].

Empirical equations derived on the basis of observations are available for estimating the peak overpressure in a blast caused by the detonation of an explosive of given strength and striking a structure located at a given distance from the center of explosion. The duration of the positive phase and the variation of the blast pressure during each phase can also be obtained from available empirical equations.

In summary, a blast load can be represented by a pressure wave in which the pressure rises very rapidly or almost instantaneously and then drops off fairly rapid, according to a specified pressure-time relationship [3].

2.3 TYPES OF EXPLOSIONS

Depending on place or location of blast, any blast can be classified as on of the following types

- Air Blast
- Surface Blast
- Underground Blast

2.3.1 AIR BLAST

The fireball doesn't come into contact with ground i.e., the blast will occur above the ground level in mid air. Detonation of weapon in the air causes hydrodynamic expansion of bomb debris, heated air (fireball) produces a strong shock wave expanding in the surrounding air.

2.3.2 SURFACE BLAST

Fireball comes into contact with the ground i.e., the location of burst is on the surface of ground. Considerable amount of more damage is expected compared to air blast but the spatial extent of its influence will less when compared to air blast.

2.3.3 UNDER GROUND BLAST

Center of explosion is located under the ground surface. The nature of loading on structures in underground blasting case is different to that of air blast and surface blast case.

2.4 DESIGN ASPECTS OF BLAST LOADING

Considering the explosive or blast as air burst, the important aspects of design are time histories of overpressure and dynamic pressure. Reflection factor is defined as the ratio of reflected overpressure to incident pressure. Therefore the governing factors are peak overpressure of the incident shock wave and angle at which it strikes the surface [1]. Peak over pressure pro can be obtained from IS:4991-1968 Table:1, in terms of ambient pressure ratio. Drag force is due to obstruction in the direction of airflow. Forces in the direction of airflow caused by acting dynamic pressure on the objects are known as drag forces. As these forces are due to the interference with airflow, they depends on characteristics of the obstruction or object i.e., these forces depends on shape, size, location and etc of structure from the explosion site. IS:4991-1968 Table:2 provides drag coefficients(C_d) for various structural configurations with appropriate governing factors.

The factors on which the over pressure and dynamic pressure depends on

- Drag coefficient (factor C_D).
- Positive phase duration.
- Peak Pressure and
- Positive phase impulse.

2.5 CUBE-ROOT SCALING LAW

To estimate the scaled distance [1] for a given explosion from the observation, it is noticed that a given pressure will occur at a distance, which is proportional to cube root of the energy yield and ground zero distance. Reference yield of one tone at a distance X, due to explosion of W_d will be same for a yield of W at a distance X from the ground zero point. It can be expressed as

$$X = X_d\left(w/w_d\right)^{(1/3)} \qquad \text{-------------------} \qquad \text{(Eq 2.1)}$$

Similarly, we can apply the cube-root scaling law to find scaled positive phase pulse duration in terms of reference yield and the distance of explosion from the structure. The equation, which gives scaled positive phase pulse duration, is t_{dd} in terms of reference duration (t_{od}) and actual yield (W_d) of blast and reference yield of blast (W) is

$$t_{dd} = t_{od}\left(w/w_d\right)^{(1/3)} \qquad \text{-------------------} \qquad \text{(Eq 2.2)}$$

2.6 NATURE OF PRESSURE PULSES

Pressure exerted by blast quantity has different presence on different ? sides of structure [1]. We can classify the nature of pressure pulse for

- Front side
- Rear side
- Roof-Side wall

From the above mentioned pressure pulse histories we can estimate the design pressure pulse for the given quantity of blast.

2.6.1 FRONT SIDE PRESSURE

Time history of pressure pulse on front wall can be estimated with the help of scaled ground distance calculated with Equation 2.1 by using cube root scaling law. For calculated scaled distance, we can get the estimated scaled parameters, P_{ro} , P_{so} , C_d , q_o and etc., which can be obtained from table:2 of IS:4991-1968 and it is shown in table 2.2. The procedure is as follows

1. Scaled ground distance can be calculated from equation-2.1
2. For calculated X pick the scaled parameters from table 2.2
3. Calculate dimension S = min(H,B/2)
4. Calculate stagnation or clearance time $t_c = {}^{3S}\!/_{U}$?
5. Get drag coefficient C_d from table 2.1 or table 2 of IS:4991-1968.
6. Evaluate pressure at t_c

The nature of pressure pulse time history for front wall is shown in Figure-2.2

2.6.2 REAR SIDE PRESSURE

Rear side pressure is one of the main factors in estimation of Time history of design pressure pulse. Rear side pressure pulse [1] starts at transit time (L/U), upto that point that rear side pressure will be zero. The nature of rear side pressure pulse time history is shown in Figure-2.3.

2.6.3 ROOF-SIDE WALL PRESSURE

The nature of rear-side pressure pulse time history is shown in Figure-2.4. It starts at (L/2U) and increases linearly upto transit time (L/U) and then decreases linearly to zero at ($L/2U+t_d$).

2.7 DESIGN PRESSURE PULSE

The design pressure pulse time history is the governing parameter, for which we will design the structure to with- stand that imposing pressure pulse on structure. We can estimate the design pressure pulse time history from front side pressure pulse time history and rear side pressure pulse time history. Design pressure at a particular instance of time can be calculated by deducing rear side pressure from front side pressure at that instance of time. The nature of Design pressure pulse time history is shown in Figure-2.5.

2.8 ISCODE: 4991-1968

According to IS:4991, the design aspect of blast loading on structures above ground level is considered. ISCode classifies a structure into two categories, they are

- Diffraction type structures
- Drag type structures

2.8.1 DIFFRACTION TYPE STRUCTURES

These are the closed structures without openings, with the total area opposing the blast. These are subjected to both the shock wave over pressure P_s and dynamic pressure q caused by blast wind [1].

2.8.2 DRAG TYPE STRUCTURES

These are the open structures composed of elements like beams, columns, trusses, etc, which have small projected area opposing the shock wave. These are mainly subjected to dynamic pressure qo.

2.8.3 CLOSED RECTANGULAR STRUCTURES

Considering a closed rectangular structure assuming that Breadth side as front face with dimensions, Height (H), Breadth (B), Length (L). IS:4991-1968 provided guidelines for calculating the pressure pulse at any time for front face, rear face and roof-side face.

2.8.3.1 FRONT FACE

As the shock wave strikes the vertical face of a structure, normal reflection occurs and the pressure on the front face instantaneously increases to the reflected overpressure (P_r). The net pressure acting on the front face at any time is the reflected overpressure P_r or ($P_s + C_d q$) whichever is less. The net average loading on the front face is a function of time. The nature of Front face pressure is shown in Figure- 2.2

2.8.3.2 REAR FACE

The nature of average loading on the rear face (B x H) is shown in the Figure-2.3, where the time has been reckoned from the instant the shock first strikes the front face.

2.8.3.3 ROOF AND SIDE WALLS

The average pressure versus time curve for roof and side walls is given in Figure-2.4, when t_{dd} is greater than the transit time (L/U). When t_c is greater than t_{dd} the load on roof and side walls may be considered as a moving triangular pulse having the peak value of overpressure (P_{so} + $C_d q$) and time t_{dd}.

2.8.3.4 OVERTURNING OF STRUCTURE

The net average load as a function of time, which tends to cause sliding and overturning of the building is obtained by subtracting the loading on back face from that on the front face.

2.8.4 OPEN OR DRAG TYPE STRUCTURES

The net translational pressure on the obstructing areas of elements may be taken as shown in Fig-2.6, where C_d is the drag coefficient depending upon the shape of the structural element given in Table-2.1 and $t_q = (1/2)t_o$, where t_o is time for actual explosion.

2.9 NEWMARK'S METHOD

Newmark.N.M [4] developed a family of time-stepping methods based on the following equations

$$\dot{u}_{i+1} = \dot{u}_i + ([(1-\gamma)\Delta t]\ \ddot{u}_i) + (\gamma\Delta t)\ \ddot{u}_{i+1} \qquad \text{(Eq 2.3)}$$

$$u_{i+1} = u_i + (\Delta t)\ \dot{u}_i + [(0.5-\beta)(\Delta t)^2]\ \ddot{u}_i + [\beta(\Delta t)^2]\ \ddot{u}_{i+1} \qquad \text{(Eq 2.4)}$$

the parameters β and γ defines the variation of acceleration over a time step and determine the stability and accuracy characteristics of the method. When $\gamma = 1/2$ and $\beta = 1/4$ the variation of acceleration is average between the interval of time steps. When $\gamma = 1/2$ and $\beta = 1/6$ the variation of acceleration is linear in the interval, but it is stable only if $\Delta t/T_n \leq 0.551$, where as average acceleration method is stable for any interval of time. Average acceleration method is given in Table 2.3.

Chapter 3

ARTIFICIAL NEURAL NETWORK APPROACH

3.1 GENERAL

New class of computing architectures known as Artificial Neural networks, inspired by structure of brain and radically different from computers is emerging now days into every field of engineering and mathematics. Artificial Neutral Networks can be utilized to address problems that are cumbersome, interactive and imprecise with traditional methods

3.2 BASIC STRUCTURE OF NEURAL NETWORK

Development of a neural network for any problem comprises of mainly eight stages [7]. They are listed as follows

- Selection of input layer nodes
- Selection of threshold function
- Configuring hidden layers
- Selection of output layer nodes
- Normalization of input/output parameters
- Presentation of training pairs
- Evaluation of net performance
- Organization of training sets

3.2.1 SELECTION OF INPUT LAYER NODES

By taking possible parameters that may influence the output, we have to configurate the input layer and these parameters vary greatly from problem to problem. The aim of the network is to map an unknown functional relationship between the input and output parameters and the performance of the network is highly sensitive to the input parameters, in addition a proper choice of input parameters may improve the net performance for the unseen problems. When it is possible, the use of binary type of input is recommended instead of normalized continuous valued input because the network is found to have performed extremely well in such a situation.

3.2.2 SELECTION OF THRESHOLD FUNCTION

Intended use of the network and method of learning is the primary criteria in selection of threshold function. For prediction problem the back propagation learning algorithm is used to train the feed forward network, then the sigmoidal non-linear function is normally used. The threshold logic has linearly varying part and the sigmoidal function has low output for the low input and high output for sufficiently high input. The choice of the sigmoidal non-linearity is very common because of two reasons

- it represents the response of actual natural neuron very closely
- it has a very simple derivative which is useful in the development of the training algorithm

3.2.3 CONFIGURING HIDDEN LAYER (S)

Most challenging part in the network development process is the selection of the number of hidden layer(s) and the number of nodes in the hidden layer(s). Unfortunately there is no fixed guidelines available for this purpose and hence this has to be done by the trail and error method. Here at this point, generally the decision about this takes time to train the network. Using a sufficient number of nodes it is proved that any functional relationship can be mapped using a network having a single hidden layer. But the increase in the number of hidden layers may improve the generalization capacity.

3.2.4 SELECTION OF OUTPUT LAYER NODES

One of the most simple tasks in the net development is the selection of the output layer nodes. Generally the number of output parameters is decided automatically by the number of desired output parameters. Often it is required to provide a node for a parameter, which is not desired, to facilitate easy mapping of the functional relationship between the input and the output layer may then be neglected.

3.2.5 NORMALIZATION OF INPUT/OUTPUT PARAMETERS

The output of a typical neural network is either binary type or it ranges between 0 to +1 and –1 to +1. This range is very convenient when simulating on computer i.e. floating-point overflow problems can be avoided. So it is essential to normalize the input /output values to suit the network functioning, of course this will create some problem when extrapolating the output information as the network will always have an upper bound for the values that it could predict due to the normalization factor. When the range of the required value is known in advance we can provide a safe margin. It was found that performance of the network is noticeably good when the normalizing values remain in the range of 0.2 to 0.8. to avoid abrupt higher values of output at the middle of the curve (a small portion), some scalar quantity is used as multiplying factor to flatten a little

$$x = \frac{1}{1+e^{-\alpha(x-\theta)}}$$

where α is slightly higher than 1.

This facilitates the net to respond more precisely when it is pressed into service for a continuous valued input/output pattern.

3.2.6 PRESENTATION OF TRAINING PAIRS

It is found that when each training pair is presented to the net and the error is back propagated until the net learnt that pair. The net takes an unusually long time to converge, but if all the training pairs are presented one after the other until the last pair in the training set, back propagation the error for each pair, then the training time is remarkably reduced. The training time is further reduced if each training pair is presented to the network 10 to 15 times (back propagating the error) before presenting the next pair. This style of feeding to be the most efficient one.

3.2.7 EVALUATION OF THE NET PERFORMANCE

To make sure that the network has learnt the desired function only, it is important to evaluate the performance of the net by submitting it to a number of unseen problems. Basically a neuron computes by classification. Therefore, the network can only try to approximate the desired output values as accurately as possible. Hence a small tolerance limit should be allowed while evaluating the performance of the network. Comparison of the percentage error in the values desired and those the network has predicted may be a better choice. When the network is used for predicting the continuous values of a sensitive parameters, care should be taken to provide enough examples in the training part of the network. Some times other learning algorithms, i.e, conjugate gradient method etc., may help in improving the performance of the neural network

3.2.8 ORGANIZATION OF TRAINING SETS

Training set contains an input and the corresponding desired output vectors for every example. The number of training pairs that should be sufficient for learning a particular process depends on the complexity of the problem, in addition the training algorithm used to train the net influences the organization of the training set.

3.3 FORMULATION, TRAINING, TESTING AND INTERROGATION OF THE NEURAL NETWORK MODELS

In this present work, for studying design pressure pulse and response of the structure, four different Network models are developed. In design pressure pulse, two Network model named Pressure Net and General Net was developed. To study Response of the structure, two Network models named Response Net and Height Net was developed.

Pressure Net contains four input parameters and ten output parameters, it is shown in Figure 3.1. Input parameters are Quantity of charge (Q), Ground zero distance (X_d), Breadth of structure (B) and Length of structure (L) respectively. Output parameters used in Pressure Net are design pressure values and their corresponding time. Five time points are chosen depending on their importance in time history of design pressure pulse and corresponding design pressure values are considered.

General Net contains six input parameters and ten output parameters, it is shown in Figure 3.2. Input parameters are Quantity of charge (Q), Ground zero distance (X_d), Type of structure, Height of structure (H), Breadth of structure (B) and Length of structure (L) respectively. In General Net Diffraction type structures (i.e. open type structures) are also considered. To incorporate type of structure as input 0 is used for open type structures and 1 is used for closed type of structures. Five time points are chosen depending on their importance in time history of design pressure pulse and corresponding design pressure values are considered as output parameters in General Net.

Response Net contains four input parameters and ten output parameters, it is shown in Figure 3.3. Input parameters are Quantity of charge (Q), Ground zero distance (X_d), Breadth of structure (B) and Length of structure (L) respectively. Output parameters used in Response Net are Response of structure and its corresponding time at five points.

Height Net contains five input parameters and ten output parameters, it is shown in Figure 3.4. Input parameters are Quantity of charge (Q), Ground zero distance (X_d), Height of structure(H), Breadth of structure (B) and Length of structure (L) respectively. Output parameters used in Height Net are Response of structure and its corresponding time at five points.

3.3.1 TRAINING

The whole training, testing and interrogating of neural networks was carried in Neural Planner, a software package used to develop and work with neural network models. The output values for training all four network models are obtained from C++ modules developed to calculate output values for the corresponding inputs.

3.3.1.1 PRESSURE NET

Some of the input values used in training Pressure Net is shown in Table 3.1. For Training Pressure Net, four input parameters are used i.e., Q, X_d, B, L and ten output parameters are used i.e., t1, t2, t3, t4, t5 and F0, F1, F2, F3, F4. The output values used for Training Pressure Net for corresponding input values are shown in Table 3.11. .

3.3.1.2 RESPONSE NET

Some of the input values used in training Response Net is shown in Table 3.1. For Training Response Net, four input parameters are used i.e., Q, X_d, B, L and ten output parameters are used i.e., t1, t2, t3, t4, t5 and disp1, disp2, disp3, disp4, disp5. The output values used for Training Response Net for corresponding input values are shown in Table 3.12.

3.3.1.3 GENERAL NET

Some of the input values used in training General Net is shown in Table 3.2. For Training General Net, six input parameters are used i.e., Q, X_d, Type of Structure, H, B, L and ten output parameters are used i.e., t1, t2, t3, t4, t5 and F0, F1, F2, F3, F4. The output values used for Training General Net for corresponding input values are shown in Table 3.13.

3.3.1.4 HEIGHT NET

Some of the input values used in training Height Net is shown in Table 3.4. For Training Height Net, five input parameters are used i.e., Q, X_d, H, B, L and ten output parameters are used i.e., t1, t2, t3, t4, t5 and disp1, disp2, disp3, disp4 and disp5 respectively. The output values used for Training Height Net for corresponding input values are shown in Table 3.14.

3.3.2 TESTING THE NEURAL NETWORK MODELS

In this present study, for testing Pressure Net and Response Net 32 input pairs was considered. Testing input pairs for both Pressure Net and Response Net is given in Table 3.4. Output values used for corresponding inputs for testing Pressure Net is shown in Table 3.15 and for Response Net is given in Table 3.16.

For testing General Net 21 input pairs are considered and their corresponding output values was tested with General Net. Input pairs are shown in Table 3.5 and corresponding output pairs used for testing General Net is given in Table 3.17. For testing Height Net 20 input pairs are considered and their corresponding output values was tested with Height Net. Input pairs are shown in Table 3.6 and corresponding output pairs used for testing Height Net is given in Table 3.18.

3.3.3 INTERROGATING THE NEURAL NETWORK MODELS

The purpose of training and testing the Network model is to make use of the interrogating facility of network, through with we can deduce or get output values for the corresponding input pairs used interrogating. In this present study, all four networks developed are interrogated with sufficient number of interrogating input pairs.

Pressure Net has been interrogated with 7 input cases, they are listed in Table 3.7 and corresponding output's obtained through interrogation of Pressure Net is shown in Table 3.19. Response Net has been interrogated with 12 input cases, those are listed in Table 3.8 and corresponding output's obtained through interrogation of Response Net is shown in Table 3.20. General Net has been interrogated with 18 input cases, those are listed in Table 3.9 and corresponding output's obtained through interrogation of Pressure Net is shown in Table 3.21. Height Net has been interrogated with 18 input cases, those are listed in Table 3.10 and corresponding output's obtained through interrogation of Pressure Net is shown in Table 3.22.

NUMERICAL STUDIES

4.1 COMPARISON OF THE RESULTS

In this present study, all four nets have been interrogated for different set of input cases. The output's obtained from four network models i.e., Pressure Net, Response Net, General Net and Height Net are compared with the outputs obtained through conventional approach and listed for comparison. The comparison of outputs with conventional approach for Pressure Net is given in Table 4.1. The comparison of outputs with conventional approach for Response Net is given in Table 4.2. The comparison of outputs with conventional approach for General Net is given in Table 4.3. The comparison of outputs with conventional approach for Height Net is given in Table 4.4.

4.2 PARAMETRIC STUDY

In this present study, analysis was carried out from output's obtained from all four nets i.e., Pressure Net, Response Net, General Net and Height Net. In analysis three aspects are considered, those are Design Pressure, Response of Structure and Type of Structure.

4.2.1 DESIGN PRESSURE

In analysis of Design Pressure seven aspects are considered, those are based on variation of quantity of charge of explosion, distance from explosion, type of structure, alignement, length ratio, breadth ratio and length and breadth rario's. The values obtained from Pressure Net & General Net for parametric study of design pressure is given in Table 4.5 & Table 4.7.

The variation of Design Pressure obtained from Pressure Net was studied on a structure of 10m x 5m x 3.5m (B,L,H) against 0.5 MT, 1.0 MT, 1.5 MT and 2.0 MT quantity of charge at 4 km distance from the structure. The variation of design pressure for various quantities of charge is shown in Figure 4.1. From the nature of design pressure curve (Figure 4.1), we can conclude that the magnitude of design pressure is much dependent on quantity of charge and rate of decay is more or less same for any quantity of charge in time.

The variation of Design Pressure obtained from Pressure Net was studied on a structure of 10m x 5m x 3.5m (B,L,H) with 1.0 MT against ground zero distances of 2.0 km, 3.0 km, 4 km and 5.0 km. The variation of design pressure is shown in Figure 4.2. From the nature of design pressure curve (Figure 4.2), we can conclude that, it is the distance of structure from blast site which determines the decay rate of design pressure pulse. If the distance of structure is more from blast site, the decay rate of design pressure is slow.

The variation of Design Pressure obtained from General Net was studied on different types of structures i.e., diffraction type and drag type structures. A structure of 5m x 10m x 3m (B,L,H) was considered against a charge of 0.5 MT at 2.0 km for both type of structures and the variation of design pressure is shown in Figure 4.5. From the nature of design pressure curve (Figure 4.5), we can conclude that, the type of structure is main governing criteria in design pressure pulse estimation. We can say that the Drag type of structures will experience very less design pressure and its duration when compared to Diffraction type of structures.

The design Pressure obtained from Pressure Net was studied on structure alignement of 10m x 15m (B,L) and 15m x10m (B,L) for 0.5 MT charge and at 2.0 km from blast site. The variation of design pressure pulse is shown in figure 4.7. We can conclude that the large dimension of structure facing blast wave experiances faster decay of design pressure pulse with respect to time.

The design pressure obtained from Pressure Net was studied on structure with varying lengths, it is found that structure with small length will experience rapid decay of design pressure pulse when compared to structure with large dimension of length. The comparison of design pressure for length ratio of ½ and 1/3 are shown in figure 4.8 and 4.9 respectively.

The design pressure obtained from Pressure Net was studied on structure with varying breadths, it is found that structure with small breadth will experience rapid decay of design pressure pulse when compared to structure with large dimension of breadth. The comparison of design pressure for breadth ratio of ½ and 1/3 are shown in figure 4.10 and 4.11 respectively.

The design pressure obtained from Pressure Net was studied on structure with same B/L ratio, it is found that structure with small individual dimensions will experience rapid decay of design pressure pulse when compared to structure with large dimension of breadth. The comparison of design pressure for same B/L ratio, with different individual dimensions is shown in figure 4.12.

4.2.2 RESPONSE OF STRUCTURE

In analysis of Response of structure seven aspects are considered, those are based on variation of quantity of charge of explosion, distance from explosion, Height of structure, alignement, length ratio, breadth ratio and length and breadth rario's. The values obtained from Response Net & Height Net for parametric study of Response of structure is given in Table 4.6 & Table 4.8.

The variation of Response of structure obtained from Response Net was studied on a structure of 15m x 20m x 3.5m (B,L,H) against 0.5 MT, 1.0 MT, 1.5 MT and 2.0 MT quantity of charge at 3 km distance from the structure. The variation of Response of structure for various quantities of charge is shown in Figure 4.3. From the variation of response of structure with respect to quantity of charge we can conclude that, when quantity of charge is more the displacement of structure is also more., but the nature of response of structure is same.

The variation of Response of structure obtained from Response Net was studied on a structure of 15m x 20m x 3.5m (B,L,H) with 0.5MT against ground zero distances of 2.0 km, 3.0 km, 4 km and 5.0 km. The variation of Response of structure is shown in Figure 4.4. From the variation of response with respect to ground zero distance of structure from blast site, we can conclude that, when distance of structure from blast site increases, the response of structure decreases.

The variation of Response of structure obtained from Height Net was studied on a structure of 5m x 10m (B,L) with 0.5MT at 2.0 km against 3.0

m, 4.0m and 5.0m height of structure. The variation of Response of structure is shown in Figure 4.6. From the variation of response of structure with respect to height of structure, we can conclude that, when height of structure increases, there response of structure also increases.

The Response of structure obtained from Response Net was studied on structure alignement of 10m x 15m (B,L) and 15m x10m (B,L) for 0.5 MT charge and at 2.0 km from blast site. The variation of response of structure is shown in figure 4.13. From the graph we can conclude that the large dimension of structure facing blast wave will experience more response than that of small dimension facing the blast wave.

The response obtained from Response Net was studied on structure with varying lengths, it is found that structure with small length will experience more response when compared to structure with large dimension of length. The comparison of design pressure for length ratio of ½ is shown in figure 4.14.

The response of structure obtained from Response was studied on structure with varying breadths, it is found that structure with small breadth will experience more response when compared to structure with large dimension of breadth when compared to structure with large dimension of breadth. The comparison of response for breadth ratio of ½ is shown in figure 4.15.

The response of structure obtained from Response Net was studied on structure with same B/L ratio, it is found that structure with small individual dimensions will experience more response when compared to structure with large dimension of breadth and length. The comparison of response of structure for same B/L ratio, with different individual dimensions is shown in figure 4.16.

4.3 OBSERVATIONS

In this present study, analysis is carried out for various governing aspects of structure, on which the Design Pressure and Response of Structure depends. Type of Structure is taken care in General Net, such that we can see the design parameters for both Drag type and Diffraction type structures. It is observed that the General Net performed successfully for both Drag type and Diffraction type structures. The problem cases are treated with different cases and varying Charge of explosive, Ground zero distance, Height of structure, Structural configuration. Circular shaped structures in plan are also considered for all four nets developed i.e., Pressure Net, Response Net, General Net and Height Net. It is observed that the four neural networks (i.e., Pressure Net, Response Net, General Net and Height Net) performed successfully

4.4 DISCUSSIONS

The performance of a Neural Network mainly depends on how it has been trained i.e., the number of inputs and their individual as well as combinational influence on the output and combination of inputs such that we can cover wide range of inputs. After examining the four networks developed (i.e., Pressure Net, Response Net, General Net and Height Net) in this present study, we can say that the performance of Neural Networks in Blast Loading on Structures, leads to the observation that Neural Networks perform successfully.

CONCLUSIONS

On the basis of Numerical studies carried out and results obtained from four network models, as discussed in the foregoing chapters, it can be concluded as follows

1. The results obtained from all four network models are very much in agreement with the results as obtained from conventional method of analysis, hence it can be concluded as Artificial Neural Networks can be augment/replace conventional method of analysis
2. Output values obtained from Pressure Net are consistently above 97% and General Net outputs are also consistently above 97% acuarracy. From obtained results we can conclude that
    - When quantity of charge increases the magnitude of design pressure also increases.
    - When distance of structure from blast site increases the rate of decay of design pressure pulse is decreasing
    - For Open type of structures, the design pressure pulse will be, of very small duration when compared to closed type of structures and its magnitude is also less.
    - When large dimension of structure is facing the wave front, the rate of decay of design pressure pulse will be more.
    - When B/L ratio of structure is same, the structures with small individual dimensions experience faster decay of design pressure pulse.

3. Output values obtained from Response Net are consistently above 97% and Height Net outputs are also consistently above 97% acuarracy. From obtained results we can conclude that
    - When quantity of charge increases the magnitude of response also increases.
    - When distance of structure from blast site increases the magnitude of response is decreasing
    - When large dimension of structure is facing the wave front, the magnitude of response of structure will be more.
    - When B/L ratio of structure is same, the structures with small individual dimensions experience more response.
4. The parametric study results concludes that the solutions follow trends consistent with that of theory/practice in both Design Pressure and Response of structure aspect.
5. On the basis of the performance of Neural Networks in Blast Loading on Structures, finally it can be concluded as the Neural Networks offer immense possibilities in future.

SCOPE FOR FURTHER STUDIES

In this present study, theoretically generated data is used for the analysis, but it is suggested that field/experimental data for training the Neural Network should be used for more realistic training patterns and hence more realistic solutions.

In this present study, we limited the analysis to small single degree of freedom systems. We can extend the same approach to more complex and Multiple degree of freedom systems also.

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TABLE 2.1 DRAG COEFFICIENT C_d

(*Clause* 6.2.1.1)

Sl No.	Shape of Element	Drag Coefficient C_d	Remarks
(1)	(2)	(3)	(4)
For Closed Rectangular Structures			
i)	Front vertical face	1·0	For above ground structures
ii)	Roof, rear and side faces for		
	$q_o = 0$ to 1·8 kg/cm^2	−0·4	
	$q_o = 1{\cdot}8$ to 3·5 kg/cm^2	−0·3	
	$q_o = 3{\cdot}5$ to 9·0 kg/cm^2	−0·2	
iii)	Front face sloping		
	4 to 1	Zero	For semi-buried structures
	1½ to 1	0·4	
For Open, Drag Type Structures			
iv)	Sphere	0·1	—
v)	Cylinder	1·2	This covers steel tubes used as columns, truss members, etc
vi)	Structural shapes	2·0	This covers flats, angles, tees, I sections, etc
vii)	Rectangular projection	1·3	This covers beam projections below or above slabs, cantilever walls standing freely above ground, etc

TABLE 2.2 BLAST PARAMETERS FROM GROUND BURST OF 1 TONNE EXPLOSIVE

(*Clause* 5.1)

DISTANCE, m x	PEAK SIDE ON OVER-PRESSURE RATIO p_{so}/p_a	MACH No. M	POSITIVE PHASE DURATION t_o, milli-secs	DURATION OF EQUIVALENT TRIANGULAR PULSE t_d, milli-secs	DYNAMIC PRESSURE RATIO q_o/p_a	PEAK RE-FLECTED OVERPRES-SURE RATIO p_{ro}/p_a
(1)	(2)	(3)	(4)	(5)	(6)	(7)
15	8·00	2·80	9·50	5·39	10·667	41·60
18	5·00	2·30	11·00	7·18	5·208	22·50
21	3·30	1·96	16·38	9·33	2·643	12·94
24	2·40	1·75	18·65	11·22	1·532	8·48
27	1·80	1·60	20·92	13·30	0·920	5·81
30	1·40	1·48	22·93	15·39	0·583	4·20
33	1·20	1·42	24·95	16·31	0·439	3·45
36	1·00	1·36	26·71	17·94	0·312	2·75
39	0·86	1·32	28·22	19·20	0·235	2·28
42	0·76	1·28	29·74	20·20	0·186	1·97
45	0·66	1·25	31·25	21·60	0·142	1·66
48	0·59	1·23	32·26	22·70	0·115	1·46
51	0·53	1·20	33·52	23·70	0·093	1·28
54	0·48	1·19	34·52	24·70	0·077	1·14
57	0·43	1·17	35·53	26·40	0·062	1·01
60	0·40	1·16	36·29	26·60	0·054	0·93
63	0·37	1·15	57·30	27·80	0·046	0·85
66	0·34	1·14	38·05	28·76	0·039	0·77
69	0·32	1·13	38·81	29·25	0·035	0·72
72	0·30	1·12	39·56	29·87	0·031	0·67
75	0·28	1·11	40·32	30·71	0·027	0·62
78	0·26	1·104	40·82	31·85	0·023	0·58
81	0·25	1·100	41·58	31·92	0·022	0·55
84	0·24	1·098	42·34	32·00	0·020	0·53
87	0·23	1·095	42·84	32·26	0·018	0·50
90	0·22	1·086	43·60	33·39	0·016	0·47
93	0·20	1·082	44·35	34·70	0·014	0·43
96	0·19	1·077	45·46	35·37	0·013	0·41
99	0·18	1·072	45·61	36·22	0·012	0·40

NOTE 1 — The value of p_a the ambient air pressure may be taken as 1 kg/cm^2 at mean sea level.

NOTE 2 — One tonne of explosive referred to in this table is equivalent to $1·5 \times 10^9$ calories.

NOTE 3 — Velocity of sound in m/s may be taken ($331·5 + 0·607\ T$) where T is the ambient temperature in centigrade.

Special cases

(1) Average acceleration method ($\gamma = \frac{1}{2}$, $\beta = \frac{1}{4}$)
(2) Linear acceleration method ($\gamma = \frac{1}{2}$, $\beta = \frac{1}{6}$)

1.0 *Initial calculations*

1.1 $\ddot{u}_0 = \dfrac{p_0 - c\dot{u}_0 - ku_0}{m}$.

1.2 Select Δt.

1.3 $\hat{k} = k + \dfrac{\gamma}{\beta\,\Delta t}c + \dfrac{1}{\beta(\Delta t)^2}m$.

1.4 $a = \dfrac{1}{\beta\,\Delta t}m + \dfrac{\gamma}{\beta}c$; and $b = \dfrac{1}{2\beta}m + \Delta t\left(\dfrac{\gamma}{2\beta} - 1\right)c$.

2.0 *Calculations for each time step, i*

2.1 $\Delta\hat{p}_i = \Delta p_i + a\dot{u}_i + b\ddot{u}_i$.

2.2 $\Delta u_i = \dfrac{\Delta\hat{p}_i}{\hat{k}}$.

2.3 $\Delta\dot{u}_i = \dfrac{\gamma}{\beta\,\Delta t}\Delta u_i - \dfrac{\gamma}{\beta}\dot{u}_i + \Delta t\left(1 - \dfrac{\gamma}{2\beta}\right)\ddot{u}_i$.

2.4 $\Delta\ddot{u}_i = \dfrac{1}{\beta(\Delta t)^2}\Delta u_i - \dfrac{1}{\beta\Delta t}\dot{u}_i - \dfrac{1}{2\beta}\ddot{u}_i$.

2.5 $u_{i+1} = u_i + \Delta u_i$, $\dot{u}_{i+1} = \dot{u}_i + \Delta\dot{u}_i$, $\ddot{u}_{i+1} = \ddot{u}_i + \Delta\ddot{u}_i$.

3.0 *Repetition for the next time step.* Replace i by $i + 1$ and implement steps 2.1 to 2.5 for the next time step.

Table 2.3 Newmark's Method

Table 3.1 Input values used for Training Pressure Net & Response Net

[LABEL]	[Q]	[Xd]	[B]	[L]
[example1]	0.5	2	5	5
[example2]	0.5	2	5	10
[example3]	0.5	2	10	5
[example4]	0.5	2	15	5
[example5]	0.5	2	15	10
[example6]	0.5	2	20	10
[example7]	0.5	2	20	20
[example8]	0.5	3	5	5
[example9]	0.5	3	5	10
[example10]	0.5	3	10	5
[example11]	0.5	3	10	10
[example12]	0.5	3	15	10
[example13]	0.5	3	15	20
[example14]	0.5	3	20	20
[example15]	0.5	4	5	5
[example16]	0.5	4	10	5
[example17]	0.5	4	10	10
[example18]	0.5	4	15	5
[example19]	0.5	4	15	10
[example20]	0.5	4	20	10
[example21]	0.5	4	20	20
[example22]	0.5	5	5	5
[example23]	0.5	5	5	10
[example24]	0.5	5	10	10
[example25]	0.5	5	10	20
[example26]	0.5	5	15	10
[example27]	0.5	5	15	20
[example28]	0.5	5	20	10
[example29]	0.5	5	20	20
[example30]	1	2	5	5

Table 3.2 Input values used for training General Net

[[LABELS]	[Q] in MT	[Xd] in km	[Type]	[H] in m	[B] in m	[L] in m
[example1]	0.5	2	1	3	5	5
[example2]	0.5	2	1	3	5	10
[example3]	0.5	2	1	3	10	5
[example4]	0.5	2	1	3	10	10
[example5]	0.5	2	1	4	5	5
[example6]	0.5	2	1	4	5	10
[example7]	0.5	2	1	4	10	5
[example8]	0.5	2	1	4	10	10
[example9]	0.5	2	1	5	5	5
[example10]	0.5	2	1	5	5	10
[example11]	0.5	2	1	5	10	5
[example12]	0.5	2	1	5	10	10
[example13]	0.5	2	0	3	5	5
[example14]	0.5	2	0	3	5	10
[example15]	0.5	2	0	3	10	5
[example16]	0.5	2	0	3	10	10
[example17]	0.5	2	0	4	5	5
[example18]	0.5	2	0	4	5	10
[example19]	0.5	2	0	4	10	5
[example20]	0.5	2	0	4	10	10
[example21]	0.5	2	0	5	5	5
[example22]	0.5	2	0	5	5	10
[example23]	0.5	2	0	5	10	5
[example24]	0.5	2	0	5	10	10
[example25]	0.5	3	1	3	5	5
[example26]	0.5	3	1	3	5	10
[example27]	0.5	3	1	3	10	5
[example28]	0.5	3	1	3	10	10
[example29]	0.5	3	1	4	5	5
[example30]	0.5	3	1	4	5	10

Table 3.3 Input values used for Training Height Net

[[LABELS]	[Q] in MT	[Xd] in km	[H] in m	[B] in m	[L] in m
EXAMPLE[1]	0.5	2	3	5	5
EXAMPLE[2]	0.5	2	3	5	10
EXAMPLE[3]	0.5	2	3	10	5
EXAMPLE[4]	0.5	2	3	10	10
EXAMPLE[5]	0.5	2	4	5	5
EXAMPLE[6]	0.5	2	4	5	10
EXAMPLE[7]	0.5	2	4	10	5
EXAMPLE[8]	0.5	2	4	10	10
EXAMPLE[9]	0.5	2	5	5	5
EXAMPLE[10]	0.5	2	5	5	10
EXAMPLE[11]	0.5	2	5	10	5
EXAMPLE[12]	0.5	2	5	10	10
EXAMPLE[13]	0.5	3	3	5	5
EXAMPLE[14]	0.5	3	3	5	10
EXAMPLE[15]	0.5	3	3	10	5
EXAMPLE[16]	0.5	3	3	10	10
EXAMPLE[17]	0.5	3	4	5	5
EXAMPLE[18]	0.5	3	4	5	10
EXAMPLE[19]	0.5	3	4	10	5
EXAMPLE[20]	0.5	3	4	10	10
EXAMPLE[21]	0.5	3	5	5	5
EXAMPLE[22]	0.5	3	5	5	10
EXAMPLE[23]	0.5	3	5	10	5
EXAMPLE[24]	0.5	3	5	10	10
EXAMPLE[25]	0.5	4	3	5	5
EXAMPLE[26]	0.5	4	3	5	10
EXAMPLE[27]	0.5	4	3	10	5
EXAMPLE[28]	0.5	4	3	10	10
EXAMPLE[29]	0.5	4	4	5	5
EXAMPLE[30]	0.5	4	4	5	10

Table 3.4 Input values used for Testing Pressure Net & Response Net

[LABELS]	[Q] in MT	[Xd] in km	[B] in m	[L] in m
[example1]	0.5	2	10	5
[example2]	0.5	2	15	5
[example3]	0.5	3	10	5
[example4]	0.5	3	15	10
[example5]	0.5	4	10	5
[example6]	0.5	4	15	10
[example7]	0.5	5	10	5
[example8]	0.5	5	15	10
[example9]	1	2	10	5
[example10]	1	2	15	10
[example11]	1	3	10	5
[example12]	1	3	15	10
[example13]	1	4	10	5
[example14]	1	4	15	10
[example15]	1	5	10	5
[example16]	1	5	15	10
[example17]	1.5	2	10	5
[example18]	1.5	2	15	10
[example19]	1.5	3	10	5
[example20]	1.5	3	15	10
[example21]	1.5	4	10	5
[example22]	1.5	4	15	10
[example23]	1.5	5	10	5
[example24]	1.5	5	15	10
[example25]	2	2	10	5
[example26]	2	2	15	10
[example27]	2	3	10	5
[example28]	2	3	15	10
[example29]	2	4	10	5
[example30]	2	4	15	10
[example31]	2	5	10	5
[example32]	2	5	15	10

Table 3.5 Input values used for Testing General Net

[LABELS]	[Q] in MT	[Xd] in km	[Type]	[H] in m	[B] in m	[L] in m
[example1]	0.5	2	1	3	10	5
[example2]	0.5	2	0	3.5	9	5
[example3]	0.5	3	1	4	10	10
[example4]	0.5	4	0	3	10	6.5
[example5]	0.5	4	1	5	7.5	10
[example6]	0.5	3	0	4	5	5
[example7]	0.5	4	1	4.5	9	10
[example8]	1	2	0	3	10	5
[example9]	1	3	1	4	10	5
[example10]	1	3	0	4.5	10	10
[example11]	1	3	1	3	10	6.5
[example12]	1	4	0	3.5	5	10
[example13]	1	4	1	4	10	5
[example14]	1	4	0	5	10	7
[example15]	0.8	2	1	3	7.5	5
[example16]	0.6	2	1	3.5	10	8
[example17]	0.7	3	0	4	10	5
[example18]	1	4	0	3	10	5
[example19]	0.6	4	0	4	10	5

Table 3.6 Input values used for Testing Height Net

[LABELS]	[Q] in MT	[Xd] in km	[H] in m	[B] in m	[L] in m
EXAMPLE[1]	0.5	2	3	10	5
EXAMPLE[2]	0.5	3	3.5	10	5
EXAMPLE[3]	0.5	3	4	8	10
EXAMPLE[4]	0.5	3	4.5	10	5
EXAMPLE[5]	0.5	4	5	9	10
EXAMPLE[6]	0.5	4	5	10	5
EXAMPLE[7]	0.5	4	4.5	6	10
EXAMPLE[8]	0.5	2	4	10	5
EXAMPLE[9]	0.5	2	3.5	7	10
EXAMPLE[10]	0.5	3	3	10	5
EXAMPLE[11]	1	4	3	5.5	10
EXAMPLE[12]	1	4	3.5	10	5
EXAMPLE[13]	1	4	4	9	10
EXAMPLE[14]	1	2	4.5	10	5
EXAMPLE[15]	1	2	5	9	10
EXAMPLE[16]	1	3	5	10	5
EXAMPLE[17]	1	3	4.5	7.5	10
EXAMPLE[18]	1	3	4	10	5
EXAMPLE[19]	1	4	3.5	8	10
EXAMPLE[20]	1	4	3	10	5

Table 3.7 Input values used for Interrogating Pressure Net

[LABELS]	[Q] in MT	[Xd] in km	[B] in m	[L] in m
[example1]	2	2	10	10
[example2]	1.5	2	10	10
[example3]	1	2	19	10
[example4]	1.2	2.2	10	9.5
[example5]	1	2	10	10
[example6]	1	2	20	10
[example7]	1.2	2.2	18.5	11

Table 3.8 Input values used for Interrogating Response Net

[LABELS]	[Q] in MT	[Xd] in km	[B] in m	[L] in m
[example1]	2	2	10	10
[example2]	0.6	2.6	11	12
[example3]	1.5	2	10	10
[example4]	1.5	2	10	5
[example5]	1.2	2.2	8	5
[example6]	1.8	3	14	12
[example7]	2	2	10	8
[example8]	1	2	10	10
[example9]	1.5	3	9	6.5
[example10]	1	2	20	10
[example11]	1.2	2.2	18.5	11
[example12]	1.4	2.8	16	10

Table 3.9 Input values used for Interrogating General Net

Case Name	[Q] in MT	[Xd] in km	[type]	[H] in m	[B] in m	[L] in m
example1	0.5	2	1	3	5	10
example2	0.5	2	0	3	5	10
example3	0.5	2	1	4	5	10
example4	0.5	2	0	4	5	10
example5	0.5	2	1	5	5	10
example6	0.5	2	0	5	5	10
example7	0.5	3	1	3	5	10
example8	0.5	3	0	3	5	10
example9	0.5	3	1	4	5	10
example10	0.5	3	0	4	5	10
example11	0.5	3	1	5	5	10
example12	0.5	3	0	5	5	10
example13	0.5	4	1	3	5	10
example14	0.5	4	0	3	5	10
example15	0.5	4	1	4	5	10
example16	0.5	4	0	4	5	10
example17	0.5	4	1	5	5	10
example18	0.5	4	0	5	5	10

Table 3.10 Input values used for Interrogating Height Net

Case Name	Q	Xd	H	B	L
example1	0.5	2	3	5	10
example2	0.5	2	4	5	10
example3	0.5	2	5	5	10
example4	0.5	3	3	5	10
example5	0.5	3	4	5	10
example6	0.5	3	5	5	10
example7	0.5	4	3	5	10
example8	0.5	4	4	5	10
example9	0.5	4	5	5	10
example10	1	2	3	5	10
example11	1	2	4	5	10
example12	1	2	5	5	10
example13	1	3	3	5	10
example14	1	3	4	5	10
example15	1	3	5	5	10
example16	1	4	3	5	10
example17	1	4	4	5	10
example18	1	4	5	5	10

Table 3.11 Output values used for Training Pressure Net

[LABEL]	[t1]	[t2]	[t3]	[t4]	[t5]	[F0]	[F1]	[F2]	[F3]	[F4]
[example1]	0.008983	0.013474	0.026948	1.055622	1.064605	588.553	377.5303	227.2099	89.26561	-1.55161
[example2]	0.013474	0.017965	0.035931	1.055622	1.073587	588.553	272.019	270.8467	86.92095	-3.10322
[example3]	0.008983	0.018864	0.034134	1.055622	1.064605	588.553	437.1526	200.6856	88.63118	-1.55161
[example4]	0.008983	0.018864	0.034134	1.055622	1.064605	588.553	437.1526	200.6856	88.63118	-1.55161
[example5]	0.017965	0.018864	0.043117	1.055622	1.073587	588.553	285.7523	264.2552	86.28652	-3.10322
[example6]	0.017965	0.018864	0.043117	1.055622	1.073587	588.553	285.7523	264.2552	86.28652	-3.10322
[example7]	0.018864	0.035931	0.061083	1.055622	1.091553	588.553	270.6122	266.1574	81.59721	-6.20643
[example8]	0.010888	0.016332	0.032665	1.523905	1.534793	230.964	150.1445	88.26643	22.67287	-0.62245
[example9]	0.016332	0.021776	0.043553	1.523905	1.545681	230.964	109.7347	109.3384	21.88033	-1.2449
[example10]	0.010888	0.022865	0.041375	1.523905	1.534793	230.964	173.0093	75.71896	22.5368	-0.62245
[example11]	0.021776	0.022865	0.052263	1.523905	1.545681	230.964	115.0546	106.2101	21.74426	-1.2449
[example12]	0.021776	0.022865	0.052263	1.523905	1.545681	230.964	115.0546	106.2101	21.74426	-1.2449
[example13]	0.022865	0.043553	0.07404	1.523905	1.567458	230.964	109.2592	107.7533	20.15918	-2.4898
[example14]	0.022865	0.043553	0.07404	1.523905	1.567458	230.964	109.2592	107.7533	20.15918	-2.4898
[example15]	0.011977	0.017966	0.035931	1.88107	1.893047	129.664	84.89278	49.25584	8.89914	-0.34184
[example16]	0.011977	0.025152	0.045513	1.88107	1.893047	129.664	97.56974	41.54999	8.851153	-0.34184
[example17]	0.023954	0.025152	0.05749	1.88107	1.905024	129.664	65.47549	60.38278	8.449326	-0.68369
[example18]	0.011977	0.025152	0.045513	1.88107	1.893047	129.664	97.56974	41.54999	8.851153	-0.34184
[example19]	0.023954	0.025152	0.05749	1.88107	1.905024	129.664	65.47549	60.38278	8.449326	-0.68369
[example20]	0.023954	0.025152	0.05749	1.88107	1.905024	129.664	65.47549	60.38278	8.449326	-0.68369
[example21]	0.025152	0.047908	0.081444	1.88107	1.928978	129.664	62.26606	61.50259	7.645669	-1.36738
[example22]	0.012498	0.018747	0.037493	2.206487	2.218985	86.105	56.55684	32.51867	4.368341	-0.2123
[example23]	0.018747	0.024995	0.049991	2.206487	2.231483	86.105	41.78276	41.66342	4.129652	-0.42459
[example24]	0.024995	0.026245	0.059989	2.206487	2.231483	86.105	43.75695	40.32217	4.108535	-0.42459
[example25]	0.026245	0.049991	0.084985	2.206487	2.256478	86.105	41.63955	41.18604	3.631157	-0.84918
[example26]	0.024995	0.026245	0.059989	2.206487	2.231483	86.105	43.75695	40.32217	4.108535	-0.42459
[example27]	0.026245	0.049991	0.084985	2.206487	2.256478	86.105	41.63955	41.18604	3.631157	-0.84918
[example28]	0.024995	0.026245	0.059989	2.206487	2.231483	86.105	43.75695	40.32217	4.108535	-0.42459
[example29]	0.026245	0.049991	0.084985	2.206487	2.256478	86.105	41.63955	41.18604	3.631157	-0.84918
[example30]	0.007333	0.010999	0.021999	0.933	0.940333	1310.822	833.5597	512.6699	258.7968	-2.62732

Table 3.12 Output values used for Training Response Net

[LABELS]	[t1] in sec	[t2] in sec	[t3] in sec	[t4] in sec	[t5] in sec	[disp1] in m	[disp2] in m	[disp3] in m	[disp4] in m	[disp5] in m
[example1]	0.0135	0.2605	0.5211	1.0556	1.0646	0.0213	0.0629	0.0655	0.1211	0.0992
[example2]	0.0135	0.2605	0.5211	1.0556	1.0736	0.0125	0.0413	0.0475	0.0892	0.0686
[example3]	0.0189	0.2592	0.5184	1.0556	1.0646	0.0327	0.0513	0.0499	0.0741	0.051
[example4]	0.0189	0.2592	0.5184	1.0556	1.0646	0.0231	0.0319	0.0321	0.0445	0.0306
[example5]	0.0189	0.2592	0.5184	1.0556	1.0736	0.0155	0.023	0.0249	0.0366	0.027
[example6]	0.0189	0.2592	0.5184	1.0556	1.0736	0.0113	0.0158	0.0174	0.0246	0.0196
[example7]	0.0189	0.2592	0.5184	1.0556	1.0916	0.0083	0.0118	0.013	0.0186	0.0159
[example8]	0.0163	0.3769	0.7538	1.5239	1.5348	0.0114	0.0273	0.0284	0.0504	0.0381
[example9]	0.0163	0.3769	0.7538	1.5239	1.5457	0.0065	0.0176	0.0205	0.0373	0.0268
[example10]	0.0229	0.3753	0.7505	1.5239	1.5348	0.0154	0.022	0.0218	0.0308	0.0206
[example11]	0.0229	0.3753	0.7505	1.5239	1.5457	0.0093	0.0147	0.016	0.0243	0.0172
[example12]	0.0229	0.3753	0.7505	1.5239	1.5457	0.0066	0.0094	0.0104	0.0149	0.0117
[example13]	0.0229	0.3753	0.7505	1.5239	1.5675	0.0046	0.0066	0.0074	0.0107	0.009
[example14]	0.0229	0.3753	0.7505	1.5239	1.5675	0.0034	0.0047	0.0053	0.0075	0.0066
[example15]	0.018	0.4658	0.9316	1.8811	1.893	0.0074	0.0162	0.0168	0.0292	0.0212
[example16]	0.0252	0.464	0.928	1.8811	1.893	0.0093	0.0129	0.0128	0.0178	0.0118
[example17]	0.0252	0.464	0.928	1.8811	1.905	0.0055	0.0084	0.0093	0.014	0.0101
[example18]	0.0252	0.464	0.928	1.8811	1.893	0.006	0.0077	0.0079	0.0104	0.0074
[example19]	0.0252	0.464	0.928	1.8811	1.905	0.0038	0.0053	0.006	0.0085	0.0068
[example20]	0.0252	0.464	0.928	1.8811	1.905	0.0027	0.0036	0.004	0.0056	0.0048
[example21]	0.0252	0.464	0.928	1.8811	1.929	0.0019	0.0026	0.003	0.0042	0.0038
[example22]	0.0187	0.5469	1.0939	2.2065	2.219	0.0053	0.011	0.0114	0.0196	0.0139
[example23]	0.0187	0.5469	1.0939	2.2065	2.2315	0.0029	0.007	0.0082	0.0146	0.0101
[example24]	0.0262	0.5451	1.0901	2.2065	2.2315	0.0037	0.0057	0.0063	0.0093	0.0069
[example25]	0.0262	0.5451	1.0901	2.2065	2.2565	0.0024	0.0037	0.0042	0.0063	0.005

Table 3.13 Output values used for Training General Net

[LABELS]	[t1] in sec	[t2] in sec	[t3] in sec	[t4] in sec	[t5] in sec	[F0] in kpa	[F1] in kpa	[F2] in kpa	[F3] in kpa	[F4] in kpa
[example1]	0.008983	0.013474	0.026948	1.055622	1.064605	588.553	377.5303	227.2099	89.26561	-1.55161
[example2]	0.013474	0.017965	0.035931	1.055622	1.073587	588.553	272.019	270.8467	86.92095	-3.10322
[example3]	0.008983	0.016169	0.030541	1.055622	1.064605	588.553	412.31	211.777	88.94841	-1.55161
[example4]	0.016169	0.017965	0.039524	1.055622	1.073587	588.553	271.3156	270.8467	86.60375	-3.10322
[example5]	0.008983	0.013474	0.026948	1.055622	1.064605	588.553	377.5303	227.2099	89.26561	-1.55161
[example6]	0.013474	0.017965	0.035931	1.055622	1.073587	588.553	272.019	270.8467	86.92095	-3.10322
[example7]	0.008983	0.021559	0.037728	1.055622	1.064605	588.553	455.7846	192.3075	88.31394	-1.55161
[example8]	0.017965	0.021559	0.04671	1.055622	1.073587	588.553	323.0162	247.737	85.96929	-3.10322
[example9]	0.008983	0.013474	0.026948	1.055622	1.064605	588.553	377.5303	227.2099	89.26561	-1.55161
[example10]	0.013474	0.017965	0.035931	1.055622	1.073587	588.553	272.019	270.8467	86.92095	-3.10322
[example11]	0.008983	0.026948	0.044914	1.055622	1.064605	588.553	481.8694	180.4354	87.67953	-1.55161
[example12]	0.017965	0.026948	0.053896	1.055622	1.073587	588.553	375.1857	224.4687	85.33487	-3.10322
[example13]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example14]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example15]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example16]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example17]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example18]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example19]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example20]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example21]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example22]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example23]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example24]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example25]	0.010888	0.016332	0.032665	1.523905	1.534793	230.964	150.1445	88.26643	22.67287	-0.62245

Table 3.14 Output values used for Training Height Net

[LABELS]	[t1]	[t2]	[t3]	[t4]	[t5]	[disp1]	[disp2]	[disp3]	[disp4]	[disp5]
EXAMPLE[1]	0.013474	0.260537	0.521074	1.055622	1.064605	0.016959	0.041856	0.04292	0.076481	0.058852
EXAMPLE[2]	0.013474	0.260537	0.521074	1.055622	1.073587	0.009904	0.027127	0.030544	0.055583	0.04004
EXAMPLE[3]	0.016169	0.259863	0.519726	1.055622	1.064605	0.018681	0.028605	0.028643	0.042322	0.02813
EXAMPLE[4]	0.016169	0.259863	0.519726	1.055622	1.073587	0.011797	0.019675	0.02134	0.033219	0.023074
EXAMPLE[5]	0.013474	0.260537	0.521074	1.055622	1.064605	0.025587	0.089004	0.09442	0.178995	0.153506
EXAMPLE[6]	0.013474	0.260537	0.521074	1.055622	1.073587	0.014943	0.058914	0.069492	0.133089	0.108261
EXAMPLE[7]	0.021559	0.258516	0.517032	1.055622	1.064605	0.052587	0.084567	0.080237	0.119731	0.08582
EXAMPLE[8]	0.021559	0.258516	0.517032	1.055622	1.073587	0.033924	0.058766	0.06033	0.094323	0.06376
EXAMPLE[9]	0.013474	0.260537	0.521074	1.055622	1.064605	0.03377	0.156589	0.172951	0.336562	0.305972
EXAMPLE[10]	0.013474	0.260537	0.521074	1.055622	1.073587	0.019722	0.105121	0.129703	0.253596	0.222768
EXAMPLE[11]	0.026948	0.257168	0.514337	1.055622	1.064605	0.113843	0.192963	0.175256	0.263425	0.203616
EXAMPLE[12]	0.026948	0.257168	0.514337	1.055622	1.073587	0.076171	0.136434	0.132316	0.206227	0.142992
EXAMPLE[13]	0.016332	0.376893	0.753786	1.523905	1.534793	0.008876	0.018312	0.018838	0.032033	0.022746
EXAMPLE[14]	0.016332	0.376893	0.753786	1.523905	1.545681	0.005027	0.011656	0.01327	0.023331	0.016011
EXAMPLE[15]	0.019599	0.376077	0.752153	1.523905	1.534793	0.008643	0.012222	0.012418	0.017577	0.011608
EXAMPLE[16]	0.019599	0.376077	0.752153	1.523905	1.545681	0.005249	0.008185	0.009075	0.013737	0.010051
EXAMPLE[17]	0.016332	0.376893	0.753786	1.523905	1.534793	0.013947	0.03825	0.040241	0.073818	0.058867
EXAMPLE[18]	0.016332	0.376893	0.753786	1.523905	1.545681	0.007899	0.025005	0.029606	0.055391	0.041953
EXAMPLE[19]	0.026132	0.374443	0.748887	1.523905	1.534793	0.025045	0.036314	0.035164	0.049883	0.034166
EXAMPLE[20]	0.026132	0.374443	0.748887	1.523905	1.545681	0.015645	0.024668	0.025973	0.039158	0.02669
EXAMPLE[21]	0.016332	0.376893	0.753786	1.523905	1.534793	0.018773	0.066163	0.071732	0.137059	0.117504
EXAMPLE[22]	0.016332	0.376893	0.753786	1.523905	1.545681	0.010633	0.044108	0.054265	0.104784	0.08615
EXAMPLE[23]	0.032665	0.37281	0.74562	1.523905	1.534793	0.055216	0.082609	0.076949	0.109672	0.080035
EXAMPLE[24]	0.032665	0.37281	0.74562	1.523905	1.545681	0.036094	0.057452	0.05731	0.085671	0.057223
EXAMPLE[25]	0.017966	0.465776	0.931552	1.88107	1.893047	0.005689	0.010869	0.01122	0.018605	0.012717

Table 3.15 Output values used for Testing Pressure Net

[LABELS]	[t1] in sec	[t2] in sec	[t3] in sec	[t4] in sec	[t5] in sec	[F0] in kpa	[F1] in kpa	[F2] in kpa	[F3] in kpa	[F4] in kpa
[example1]	0.008983	0.018864	0.034134	1.055622	1.064605	588.553	437.1526	200.6856	88.63118	-1.55161
[example2]	0.008983	0.018864	0.034134	1.055622	1.064605	588.553	437.1526	200.6856	88.63118	-1.55161
[example3]	0.010888	0.022865	0.041375	1.523905	1.534793	230.964	173.0093	75.71896	22.5368	-0.62245
[example4]	0.021776	0.022865	0.052263	1.523905	1.545681	230.964	115.0546	106.2101	21.74426	-1.2449
[example5]	0.011977	0.025152	0.045513	1.88107	1.893047	129.664	97.56974	41.54999	8.851153	-0.34184
[example6]	0.023954	0.025152	0.05749	1.88107	1.905024	129.664	65.47549	60.38278	8.449326	-0.68369
[example7]	0.012498	0.026245	0.047491	2.206487	2.218985	86.105	64.93098	27.1484	4.347225	-0.2123
[example8]	0.024995	0.026245	0.059989	2.206487	2.231483	86.105	43.75695	40.32217	4.108535	-0.42459
[example9]	0.007333	0.015399	0.027865	0.933	0.940333	1310.822	968.5684	463.6518	257.1134	-2.62732
[example10]	0.014666	0.015399	0.035198	0.933	0.947666	1310.822	626.3149	580.4134	252.3818	-5.25465
[example11]	0.009711	0.020393	0.036902	1.539	1.548711	425.46	317.2486	143.4855	56.74715	-0.89488
[example12]	0.019422	0.020393	0.046613	1.539	1.558422	425.46	209.0372	193.2406	55.47961	-1.78976
[example13]	0.011228	0.02358	0.042668	2.02	2.031228	199.561	149.6325	64.93665	18.01593	-0.42795
[example14]	0.022457	0.02358	0.053896	2.02	2.042457	199.561	99.70401	92.00439	17.48325	-0.8559
[example15]	0.011977	0.025152	0.045513	2.37	2.381977	129.664	97.65264	41.6465	8.968699	-0.27132
[example16]	0.023954	0.025152	0.05749	2.37	2.393954	129.664	65.64128	60.54981	8.649768	-0.54264
[example17]	0.006249	0.013123	0.023746	0.821905	0.828154	2279.25	1678.445	822.8149	508.4795	-3.85086
[example18]	0.012498	0.013123	0.029995	0.821905	0.834403	2279.25	1077.641	999.8561	500.6176	-7.70172
[example19]	0.008983	0.018864	0.034134	1.52247	1.531453	588.553	437.8716	201.672	90.03104	-1.07583
[example20]	0.017965	0.018864	0.043117	1.52247	1.540436	588.553	287.1902	265.7175	88.40534	-2.15165
[example21]	0.010568	0.022193	0.040158	2.053617	2.064185	278.575	208.5247	92.24638	30.4664	-0.52129
[example22]	0.021136	0.022193	0.050726	2.053617	2.074753	278.575	138.4744	127.9036	29.78247	-1.04258
[example23]	0.011498	0.024146	0.043692	2.472583	2.484081	168.158	126.3919	54.5256	13.81957	-0.3109
[example24]	0.022996	0.024146	0.05519	2.472583	2.495579	168.158	84.62585	78.09254	13.44178	-0.6218
[example25]	0.006249	0.013123	0.023746	0.904623	0.910872	2279.25	1679.164	823.9373	510.2254	-3.49874

Table 3.16 Output Values used for Testing Response Net

[LABELS]	[t1] in sec	[t2] in sec	[t3] in sec	[t4] in sec	[t5] in sec	[disp1] in m	[disp2] in m	[disp3] in m	[disp4] in m	[disp5] in m
EXAMPLE[1]	0.0189	0.2592	0.5184	1.0556	1.0646	0.0327	0.0513	0.0499	0.0741	0.051
EXAMPLE[2]	0.0189	0.2592	0.5184	1.0556	1.0646	0.0231	0.0319	0.0321	0.0445	0.0306
EXAMPLE[3]	0.0229	0.3753	0.7505	1.5239	1.5348	0.0154	0.022	0.0218	0.0308	0.0206
EXAMPLE[4]	0.0229	0.3753	0.7505	1.5239	1.5457	0.0066	0.0094	0.0104	0.0149	0.0117
EXAMPLE[5]	0.0252	0.464	0.928	1.8811	1.893	0.0093	0.0129	0.0128	0.0178	0.0118
EXAMPLE[6]	0.0252	0.464	0.928	1.8811	1.905	0.0038	0.0053	0.006	0.0085	0.0068
EXAMPLE[7]	0.0262	0.5451	1.0901	2.2065	2.219	0.0064	0.0087	0.0087	0.0119	0.0079
EXAMPLE[8]	0.0262	0.5451	1.0901	2.2065	2.2315	0.0026	0.0036	0.004	0.0057	0.0046
EXAMPLE[9]	0.0154	0.2294	0.4588	0.933	0.9403	0.058	0.1005	0.0978	0.1529	0.1096
EXAMPLE[10]	0.0154	0.2294	0.4588	0.933	0.9477	0.0303	0.0478	0.0511	0.0773	0.0538
EXAMPLE[11]	0.0204	0.3797	0.7593	1.539	1.5487	0.0255	0.0378	0.0376	0.0546	0.0366
EXAMPLE[12]	0.0204	0.3797	0.7593	1.539	1.5584	0.0116	0.0168	0.0184	0.0268	0.0202
EXAMPLE[13]	0.0236	0.4991	0.9982	2.02	2.0312	0.0136	0.0191	0.0191	0.0268	0.0177
EXAMPLE[14]	0.0236	0.4991	0.9982	2.02	2.0425	0.0057	0.0081	0.009	0.0129	0.0102
EXAMPLE[15]	0.0252	0.5862	1.1724	2.37	2.382	0.0093	0.0127	0.0128	0.0177	0.0117
EXAMPLE[16]	0.0252	0.5862	1.1724	2.37	2.394	0.0038	0.0053	0.0059	0.0085	0.0068
EXAMPLE[17]	0.0131	0.2022	0.4044	0.8219	0.8282	0.0824	0.1574	0.1531	0.2497	0.1869
EXAMPLE[18]	0.0131	0.2022	0.4044	0.8219	0.8344	0.0464	0.0777	0.0824	0.128	0.0862
EXAMPLE[19]	0.0189	0.3759	0.7518	1.5225	1.5315	0.0326	0.0499	0.0496	0.0734	0.0497
EXAMPLE[20]	0.0189	0.3759	0.7518	1.5225	1.5404	0.0154	0.0227	0.0248	0.0364	0.0267
EXAMPLE[21]	0.0222	0.5079	1.0157	2.0536	2.0642	0.018	0.0257	0.0258	0.0366	0.0242
EXAMPLE[22]	0.0222	0.5079	1.0157	2.0536	2.0748	0.0078	0.0111	0.0124	0.0178	0.0138
EXAMPLE[23]	0.0241	0.6121	1.2242	2.4726	2.4841	0.0117	0.0162	0.0163	0.0227	0.0149
EXAMPLE[24]	0.0241	0.6121	1.2242	2.4726	2.4956	0.0049	0.0068	0.0076	0.0109	0.0087
EXAMPLE[25]	0.0131	0.2229	0.4457	0.9046	0.9109	0.0824	0.1556	0.1526	0.2488	0.1853

Table 3.17 Output values used for Testing General Net

[LABELS]	[t1]	[t2]	[t3]	[t4]	[t5]	[F0]	[F1]	[F2]	[F3]	[F4]
[example1]	0.008983	0.016169	0.030541	1.055622	1.064605	588.553	412.31	211.777	88.94841	-1.55161
[example2]	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0
[example3]	0.021776	0.026132	0.056619	1.523905	1.545681	230.964	129.3452	98.38065	21.67623	-1.2449
[example4]	0	0.003352	0.006704	0.010056	0.01676	12.24717	9.797735	7.348301	4.898867	0
[example5]	0.023954	0.026948	0.059885	1.88107	1.905024	129.664	69.70114	57.81717	8.437327	-0.68369
[example6]	0	0.002822	0.005644	0.008466	0.01411	30.94715	24.75772	18.56829	12.37886	0
[example7]	0.023954	0.032338	0.067071	1.88107	1.905024	129.664	79.56101	51.82474	8.401342	-0.68369
[example8]	0	0.001638	0.003276	0.004914	0.00819	348.0567	278.4453	208.834	139.2227	0
[example9]	0.009711	0.023307	0.040787	1.539	1.548711	425.46	330.6166	137.0425	56.5981	-0.89488
[example10]	0	0.002293	0.004586	0.006879	0.011465	76.77527	61.42022	46.06516	30.71011	0
[example11]	0.012624	0.01748	0.035931	1.539	1.551624	425.46	261.614	169.498	56.51596	-1.16335
[example12]	0	0.002974	0.005948	0.008922	0.01487	24.49434	19.59547	14.6966	9.797735	0
[example13]	0.011228	0.026948	0.047159	2.02	2.031228	199.561	155.807	61.46827	17.97404	-0.42795
[example14]	0	0.002974	0.005948	0.008922	0.01487	24.49434	19.59547	14.6966	9.797735	0
[example15]	0.008213	0.014783	0.027924	1.041573	1.049785	859.024	599.9319	313.1522	149.1147	-1.917
[example16]	0.01314	0.017247	0.036136	0.946331	0.959472	859.024	502.4742	348.6932	145.8902	-3.37588
[example17]	0	0.002671	0.005342	0.008013	0.013355	41.08728	32.86982	24.65237	16.43491	0
[example18]	0	0.002974	0.005948	0.008922	0.01487	24.49434	19.59547	14.6966	9.797735	0
[example19]	0	0.003226	0.006452	0.009678	0.01613	15.14435	12.11548	9.08661	6.057739	0

Table 3.18 Output values used for Testing Height Net

[LABELS]	[t1] in sec	[t2] in sec	[t3] in sec	[t4] in sec	[t5] in sec	[disp1] in m	[disp2] in m	[disp3] in m	[disp4] in m	[disp5] in m
EXAMPLE[1]	0.016169	0.259863	0.519726	1.055622	1.064605	0.018681	0.028605	0.028643	0.042322	0.02813
EXAMPLE[2]	0.022865	0.37526	0.75052	1.523905	1.534793	0.015382	0.021996	0.021784	0.030845	0.020581
EXAMPLE[3]	0.026132	0.374443	0.748887	1.523905	1.545681	0.017118	0.029233	0.030498	0.047696	0.031989
EXAMPLE[4]	0.029398	0.373627	0.747253	1.523905	1.534793	0.038156	0.05618	0.053306	0.075799	0.053584
EXAMPLE[5]	0.032338	0.462183	0.924366	1.88107	1.905024	0.020101	0.033261	0.033977	0.052253	0.034562
EXAMPLE[6]	0.035931	0.461285	0.92257	1.88107	1.893047	0.034038	0.04836	0.045598	0.063292	0.045087
EXAMPLE[7]	0.021559	0.464878	0.929756	1.88107	1.905024	0.008586	0.021555	0.024753	0.044306	0.032174
EXAMPLE[8]	0.021559	0.258516	0.517032	1.055622	1.064605	0.052587	0.084567	0.080237	0.119731	0.08582
EXAMPLE[9]	0.018864	0.259189	0.518379	1.055622	1.073587	0.022382	0.045532	0.048064	0.08027	0.055733
EXAMPLE[10]	0.019599	0.376077	0.752153	1.523905	1.534793	0.008643	0.012222	0.012418	0.017577	0.011608
EXAMPLE[11]	0.018527	0.500368	1.000736	2.02	2.042457	0.005182	0.010336	0.01171	0.019735	0.013229
EXAMPLE[12]	0.02358	0.499105	0.99821	2.02	2.031228	0.013645	0.019076	0.019086	0.026774	0.017696
EXAMPLE[13]	0.026948	0.498263	0.996526	2.02	2.042457	0.014581	0.023181	0.024619	0.037466	0.02505
EXAMPLE[14]	0.019799	0.2283	0.456601	0.933	0.940333	0.137522	0.255144	0.236236	0.374287	0.293055
EXAMPLE[15]	0.019799	0.2283	0.456601	0.933	0.947666	0.113629	0.263891	0.260184	0.445821	0.334215
EXAMPLE[16]	0.029133	0.377467	0.754933	1.539	1.548711	0.089779	0.140467	0.131343	0.193131	0.143676
EXAMPLE[17]	0.02185	0.379288	0.758575	1.539	1.558422	0.03232	0.068725	0.073188	0.124807	0.087155
EXAMPLE[18]	0.023307	0.378923	0.757847	1.539	1.548711	0.041182	0.062172	0.060394	0.088128	0.061187
EXAMPLE[19]	0.02358	0.499105	0.99821	2.02	2.042457	0.009148	0.01524	0.016712	0.026126	0.017829
EXAMPLE[20]	0.020211	0.499947	0.999894	2.02	2.031228	0.00765	0.010618	0.010873	0.015263	0.010041

Table 3.19 Output values obtained from Interrogating Pressure Net

[LABEL]	[t1] in sec	[t2] in sec	[t3] in sec	[t4] in sec	[t5] in sec
example1	0.0124	0.0131	0.0299	0.9	0.917
example2	0.0125	0.0131	0.0299	0.822	0.834
example3	0.0147	0.0154	0.0352	0.933	0.947
example4	0.0139	0.0154	0.0345	0.992	1.005
example5	0.0146	0.0154	0.0351	0.933	0.948
example6	0.0147	0.0154	0.0352	0.933	0.948
example7	0.0154	0.0161	0.0366	0.992	1.007

[F0] in kpa	[F1] in kpa	[F2] in kpa	[F3] in kpa	[F4] in kpa
2279.25	1079.07	1001.33	503.08	-7
2279.25	1077.64	999.85	500.61	-7.7
1310.82	626.31	580.41	252.38	-5.2
1310.82	661.07	569.29	253.73	-4.6
1310.82	626.31	580.41	252.38	-5.2
1310.82	626.31	580.41	252.38	-5.2
1310.82	592.67	592.23	252.39	-5.4

Table 3.20 Output values obtained from Interrogating Response Net

[LABEL]	t1] in sec	[t2] in sec	[t3] in sec	[t4] in sec	[t5] in sec	[disp1] in m	[disp2] in m	[disp3] in m	[disp4] in m	[disp5] in m
example1	0.0127	0.217	0.433	0.882	0.888	0.05703	0.1144	0.121817	0.203022	0.140521
example2	0.0213	0.33	0.661	1.341	1.368	0.011418	0.017336	0.019095	0.027752	0.019839
example3	0.0129	0.217	0.434	0.883	0.889	0.05462	0.107588	0.113294	0.190165	0.137849
example4	0.0129	0.217	0.434	0.882	0.887	0.075006	0.146444	0.146301	0.241056	0.198883
example5	0.0141	0.236	0.473	0.96	0.966	0.055816	0.115229	0.116962	0.192212	0.162331
example6	0.0182	0.364	0.727	1.477	1.498	0.016652	0.022809	0.025641	0.038035	0.025701
example7	0.0127	0.217	0.434	0.882	0.888	0.064477	0.127731	0.133301	0.220813	0.160049
example8	0.0148	0.228	0.455	0.926	0.935	0.039304	0.071544	0.07555	0.122022	0.08774
example9	0.0185	0.379	0.757	1.535	1.543	0.027923	0.044865	0.047338	0.072933	0.054805
example10	0.0148	0.227	0.454	0.925	0.934	0.023962	0.035154	0.037814	0.054738	0.042055
example11	0.0148	0.236	0.471	0.959	0.969	0.023777	0.034605	0.037488	0.055063	0.04184
example12	0.0179	0.332	0.665	1.348	1.367	0.015849	0.021654	0.023903	0.034734	0.025833

Table 3.21 Output values obtained from Interrogating General Net

Case name	[t1] in sec	[t2] in sec	[t3] in sec	[t4] in sec	[t5] in sec	[F0] in kpa	[F1] in kpa	[F2] in kpa	[F3] in kpa	[F4] in kpa
Example1	0.013398	0.015758	0.035106	1.05192	1.07156	593.245	292.153	249.835	79.2878	-3.01427
Example2	2.76E-05	0.002178	0.004808	0.00522	0.008482	122.091	95.8449	73.6	47.3027	-5.26E-05
Example3	0.013939	0.015988	0.035902	1.05317	1.07326	597.197	292.845	253.315	80.4792	-3.02897
Example4	2.76E-05	0.002173	0.0048	0.005218	0.00848	122.224	96.3487	73.7228	47.4319	-5.26E-05
Example5	0.014523	0.016229	0.036768	1.05413	1.07511	600.989	293.84	257.044	81.7481	-3.04912
Example6	2.75E-05	0.002171	0.004797	0.005216	0.008478	122.459	96.6846	73.8636	47.5653	-5.26E-05
Example7	0.016245	0.019559	0.042289	1.52445	1.54723	231.451	127.852	94.9764	24.4588	-1.05033
Example8	3.23E-05	0.002729	0.005477	0.008654	0.011799	13.6408	11.9383	17.0889	5.88907	-5.26E-05
Example9	0.016823	0.019875	0.043269	1.52593	1.54886	232.631	126.991	97.2964	24.8011	-1.08158
Example10	3.22E-05	0.002703	0.00545	0.008675	0.01184	13.7636	12.1224	17.3876	5.9605	-5.26E-05
Example11	0.017426	0.020225	0.044339	1.52735	1.55054	233.762	126.127	99.8198	25.1697	-1.1169
Example12	3.21E-05	0.002685	0.005432	0.0087	0.01188	13.8991	12.312	17.6981	6.03672	-5.26E-05
Example13	0.018301	0.022407	0.047684	1.8722	1.90072	119.617	65.777	50.0569	11.7679	-0.63113
Example14	4.91E-05	0.003153	0.006137	0.007968	0.010955	12.2682	11.9003	8.26873	5.21539	-5.26E-05
Example15	0.018876	0.022797	0.048814	1.87234	1.90081	119.813	64.9023	51.307	11.8687	-0.65336
Example16	4.89E-05	0.003122	0.006102	0.007961	0.010963	12.2681	11.9298	8.26832	5.21612	-5.26E-05
Example17	0.019452	0.023229	0.05003	1.87247	1.90089	120.011	63.9967	52.6847	11.9793	-0.6783
Example18	4.88E-05	0.003109	0.006087	0.007961	0.010969	12.2681	11.9469	8.26874	5.21698	-5.26E-05

Table 3.22 Output values obtained from Interrogating Height Net

Case Name	[t1] in sec	[t2] in sec	[t3] in sec	[t4] in sec	[t5] in sec	[disp1] in m	[disp2] in m	[disp3] in m	[disp4] in m	[disp5] in m
example1	0.013973	0.260482	0.521918	1.0569	1.07154	0.013574	0.035536	0.039089	0.070183	0.050262
example2	0.013522	0.259967	0.520638	1.05587	1.0682	0.017699	0.063495	0.070264	0.136733	0.104414
example3	0.013189	0.259571	0.519236	1.05717	1.06422	0.02115	0.106774	0.123742	0.2501	0.211241
example4	0.016309	0.377076	0.752392	1.52234	1.54374	0.008334	0.015922	0.017997	0.02841	0.020972
example5	0.016187	0.377324	0.752929	1.52332	1.5468	0.011452	0.028763	0.031374	0.054819	0.040763
example6	0.016208	0.377856	0.754057	1.52616	1.55052	0.015556	0.050596	0.053542	0.102308	0.077149
example7	0.01719	0.465901	0.930592	1.88291	1.89817	0.006317	0.010179	0.012071	0.017801	0.013507
example8	0.017532	0.465685	0.929896	1.88265	1.89808	0.008078	0.015944	0.018538	0.029281	0.022308
example9	0.018231	0.465613	0.929384	1.88341	1.89858	0.011205	0.029557	0.032964	0.057628	0.043975
example10	0.0115	0.229838	0.460029	0.940341	0.941793	0.018982	0.05674	0.069436	0.132894	0.098523
example11	0.011563	0.229801	0.459837	0.940587	0.941577	0.023424	0.116615	0.147965	0.297452	0.248766
example12	0.01169	0.229767	0.459625	0.940962	0.941282	0.026768	0.212052	0.274782	0.553978	0.484069
example13	0.014673	0.381389	0.764801	1.53792	1.5629	0.011181	0.025552	0.029535	0.050755	0.037366
example14	0.014222	0.380798	0.7636	1.53538	1.55934	0.015502	0.047116	0.053246	0.101371	0.076464
example15	0.013976	0.380669	0.762902	1.53721	1.55625	0.020384	0.080674	0.090817	0.185093	0.145506
example16	0.017092	0.498548	0.995381	2.01314	2.02217	0.007429	0.013286	0.01548	0.024316	0.01785
example17	0.016931	0.499667	0.998222	2.01677	2.0301	0.010145	0.023392	0.026349	0.046131	0.033523
example18	0.016883	0.500205	0.999701	2.01842	2.03473	0.014587	0.044781	0.04827	0.095072	0.068595

Table 4.1 Comparison of results between Pressure Net and Analytical method

[LABEL]	N-O [t1]	P-O[t1]	Percent	N-O [t2]	P-O[t2]	Percent	N-O [t3]	P-O[t3]	Percent
1	0.0124	0.0123	99	0.0131	0.0129	98	0.0299	0.0274	92
2	0.0125	0.0127	98	0.0131	0.0131	100	0.0299	0.0282	94
3	0.0147	0.0149	99	0.0154	0.016	96	0.0352	0.0354	99
4	0.0139	0.0147	95	0.0154	0.0159	97	0.0345	0.035	98
5	0.0146	0.0146	100	0.0154	0.0157	98	0.0351	0.0346	99
6	0.0147	0.0149	99	0.0154	0.016	96	0.0352	0.0354	99
7	0.0154	0.0154	100	0.0161	0.0165	97	0.0366	0.0366	100

N-O [t4]	P-O[t4]	Percent	N-O [t5]	P-O[t5]	Percent	N-O [F1]	P-O[F1]	Percent
0.9	0.85	94	0.917	0.851	92	2279.25	2234.12	98
0.822	0.841	98	0.834	0.853	98	2279.25	2221.95	97
0.933	0.957	97	0.947	0.976	97	1310.82	1400.71	93
0.992	1.009	98	1.005	1.03	97	1310.82	1289.79	98
0.933	0.961	97	0.948	0.98	97	1310.82	1379.09	95
0.933	0.956	97	0.948	0.975	97	1310.82	1403.19	93
0.992	1.006	98	1.007	1.027	98	1310.82	1304.7	99

Table 4.1 Comparison of results between Pressure Net and Analytical method (Continued)

N-O [F2]	P-O[F2]	Percent	N-O [F3]	P-O[F3]	Percent	N-O [F4]	P-O[F4]	Percent	N-O [F5]	P-O[F5]	Percent
1079.07	1148.74	94	1001.33	943.21	94	503.08	507.54	99	-7	-7.4	94
1077.64	1038.3	96	999.85	926.73	92	500.61	479.75	96	-7.7	-7.2	93
626.31	616.55	98	580.41	571.44	98	252.38	243.11	96	-5.2	-4.9	94
661.07	605.84	91	569.29	540.62	95	253.73	233.1	91	-4.6	-4.5	98
626.31	613.65	98	580.41	566.32	97	252.38	241.18	95	-5.2	-4.9	94
626.31	617.11	98	580.41	572.04	98	252.38	243.41	96	-5.2	-4.9	94
592.67	602.46	98	592.23	545	91	252.39	233.95	92	-5.4	-4.9	90

Table 4.2 Comparison of results between Response Net and Analytical Method

[LABEL]	N-O [t1]	P-O [t1]	Accuracy	N-O [t2]	P-O [t2]	Accuracy	N-O [t3]	P-O [t3]	Accuracy
example1	0.0127	0.0131	97	0.217	0.222	98	0.433	0.445	97
example2	0.0213	0.0212	99	0.33	0.338	98	0.661	0.677	98
example3	0.0129	0.0131	98	0.217	0.202	92	0.434	0.404	92
example4	0.0129	0.0131	98	0.217	0.202	92	0.434	0.404	92
example5	0.0141	0.0153	92	0.236	0.244	97	0.473	0.488	97
example6	0.0182	0.0188	97	0.364	0.399	91	0.727	0.799	91
example7	0.0127	0.0131	97	0.217	0.222	98	0.434	0.445	97
example8	0.0148	0.0153	97	0.228	0.229	99	0.455	0.458	99
example9	0.0185	0.0188	98	0.379	0.376	99	0.757	0.751	99
example10	0.0148	0.0153	97	0.227	0.229	99	0.454	0.458	99
example11	0.0148	0.0153	97	0.236	0.244	97	0.471	0.488	96
example12	0.0179	0.0188	95	0.332	0.366	91	0.665	0.734	91
example13	0.013	0.0131	99	0.215	0.222	97	0.435	0.445	98
example14	0.02	0.02	100	0.482	0.463	96	0.965	0.925	96
example15	0.0149	0.0154	97	0.228	0.229	99	0.456	0.458	99
example16	0.0185	0.0188	98	0.379	0.376	99	0.76	0.751	99
example17	0.0148	0.0154	96	0.236	0.244	97	0.472	0.488	97
example18	0.0147	0.0153	96	0.227	0.229	99	0.455	0.458	99

Table 4.2 Comparison of results between Response Net and Analytical Method (continued)

N-O [t4]	P-O [t4]	Accuracy	N-O [t5]	P-O [t5]	Accuracy	N-O [disp1]	P-O [disp1]	Accuracy
0.882	0.904	97	0.888	0.917	97	0.05703	0.05425	95
1.341	1.375	97	1.368	1.399	98	0.011418	0.011245	98
0.883	0.821	92	0.889	0.834	93	0.05462	0.054312	99
0.882	0.822	93	0.887	0.828	93	0.075006	0.082436	91
0.96	0.991	97	0.966	0.998	97	0.055816	0.062398	90
1.477	1.617	91	1.498	1.639	91	0.016652	0.0158	95
0.882	0.904	97	0.888	0.914	97	0.064477	0.063624	99
0.926	0.933	99	0.935	0.947	99	0.039304	0.037531	95
1.535	1.522	99	1.543	1.534	99	0.027923	0.029709	94
0.925	0.933	99	0.934	0.947	99	0.023962	0.023212	97
0.959	0.991	97	0.969	1.007	96	0.023777	0.023917	99
1.348	1.487	91	1.367	1.505	91	0.015849	0.014463	90
0.867	0.904	96	0.884	0.904	98	0.124877	0.129786	96
1.952	1.872	96	1.945	1.872	96	0.030601	0.029176	95
0.921	0.933	99	0.928	0.933	99	0.093014	0.093644	99
1.53	1.522	99	1.522	1.522	100	0.059429	0.060187	99
0.957	0.991	96	0.963	0.991	97	0.049877	0.048378	97
0.924	0.933	99	0.929	0.933	99	0.045398	0.043439	95

Table 4.2 Comparison of results between Response Net and Analytical Method (continued)

N-O disp2	P-O disp2	Accuracy	N-O disp3	P-O disp3	Accuracy	N-O disp4	P-O disp4	Accuracy	N-O disp5	P-O disp5	Accuracy
0.1144	0.11101	97	0.121817	0.117917	97	0.203022	0.198542	98	0.140521	0.13533	96
0.017336	0.01787	97	0.019095	0.019572	97	0.027752	0.029806	93	0.019839	0.021564	92
0.107588	0.112235	96	0.113294	0.118236	96	0.190165	0.199111	95	0.137849	0.136722	99
0.146444	0.157406	93	0.146301	0.153102	95	0.241056	0.249667	96	0.198883	0.186929	94
0.115229	0.120598	95	0.116962	0.116618	99	0.192212	0.191163	99	0.162331	0.153339	94
0.022809	0.022382	98	0.025641	0.0247	96	0.038035	0.036811	97	0.025701	0.027148	95
0.127731	0.125859	98	0.133301	0.129491	97	0.220813	0.215297	97	0.160049	0.148209	92
0.071544	0.070602	99	0.07555	0.074554	99	0.122022	0.121477	99	0.08774	0.082078	93
0.044865	0.048435	93	0.047338	0.049193	96	0.072933	0.075599	96	0.054805	0.049743	90
0.035154	0.033634	95	0.037814	0.036459	96	0.054738	0.052747	96	0.042055	0.039525	93
0.034605	0.035549	97	0.037488	0.038712	97	0.055063	0.056896	97	0.04184	0.042294	99
0.021654	0.020991	97	0.023903	0.023025	96	0.034734	0.033483	96	0.025833	0.025024	97
0.247095	0.237901	96	0.230882	0.225857	98	0.377373	0.362837	96	0.362076	0.362837	99
0.037747	0.037398	99	0.03691	0.03628	98	0.049158	0.047399	96	0.044862	0.047399	95
0.161964	0.156035	96	0.149948	0.145145	97	0.229161	0.221589	96	0.227373	0.221589	97
0.089152	0.090361	99	0.083274	0.083991	99	0.11898	0.121876	98	0.118003	0.121876	97
0.068096	0.064935	95	0.065852	0.064276	97	0.090979	0.087069	95	0.087851	0.087069	99
0.062241	0.057413	91	0.060627	0.057099	94	0.082763	0.076479	92	0.078866	0.076479	97

Table 4.3 Comparison of results for General Net

Case Name	N-O(t1)	P-O[t1]	N-O(t2)	P-O[t2]	N-O(t3)	P-O[t3]	N-O(t4)	P-O[t4]	N-O(t5)	P-O[t5]
example1	0.013398	0.013474	0.015758	0.017965	0.035106	0.035931	1.05192	1.055622	1.07156	1.073587
example2	2.76E-05	0	0.002178	0.002092	0.004808	0.004184	0.00522	0.006276	0.008482	0.01046
example3	0.013939	0.013474	0.015988	0.017965	0.035902	0.035931	1.05317	1.055622	1.07326	1.073587
example4	2.76E-05	0	0.002173	0.002092	0.0048	0.004184	0.005218	0.006276	0.00848	0.01046
example5	0.014523	0.013474	0.016229	0.017965	0.036768	0.035931	1.05413	1.055622	1.07511	1.073587
example6	2.75E-05	0	0.002171	0.002092	0.004797	0.004184	0.005216	0.006276	0.008478	0.01046
example7	0.016245	0.016332	0.019559	0.021776	0.042289	0.043553	1.52445	1.523905	1.54723	1.545681
example8	3.23E-05	0	0.002729	0.002822	0.005477	0.005644	0.008654	0.008466	0.011799	0.01411
example9	0.016823	0.016332	0.019875	0.021776	0.043269	0.043553	1.52593	1.523905	1.54886	1.545681
example10	3.22E-05	0	0.002703	0.002822	0.00545	0.005644	0.008675	0.008466	0.01184	0.01411
example11	0.017426	0.016332	0.020225	0.021776	0.044339	0.043553	1.52735	1.523905	1.55054	1.545681
example12	3.21E-05	0	0.002685	0.002822	0.005432	0.005644	0.0087	0.008466	0.01188	0.01411
example13	0.018301	0.017966	0.022407	0.023954	0.047684	0.047908	1.8722	1.88107	1.90072	1.905024
example14	4.91E-05	0	0.003153	0.003352	0.006137	0.006704	0.007968	0.010056	0.010955	0.01676
example15	0.018876	0.017966	0.022797	0.023954	0.048814	0.047908	1.87234	1.88107	1.90081	1.905024
example16	4.89E-05	0	0.003122	0.003352	0.006102	0.006704	0.007961	0.010056	0.010963	0.01676
example17	0.019452	0.017966	0.023229	0.023954	0.05003	0.047908	1.87247	1.88107	1.90089	1.905024
example18	4.88E-05	0	0.003109	0.003352	0.006087	0.006704	0.007961	0.010056	0.010969	0.01676

Table 4.3 Comparison of results for General Net (continued)

Case Name	N-O(F0)	P-O[F0]	N-O(F1)	P-O[F1]	N-O(F2)	P-O[F2]	N-O(F3)	P-O[F3]	N-O(F4)	P-O[F4]
example1	593.245	588.553	292.153	272.019	249.835	270.8467	79.2878	86.92095	-3.01427	-3.10322
example2	122.091	121.1548	95.8449	96.92384	73.6	72.69288	47.3027	48.46192	-5.26E-05	0
example3	597.197	588.553	292.845	272.019	253.315	270.8467	80.4792	86.92095	-3.02897	-3.10322
example4	122.224	121.1548	96.3487	96.92384	73.7228	72.69288	47.4319	48.46192	-5.26E-05	0
example5	600.989	588.553	293.84	272.019	257.044	270.8467	81.7481	86.92095	-3.04912	-3.10322
example6	122.459	121.1548	96.6846	96.92384	73.8636	72.69288	47.5653	48.46192	-5.26E-05	0
example7	231.451	230.964	127.852	109.7347	94.9764	109.3384	24.4588	21.88033	-1.05033	-1.2449
example8	13.6408	30.94715	11.9383	24.75772	17.0889	18.56829	5.88907	12.37886	-5.26E-05	0
example9	232.631	230.964	126.991	109.7347	97.2964	109.3384	24.8011	21.88033	-1.08158	-1.2449
example10	13.7636	30.94715	12.1224	24.75772	17.3876	18.56829	5.9605	12.37886	-5.26E-05	0
example11	233.762	230.964	126.127	109.7347	99.8198	109.3384	25.1697	21.88033	-1.1169	-1.2449
example12	13.8991	30.94715	12.312	24.75772	17.6981	18.56829	6.03672	12.37886	-5.26E-05	0
example13	119.617	129.664	65.777	62.50716	50.0569	62.30624	11.7679	8.497313	-0.63113	-0.68369
example14	12.2682	12.24717	11.9003	9.797735	8.26873	7.348301	5.21539	4.898867	-5.26E-05	0
example15	119.813	129.664	64.9023	62.50716	51.307	62.30624	11.8687	8.497313	-0.65336	-0.68369
example16	12.2681	12.24717	11.9298	9.797735	8.26832	7.348301	5.21612	4.898867	-5.26E-05	0
example17	120.011	129.664	63.9967	62.50716	52.6847	62.30624	11.9793	8.497313	-0.6783	-0.68369
example18	12.2681	12.24717	11.9469	9.797735	8.26874	7.348301	5.21698	4.898867	-5.26E-05	0

Table 4.4 Comparison of results for Height Net

Case Name	N-O(t1)	P-O(t1)	N-O(t2)	P-O(t2)	N-O(t3)	P-O [t3]	N-O[t4]	P-O[t4]	N-O[t5)	P-O[t5]
Example 1	0.013973	0.013474	0.260482	0.260537	0.521918	0.521074	1.0569	1.055622	1.07154	1.073587
Example 2	0.013522	0.013474	0.259967	0.260537	0.520638	0.521074	1.05587	1.055622	1.0682	1.073587
Example 3	0.013189	0.013474	0.259571	0.260537	0.519236	0.521074	1.05717	1.055622	1.06422	1.073587
Example 4	0.016309	0.016332	0.377076	0.376893	0.752392	0.753786	1.52234	1.523905	1.54374	1.545681
Example 5	0.016187	0.016332	0.377324	0.376893	0.752929	0.753786	1.52332	1.523905	1.5468	1.545681
Example 6	0.016208	0.016332	0.377856	0.376893	0.754057	0.753786	1.52616	1.523905	1.55052	1.545681
Example 7	0.01719	0.017966	0.465901	0.465776	0.930592	0.931552	1.88291	1.88107	1.89817	1.905024
Example 8	0.017532	0.017966	0.465685	0.465776	0.929896	0.931552	1.88265	1.88107	1.89808	1.905024
Example 9	0.018231	0.017966	0.465613	0.465776	0.929384	0.931552	1.88341	1.88107	1.89858	1.905024
Example 10	0.0115	0.010999	0.229838	0.2305	0.460029	0.461	0.940341	0.933	0.941793	0.947666
Example 11	0.011563	0.010999	0.229801	0.2305	0.459837	0.461	0.940587	0.933	0.941577	0.947666
Example 12	0.01169	0.010999	0.229767	0.2305	0.459625	0.461	0.940962	0.933	0.941282	0.947666
Example 13	0.014673	0.014567	0.381389	0.381108	0.764801	0.762217	1.53792	1.539	1.5629	1.558422
Example 14	0.014222	0.014567	0.380798	0.381108	0.7636	0.762217	1.53538	1.539	1.55934	1.558422
Example 15	0.013976	0.014567	0.380669	0.381108	0.762902	0.762217	1.53721	1.539	1.55625	1.558422
Example 16	0.017092	0.016843	0.498548	0.500789	0.995381	1.001579	2.01314	2.02	2.02217	2.042457
Example 17	0.016931	0.016843	0.499667	0.500789	0.998222	1.001579	2.01677	2.02	2.0301	2.042457
Example 18	0.016883	0.016843	0.500205	0.500789	0.999701	1.001579	2.01842	2.02	2.03473	2.042457

Table 4.4 Comparison of results for Height Net

Case Name	N-O [disp1]	P-O [disp1]	N-O [disp 2]	P-O [disp 2]	N-O [disp 3]	P-O [disp3]	N-O [disp 4]	P-O [disp 4]	N-O [disp 5]	P-O [disp 5]
Example 1	0.013574	0.009904	0.035536	0.027127	0.039089	0.030544	0.070183	0.055583	0.050262	0.04004
Example 2	0.017699	0.014943	0.063495	0.058914	0.070264	0.069492	0.136733	0.133089	0.104414	0.108261
Example 3	0.02115	0.019722	0.106774	0.105121	0.123742	0.129703	0.2501	0.253596	0.211241	0.222768
Example 4	0.008334	0.005027	0.015922	0.011656	0.017997	0.01327	0.02841	0.023331	0.020972	0.016011
Example 5	0.011452	0.007899	0.028763	0.025005	0.031374	0.029606	0.054819	0.055391	0.040763	0.041953
Example 6	0.015556	0.010633	0.050596	0.044108	0.053542	0.054265	0.102308	0.104784	0.077149	0.08615
Example 7	0.006317	0.003168	0.010179	0.006843	0.012071	0.007844	0.017801	0.013546	0.013507	0.009187
Example 8	0.008078	0.005095	0.015944	0.014622	0.018538	0.017393	0.029281	0.032067	0.022308	0.023519
Example 9	0.011205	0.00694	0.029557	0.025634	0.032964	0.03163	0.057628	0.060451	0.043975	0.048022
Example 10	0.018982	0.016199	0.05674	0.05325	0.069436	0.061297	0.132894	0.11523	0.098523	0.087827
Example 11	0.023424	0.023629	0.116615	0.117034	0.147965	0.142829	0.297452	0.279096	0.248766	0.239893
Example 12	0.026768	0.030705	0.212052	0.21091	0.274782	0.271047	0.553978	0.536006	0.484069	0.49125
Example 13	0.011181	0.00797	0.025552	0.019851	0.029535	0.022864	0.050755	0.041001	0.037366	0.028405
Example 14	0.015502	0.012212	0.047116	0.042576	0.053246	0.051408	0.101371	0.097703	0.076464	0.075833
Example 15	0.020384	0.016236	0.080674	0.075407	0.090817	0.094978	0.185093	0.185577	0.145506	0.156154
Example 16	0.007429	0.004523	0.013286	0.010055	0.01548	0.011608	0.024316	0.020251	0.01785	0.013658
Example 17	0.010145	0.007159	0.023392	0.021394	0.026349	0.025782	0.046131	0.04796	0.033523	0.035414
Example 18	0.014587	0.009671	0.044781	0.037513	0.04827	0.04704	0.095072	0.090561	0.068595	0.072577

Table 4.5 Values used for Parametric study of Design Pressure from Pressure Net

Case Name	Q	Xd	B	L	t1	t2	t3	t4	t5	F0	F1	F2	F3	F4
example1	0.5	2	10	15	0.016895	0.021139	0.043719	1.05662	1.06096	585.736	325.446	286.547	95.8126	-3.96021
example2	0.5	2	15	10	0.016812	0.018321	0.040057	1.05613	1.05864	580.248	338.358	284.818	95.4178	-3.52578
example3	0.5	3	10	15	0.020897	0.027424	0.05458	1.55138	1.5583	237.952	117.761	101.161	20.0641	-1.46917
example4	0.5	3	15	10	0.02077	0.022469	0.049152	1.551	1.55293	235.63	123.403	100.668	20.046	-1.21884
example5	0.5	4	10	15	0.022817	0.033343	0.062573	1.91385	1.92368	147.555	70.7698	51.0343	8.30175	-0.76184
example6	0.5	4	15	10	0.022702	0.026065	0.055528	1.91562	1.91946	145.962	73.9578	51.0214	8.30802	-0.58463
example7	0.5	2	15	5	0.00676	0.017893	0.033351	1.05528	1.0546	572.648	408.174	239.059	100.061	-1.20901
example8	0.5	2	15	10	0.016812	0.018321	0.040057	1.05613	1.05864	580.248	338.358	284.818	95.4178	-3.52578
example9	0.5	2	15	15	0.01722	0.021471	0.044507	1.05631	1.06061	585.474	324.861	286.31	95.5186	-3.9902
example10	1	3	15	5	0.009025	0.019687	0.037861	1.56867	1.5709	384.383	262.187	150.715	52.6076	-0.54353
example11	1	3	15	10	0.01934	0.020362	0.045511	1.56983	1.5791	388.928	215.737	182.654	49.7903	-1.79332
example12	1	3	15	15	0.019723	0.024679	0.051011	1.56924	1.58283	391.782	205.105	183.061	49.5707	-2.10982
example13	1	3	15	20	0.020196	0.039301	0.066108	1.5632	1.59066	396.373	175.944	179.684	48.0747	-3.17067
example14	1	3	5	15	0.016944	0.021214	0.043404	1.56957	1.58363	393.982	208.84	184.706	51.0756	-1.93863
example15	1	3	10	15	0.019444	0.024312	0.050214	1.56999	1.58363	392.15	205.35	183.11	49.717	-2.09103
example16	1	3	15	15	0.019723	0.024679	0.051011	1.56924	1.58283	391.782	205.105	183.061	49.5707	-2.10982
example17	1	3	20	15	0.019767	0.024682	0.051063	1.56838	1.58203	391.303	205.275	183.258	49.554	-2.11107

Table 4.6 Values used for Parametric study of Design Pressure from Pressure Net

Case Name	Q	Xd	B	L	t1	t2	t3	t4	t5	disp1	disp2	disp3	disp4	disp5
example1	2	2	10	10	0.01274	0.217015	0.433724	0.88216	0.887866	0.05703	0.1144	0.121817	0.203022	0.140521
example2	0.6	2.6	11	12	0.021366	0.330945	0.661312	1.34135	1.36846	0.011418	0.017336	0.019095	0.027752	0.018839
example3	1.5	2	10	10	0.012905	0.217468	0.434502	0.883531	0.889153	0.05462	0.107588	0.113294	0.190165	0.137849
example4	1.5	2	10	5	0.012937	0.217451	0.434673	0.882877	0.887489	0.075006	0.146444	0.146301	0.241056	0.198883
example5	1.2	2.2	8	5	0.014182	0.236689	0.472728	0.959777	0.966271	0.055716	0.115229	0.116962	0.192212	0.162331
example6	1.8	3	14	12	0.018242	0.364105	0.7275	1.47717	1.49833	0.016652	0.022809	0.025641	0.038035	0.025701
example7	2	2	10	8	0.01276	0.216999	0.433783	0.881846	0.887299	0.064477	0.127731	0.133301	0.220813	0.160049
example8	1	2	10	10	0.014797	0.228143	0.455634	0.926364	0.934907	0.039304	0.071544	0.07555	0.122022	0.08774
example9	1.5	3	9	6.5	0.018528	0.379182	0.757182	1.53532	1.54363	0.027923	0.044865	0.047338	0.072933	0.054805
example10	1	2	20	10	0.014806	0.227762	0.45487	0.924939	0.934102	0.023962	0.035154	0.037814	0.054738	0.042055
example11	1.2	2.2	18.5	11	0.014867	0.236175	0.471545	0.958775	0.969682	0.023777	0.034605	0.037488	0.055063	0.04184
example12	1.4	2.8	16	10	0.017914	0.33257	0.663933	1.34743	1.3667	0.015849	0.021654	0.023903	0.034734	0.025833
example13	0.5	2	10	15	0.019369	0.259635	0.518722	1.05427	1.07472	0.014761	0.024705	0.027479	0.041054	0.026405
example14	0.5	2	15	10	0.019363	0.259144	0.517571	1.05257	1.06946	0.014201	0.020633	0.02226	0.030759	0.022347
example15	0.5	2	15	5	0.019308	0.259269	0.51769	1.05314	1.06492	0.019793	0.028271	0.029056	0.039136	0.031122
example16	0.5	2	15	10	0.019363	0.259144	0.517571	1.05257	1.06946	0.014201	0.020633	0.02226	0.030759	0.022347
example17	0.5	2	15	15	0.019415	0.259156	0.517711	1.05252	1.0724	0.011619	0.016987	0.018817	0.026259	0.01831
example18	0.5	2	5	15	0.013239	0.260921	0.521639	1.05525	1.0831	0.007805	0.032367	0.039093	0.078628	0.049383
example19	0.5	2	10	15	0.019369	0.259635	0.518722	1.05427	1.07472	0.014761	0.024705	0.027479	0.041054	0.026405
example20	0.5	2	15	15	0.019415	0.259156	0.517711	1.05252	1.0724	0.011619	0.016987	0.018817	0.026259	0.01831
example21	1	2	5	10	0.011022	0.228792	0.457123	0.926851	0.938755	0.019611	0.090078	0.105051	0.210549	0.163244
example22	1	2	10	20	0.014789	0.22817	0.455791	0.926359	0.937983	0.025895	0.04701	0.052672	0.085741	0.055995

Table 4.7 Values obtained for Parametric study from General Net

Case Name	Q	Xd	type	H	B	L	t1	t2	t3	t4	t5	F0	F1	F2	F3	F4
example1	0.5	2	1	3	5	10	0.013474	0.017965	0.035931	1.055622	1.073587	588.553	272.019	270.8467	86.92095	-3.10322
example2	0.5	2	0	3	5	10	0	0.002092	0.004184	0.006276	0.01046	121.1548	96.92384	72.69288	48.46192	0

Table 4.8 Values obtained for Parametric study from Height Net

Case Name	Q	Xd	H	B	L	t1	t2	t3	t4	t5	disp1	disp2	disp3	disp4	disp5
example1	0.5	2	3	5	10	0.013973	0.260482	0.521918	1.0569	1.07154	0.013574	0.035536	0.039089	0.070183	0.050262
example2	0.5	2	4	5	10	0.013522	0.259967	0.520638	1.05587	1.0682	0.017699	0.063495	0.070264	0.136733	0.104414
example3	0.5	2	5	5	10	0.013189	0.259571	0.519236	1.05717	1.06422	0.02115	0.106774	0.123742	0.2501	0.211241

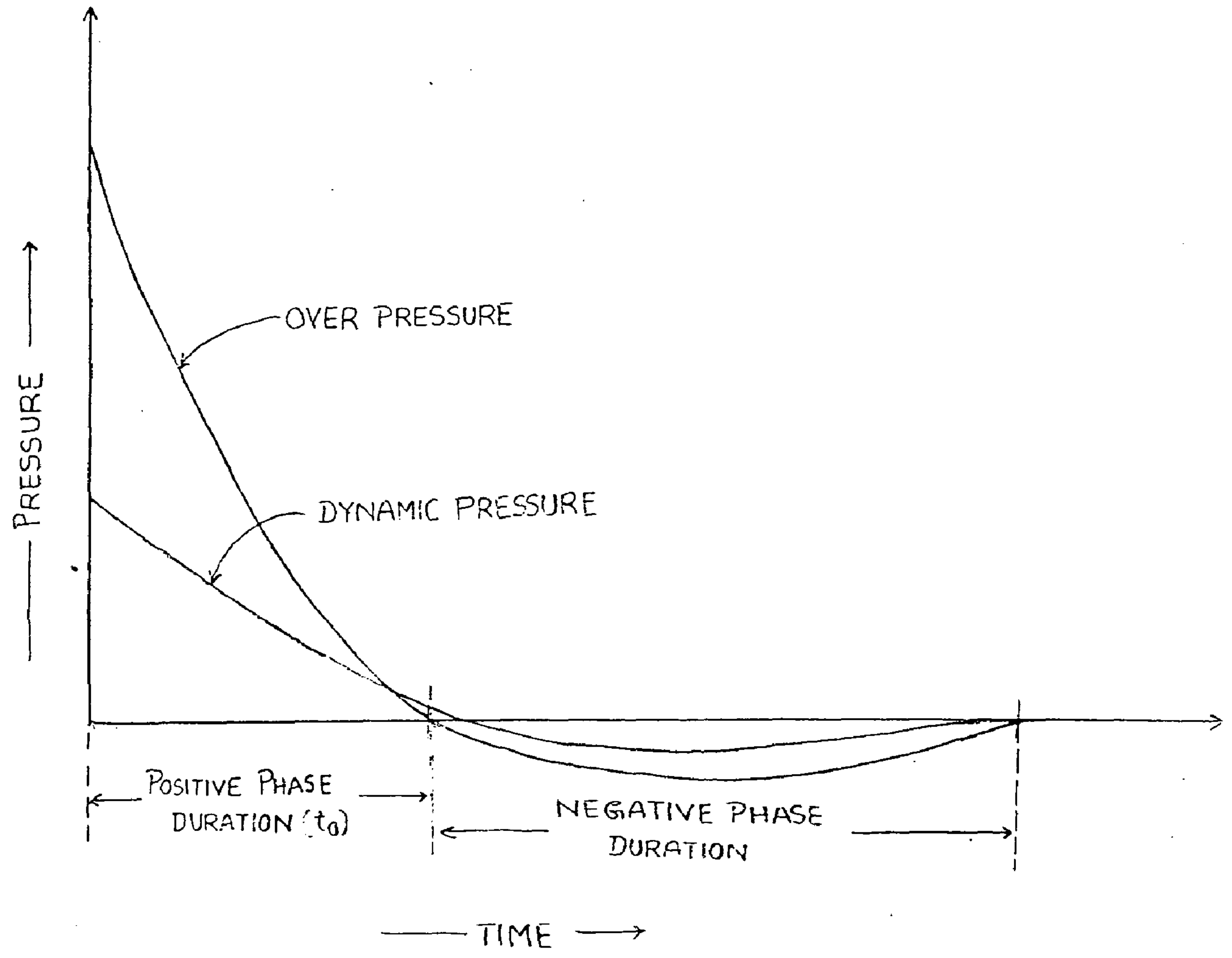


Figure 2.1 . Nature of Time History of Blast Pressure

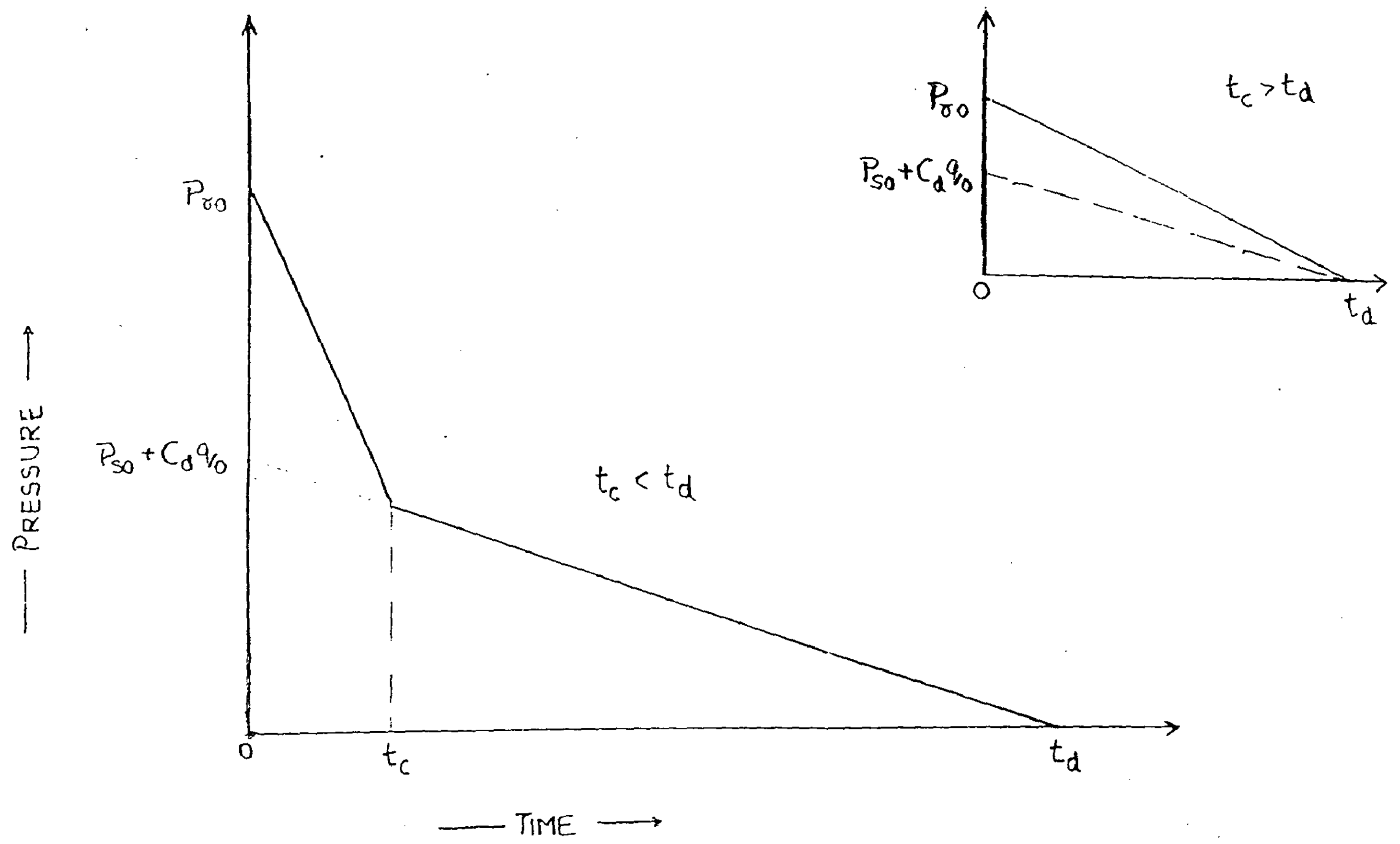


Figure 2.2 Nature of Time History of Pressure on Front wall

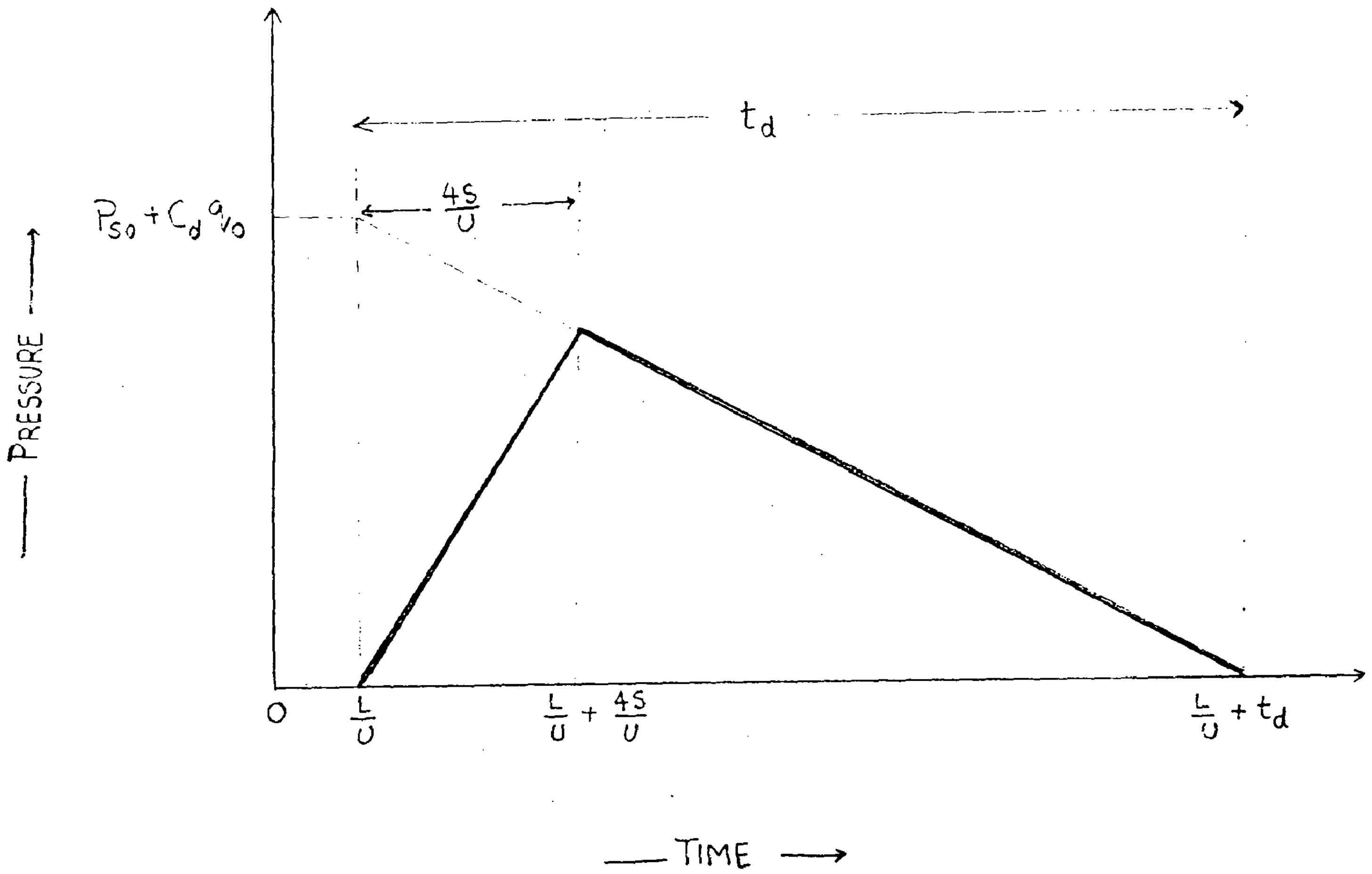


Figure 2.3 Nature of Time History of Pressure on Rear wall

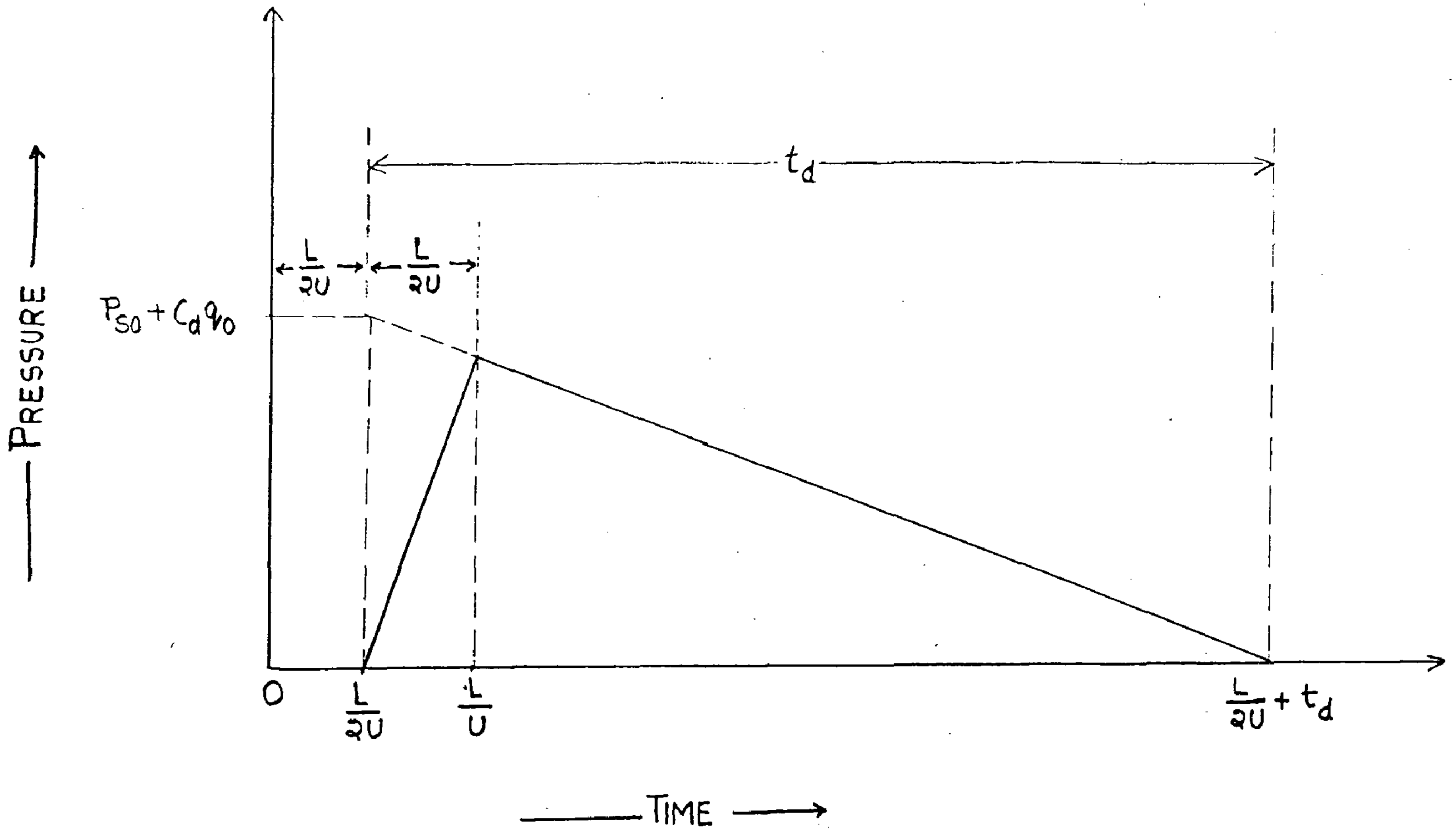


Figure 2.4 Nature of Time History of Pressure on Rear-Side wall

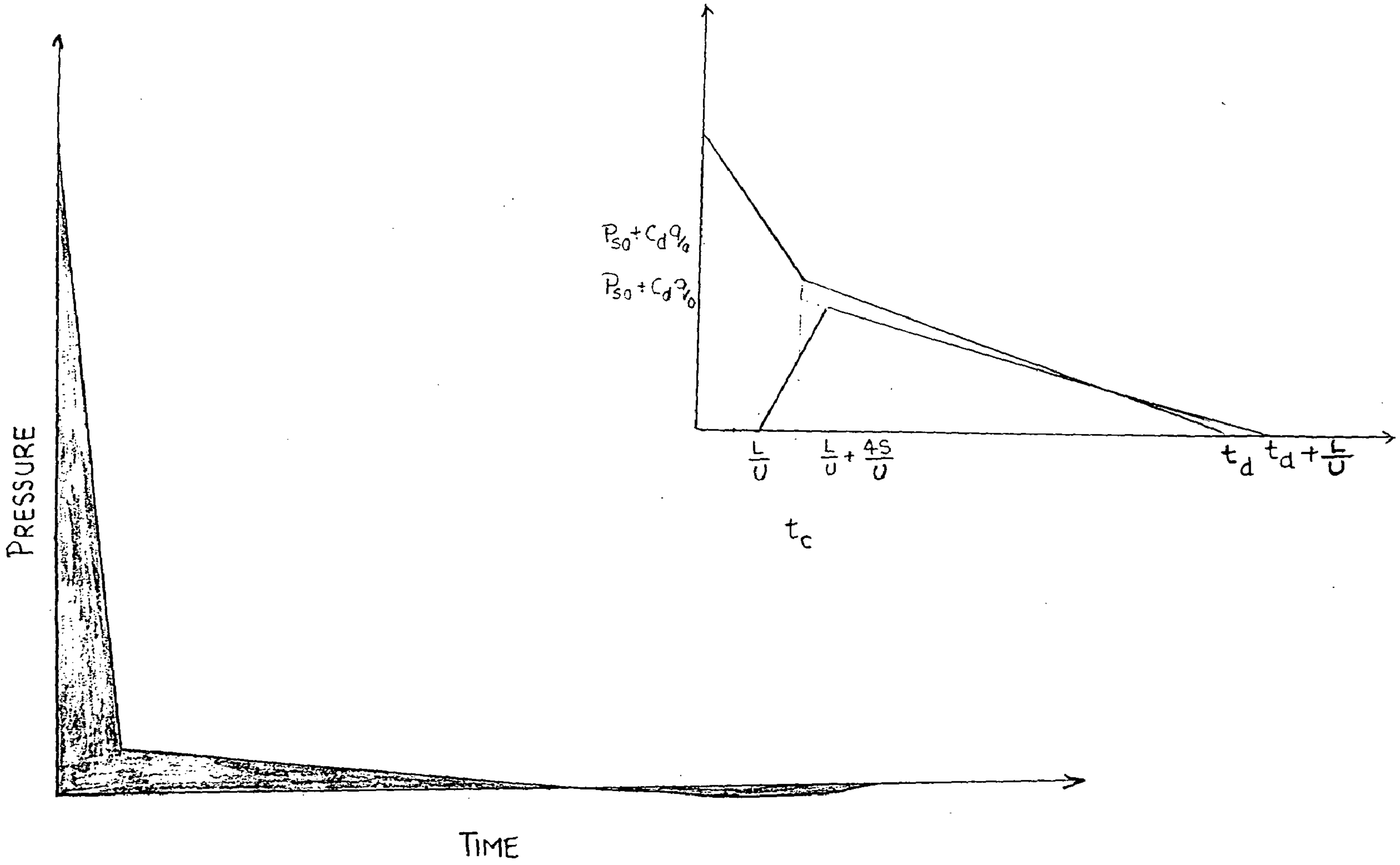


Figure 2.5 Nature of Time History of Design Pressure

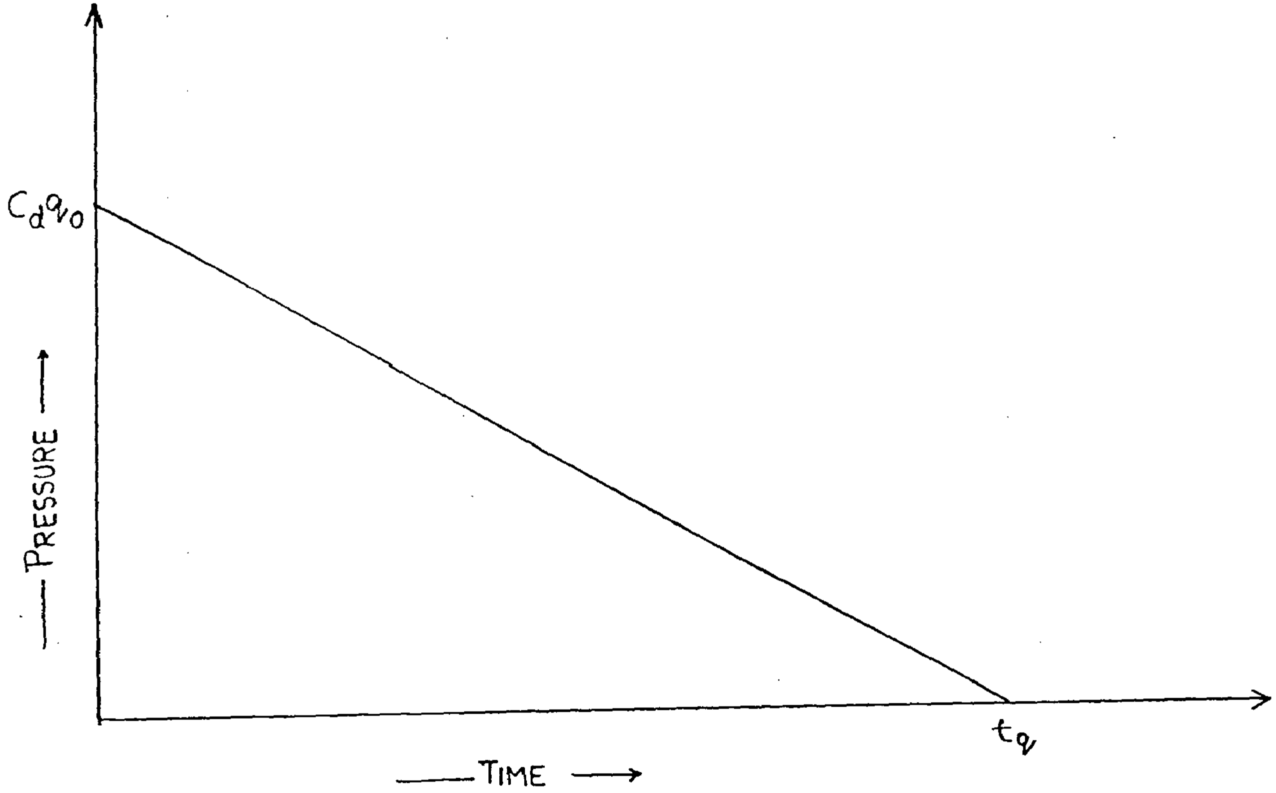


Figure 2.6 Nature of Time History of Pressure for Open Structures

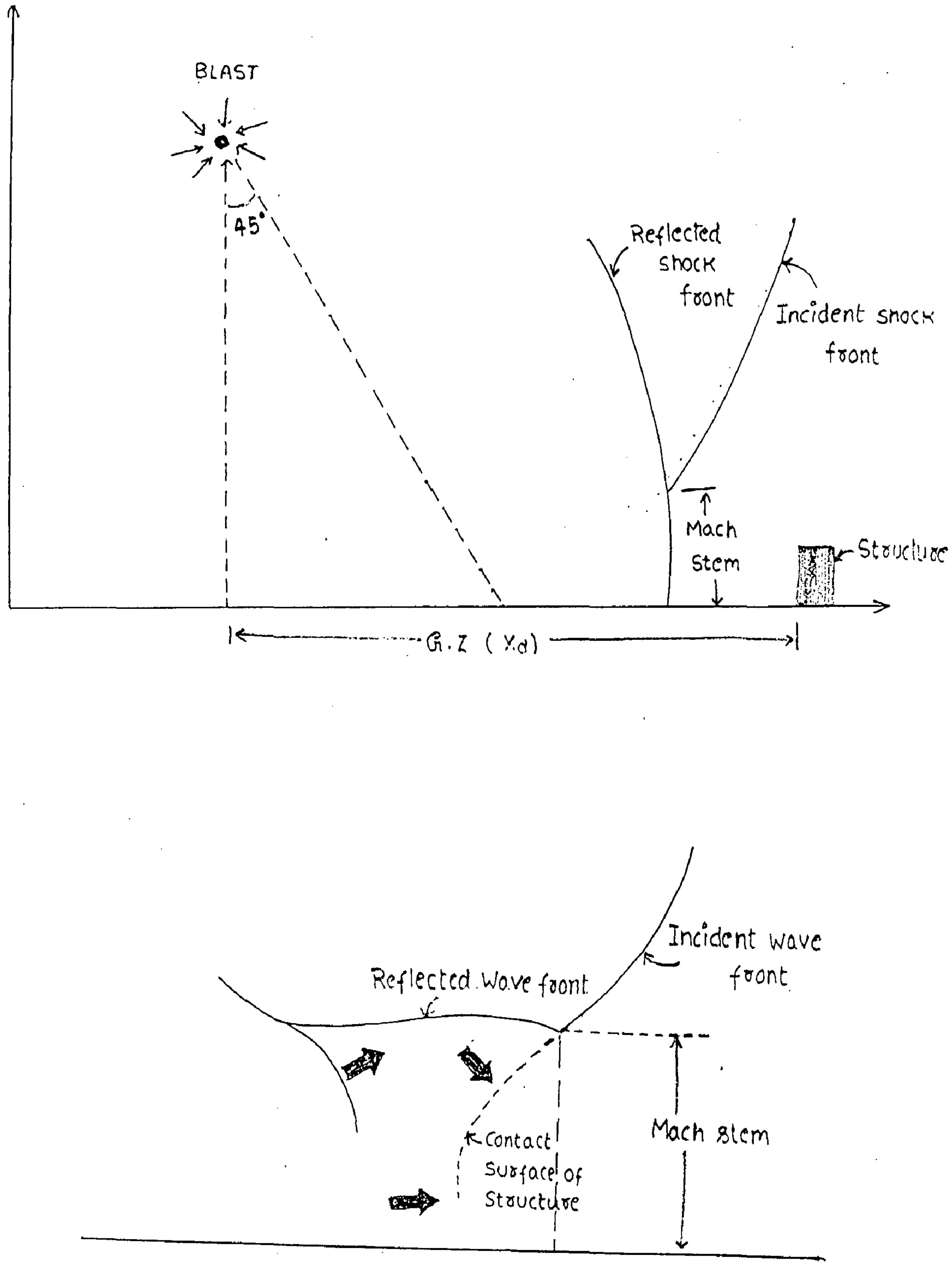


Figure 2.7 Blast Phenomenon

Fig 4.1 Comparison of Design Pressure for Varrying Blast Load Keeping Xd & Structure Same

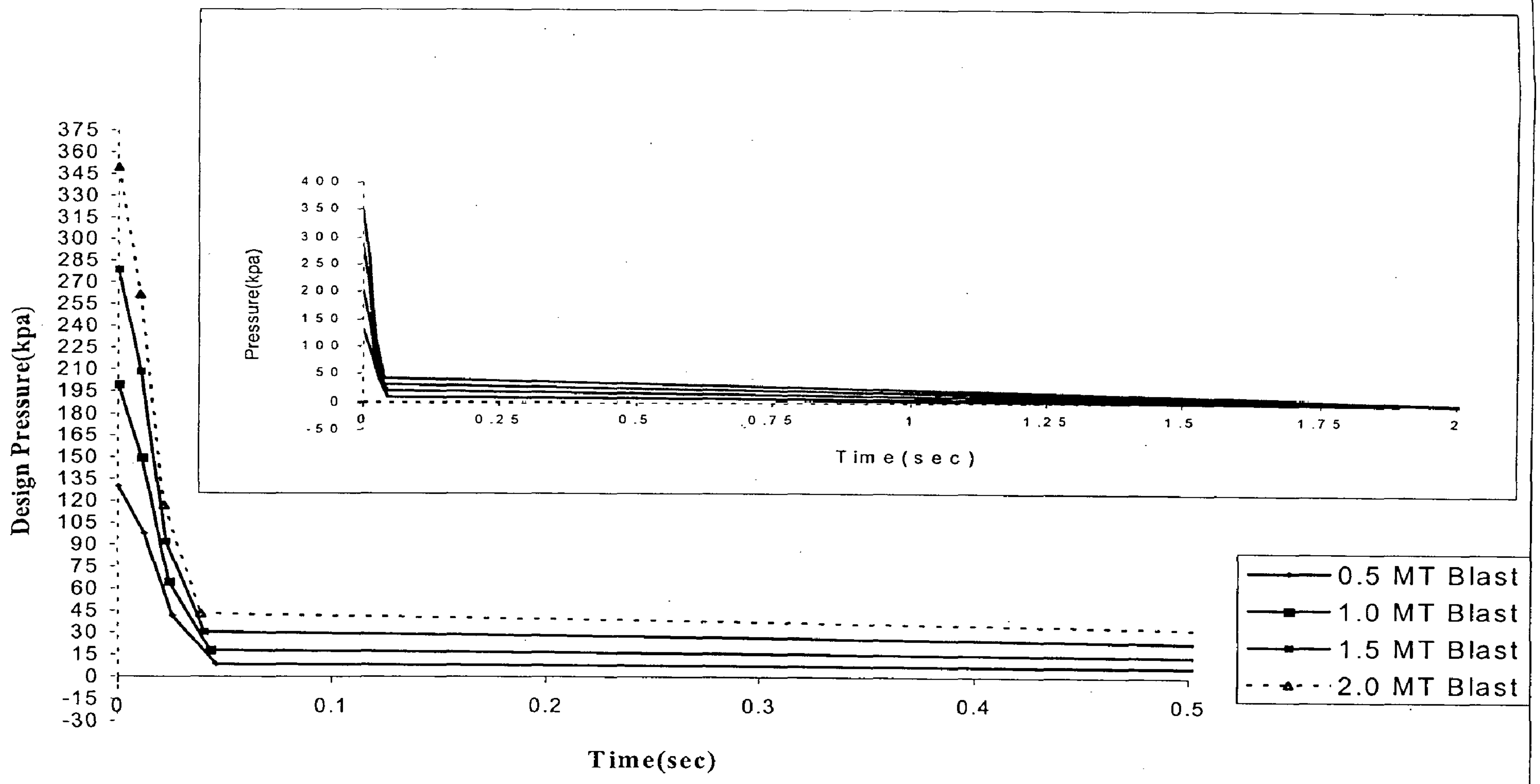


Figure 4.2 Comparison of design pressure for varrying distance keeping other parameters same

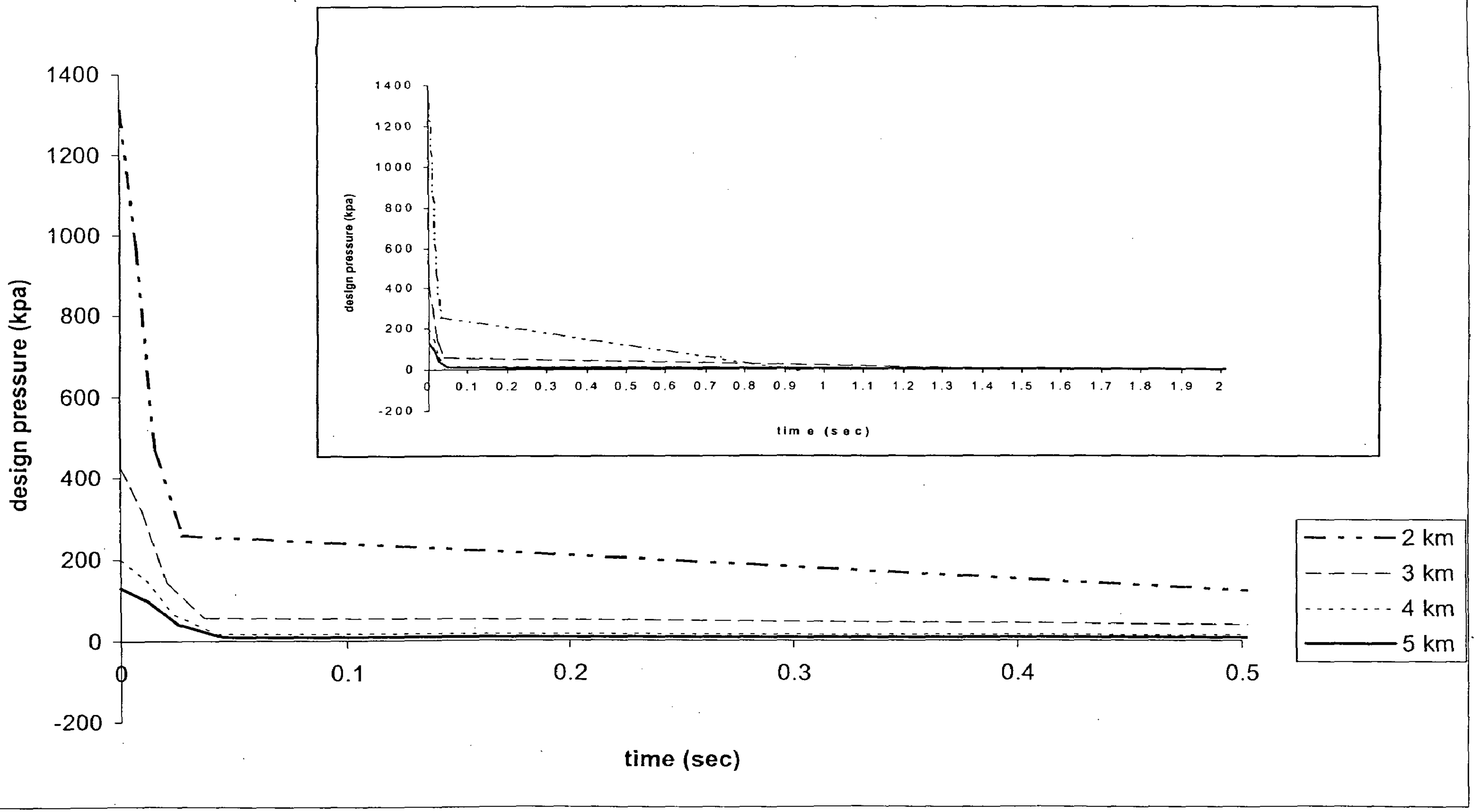


Fig 4.3 Comparison of Response for various charge of blast

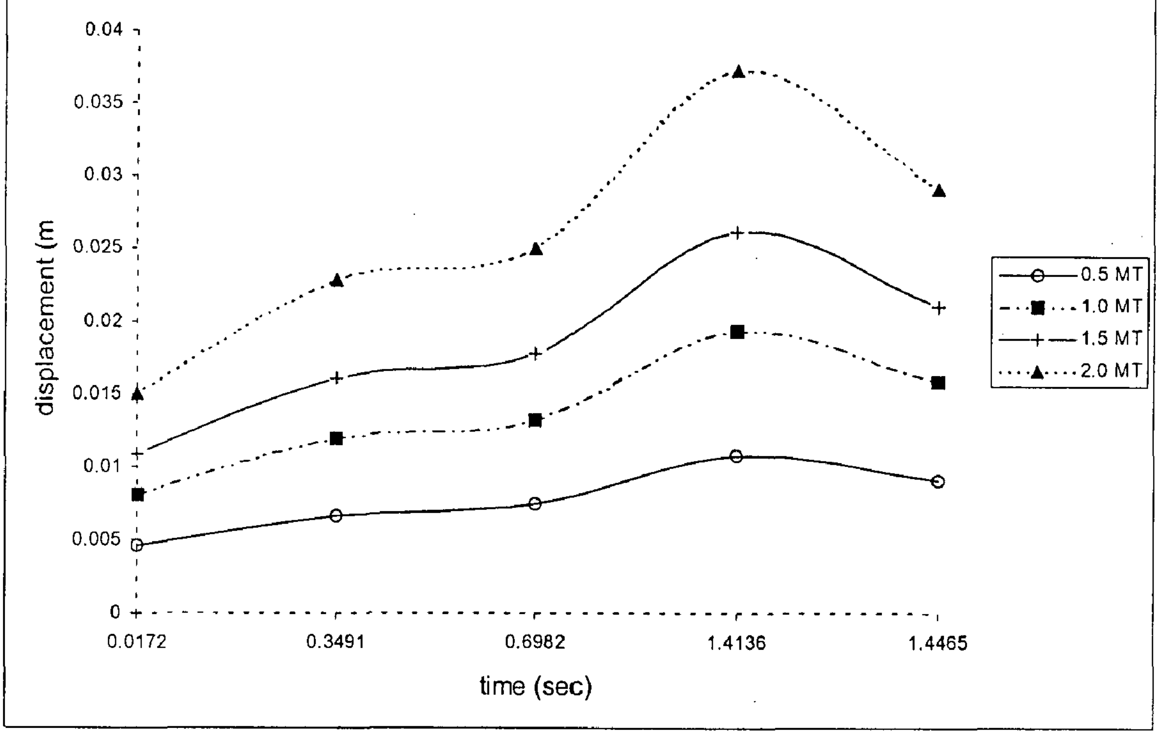


Fig 4.4 Comparison of Response for various distances

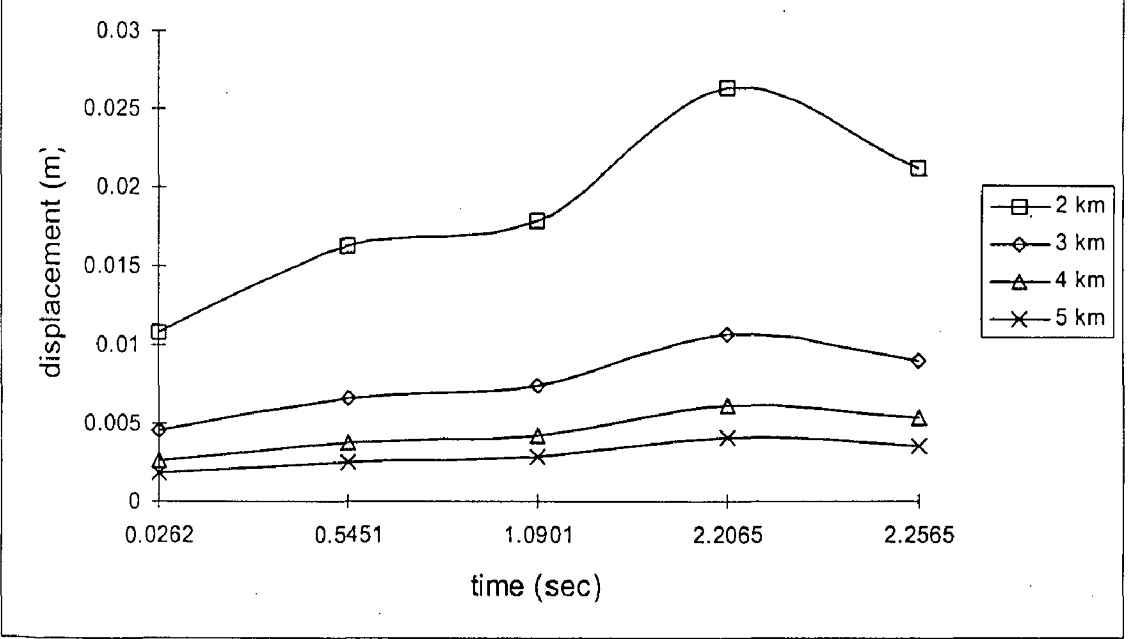


Figure 4.5 comparison of design pressure for different types of structures

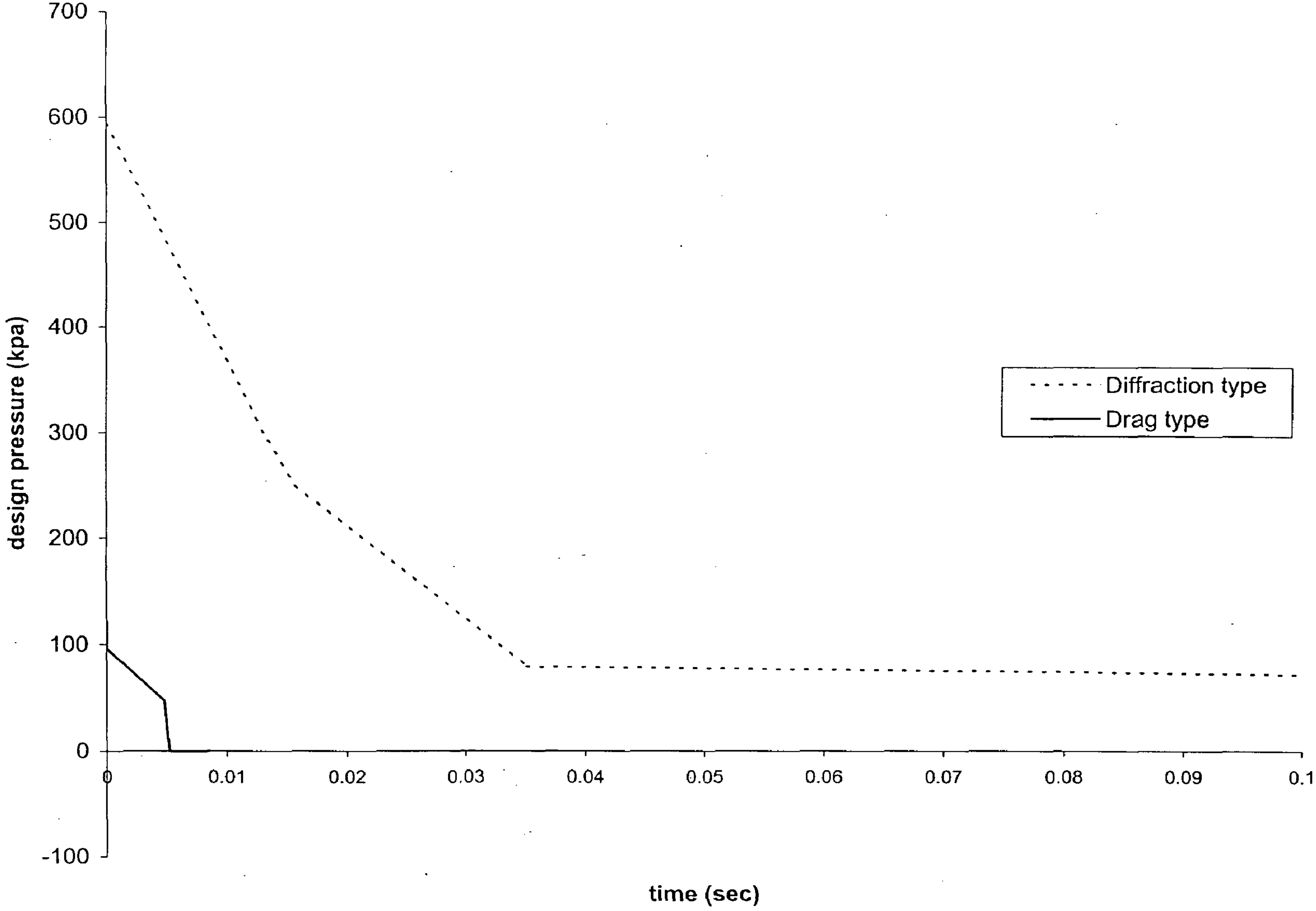


Fig 4.6 Comparison of Response for various heights of structure

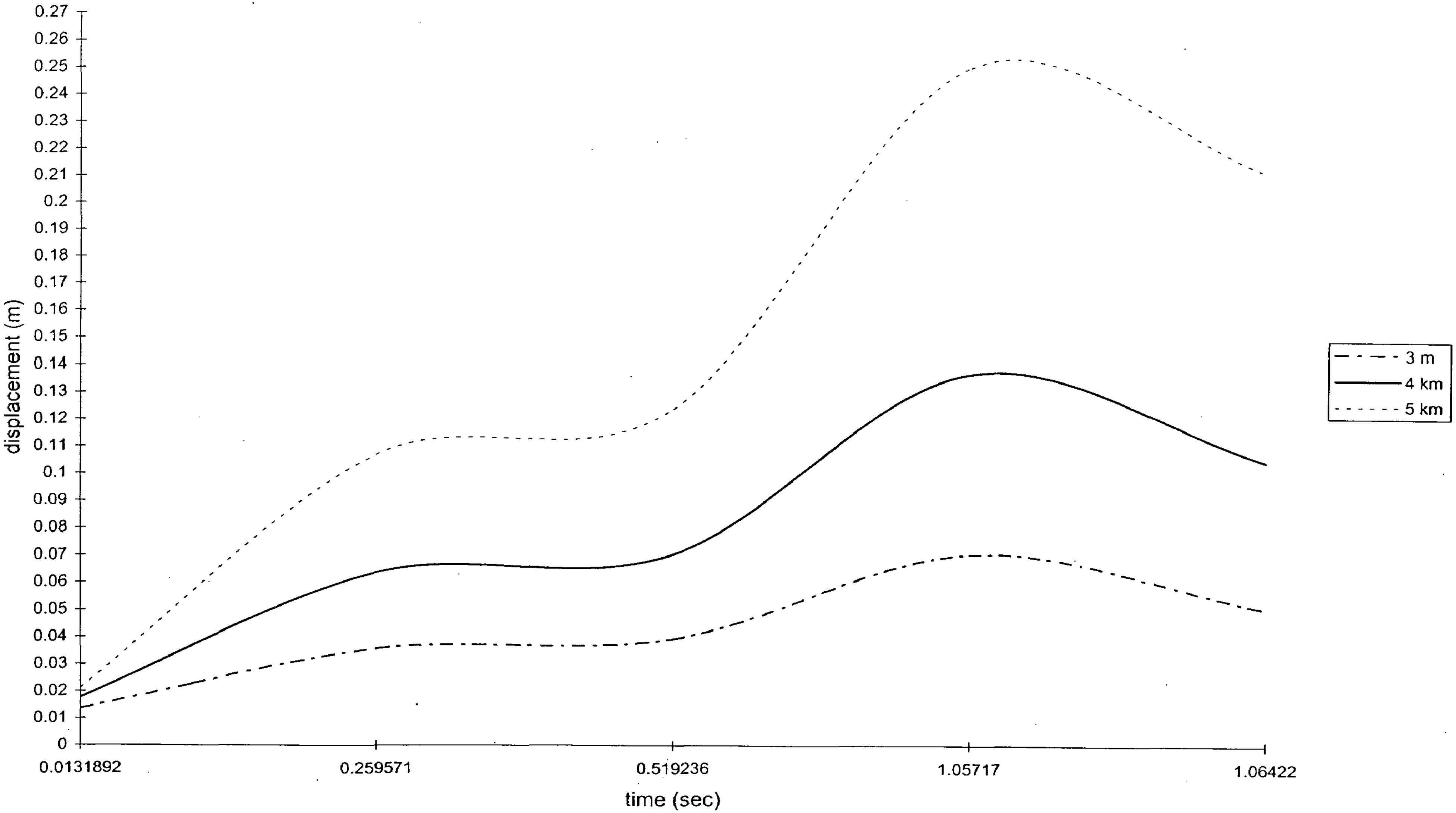


Figure 4.7 Design pressure for different alignement

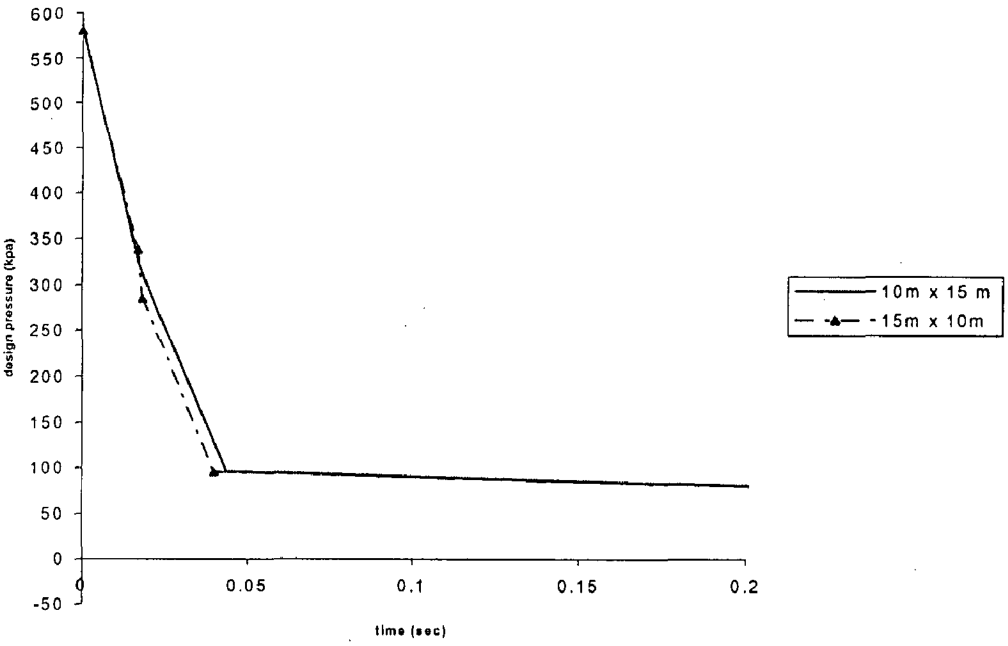


Figure 4.8 Comparison of design pressure for Length ratio of 1/2

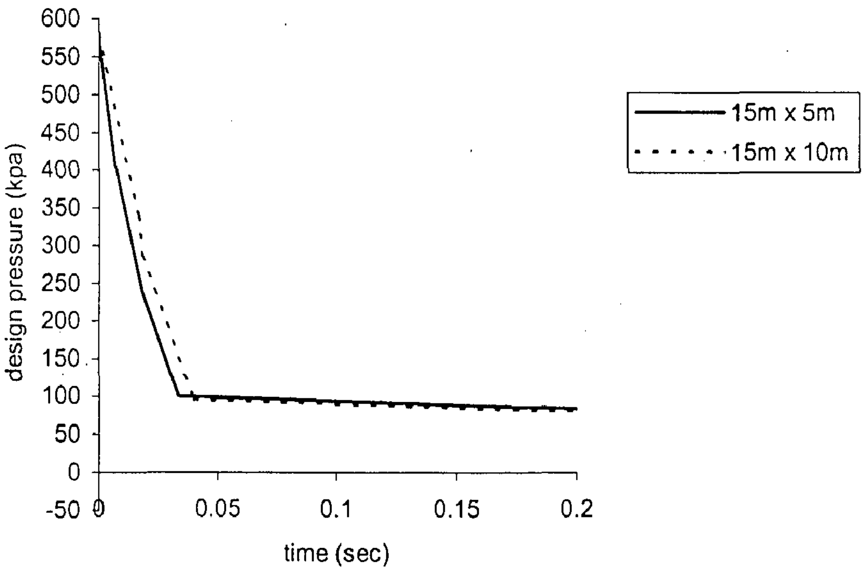


Fig 4.9 Comparison of design pressure for Length ratio of 1/3

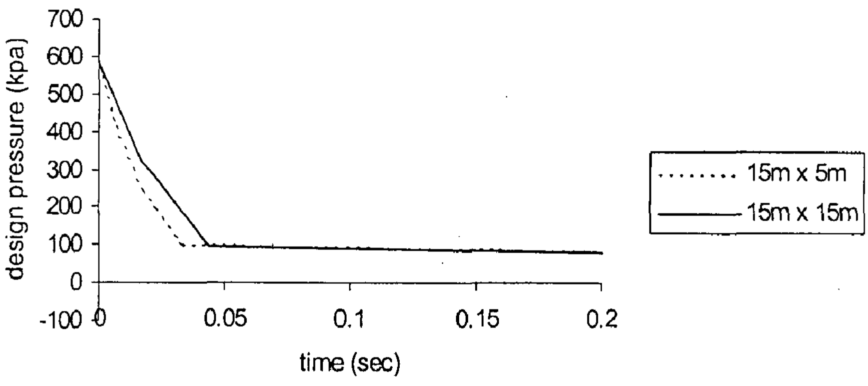
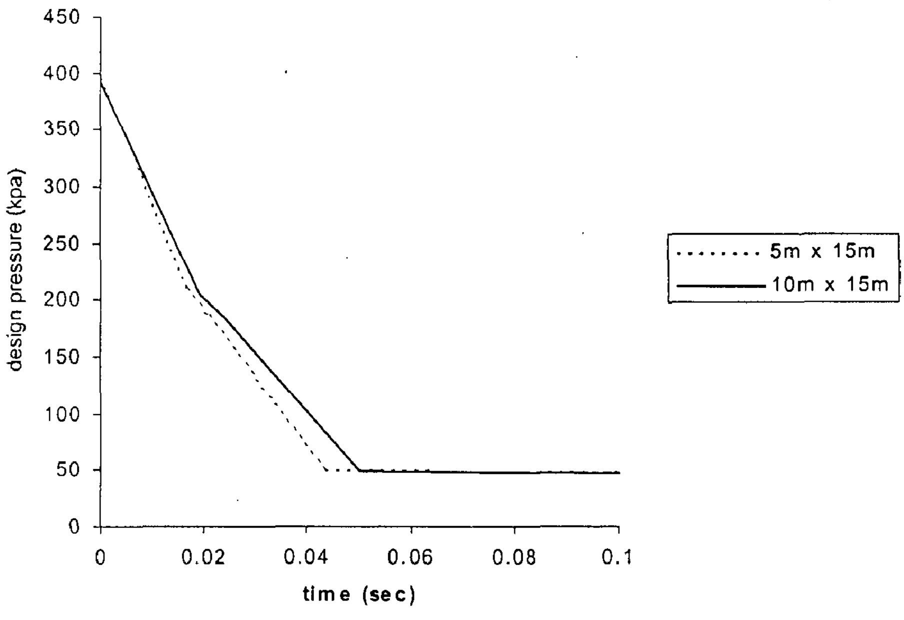


Figure 4.10 Comparison of Design Pressure for varying Breadth of Structure



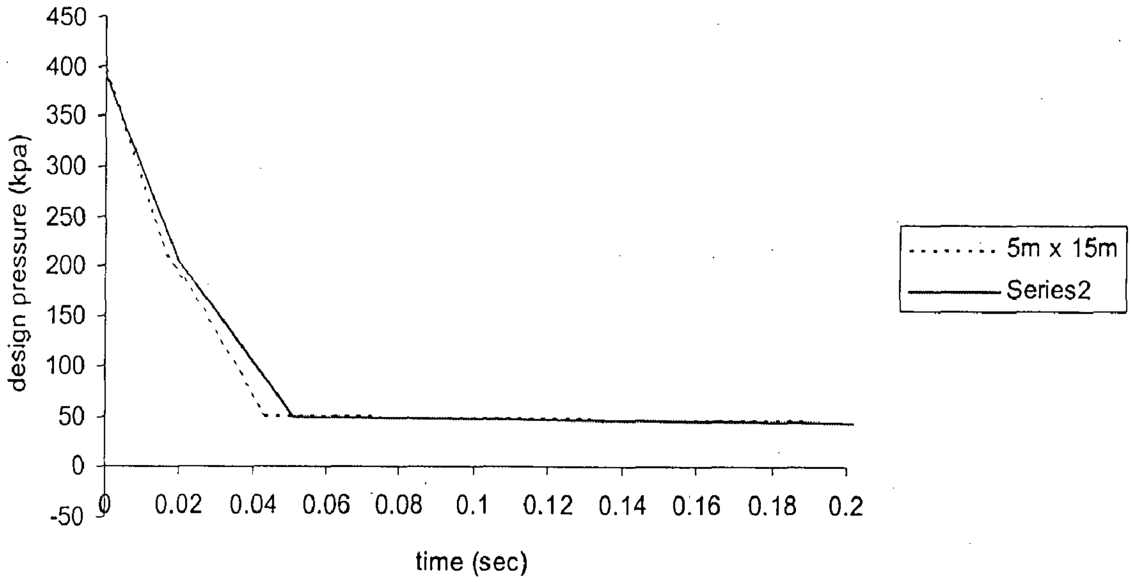


Figure 4.11 Comparison of Design Pressure for Breadth ratio of 1/3

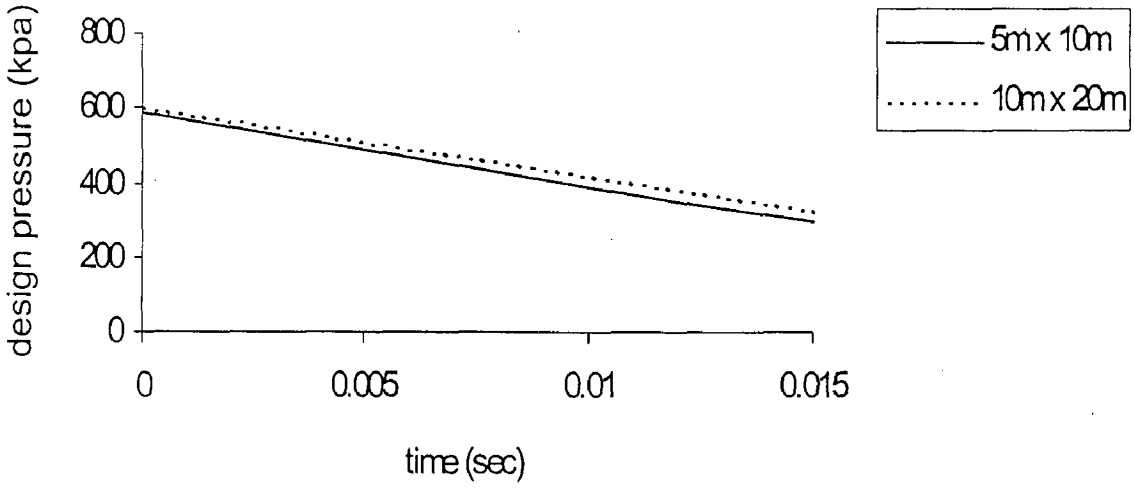


Figure 4.12 Comparison of Design Pressure for same B/L ratio

Figure 4.13 Comparison of Response of structure for different alignement

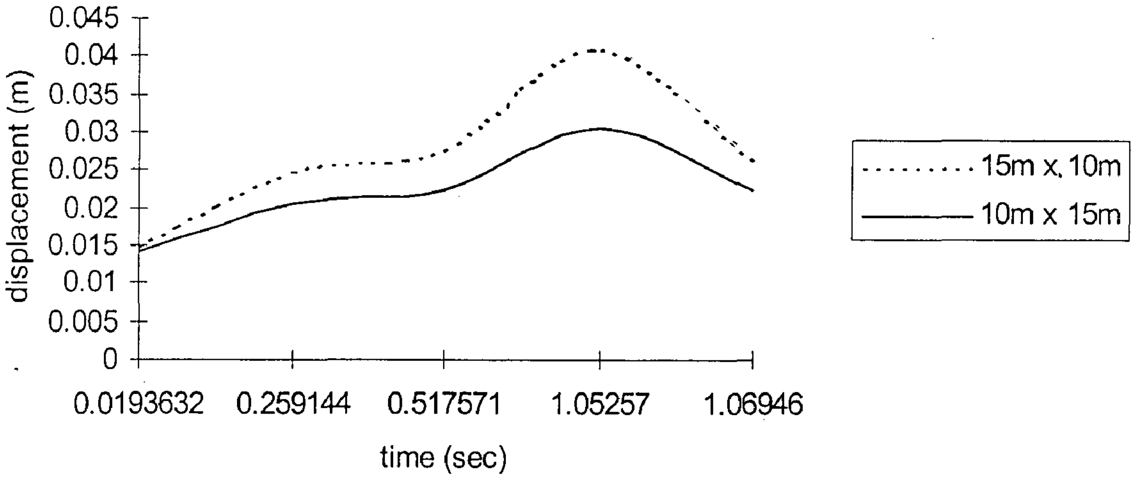
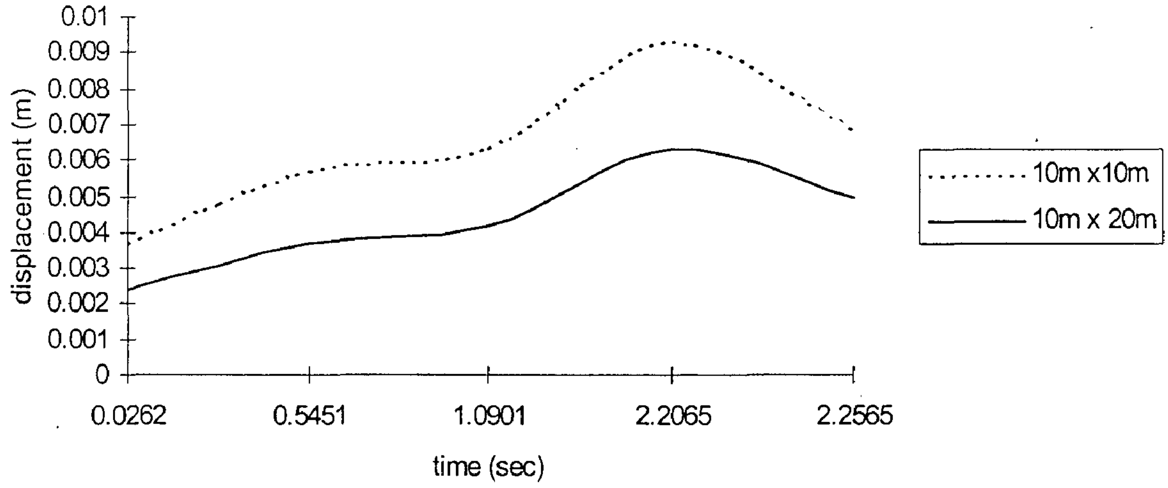


Figure 4.14 Comparison of response for length ratio of 1/2



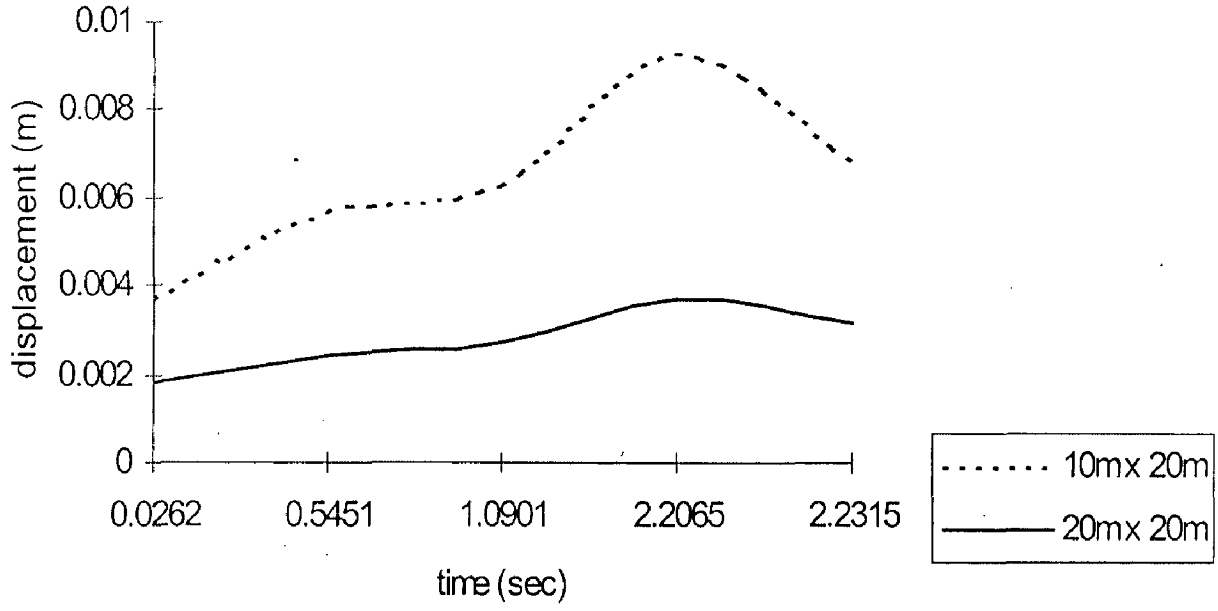
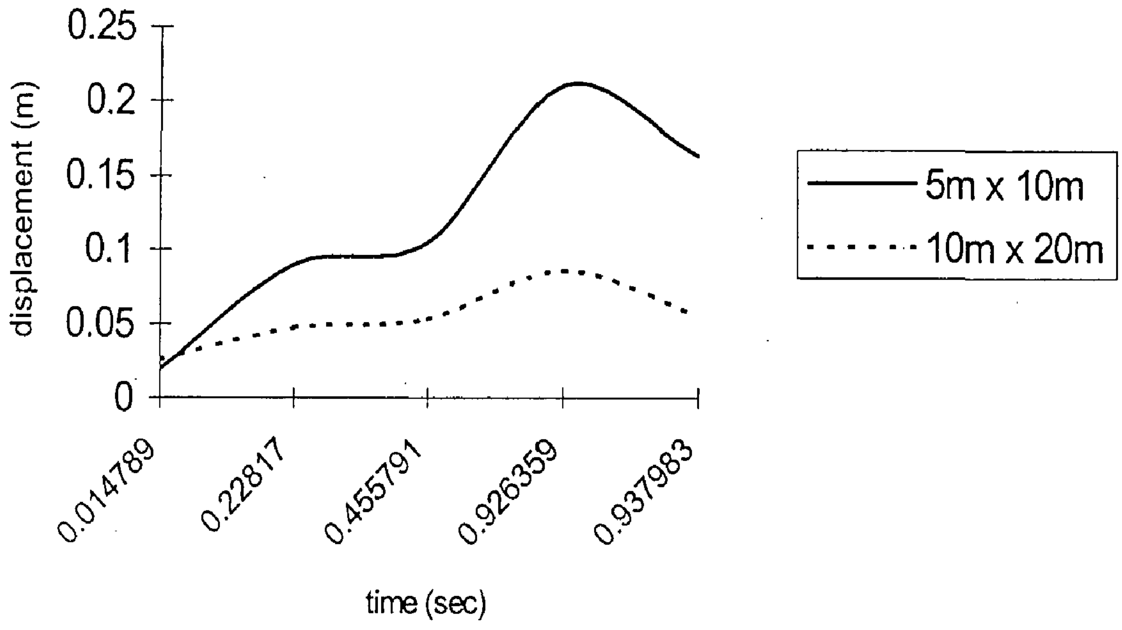


Figure 4.15 Comparison of Reponse of structure for Breadth ratio of 1/2

Figure 4.16 Comparison of response for same B/L ratio



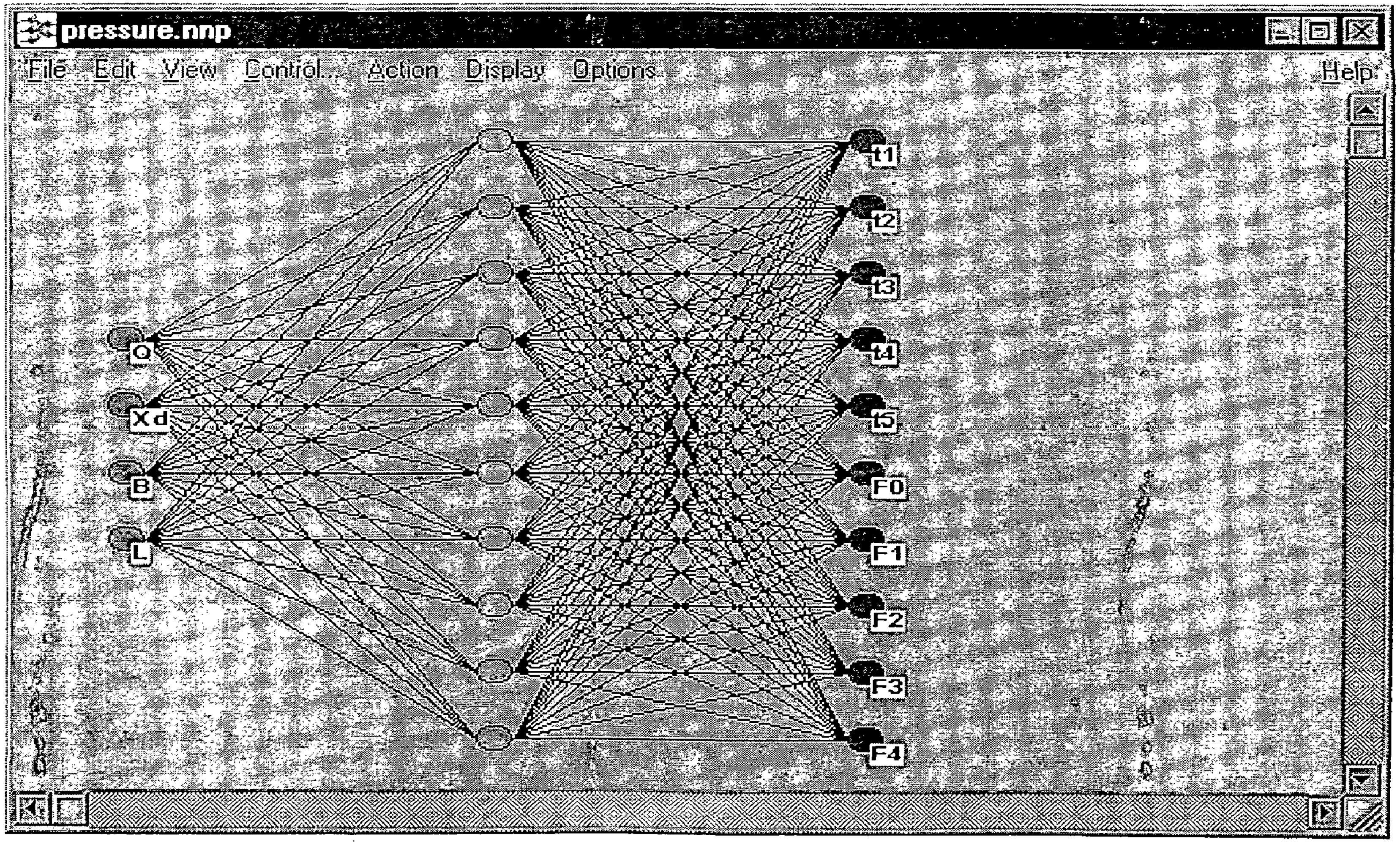


Figure 3.1 Pressure Net

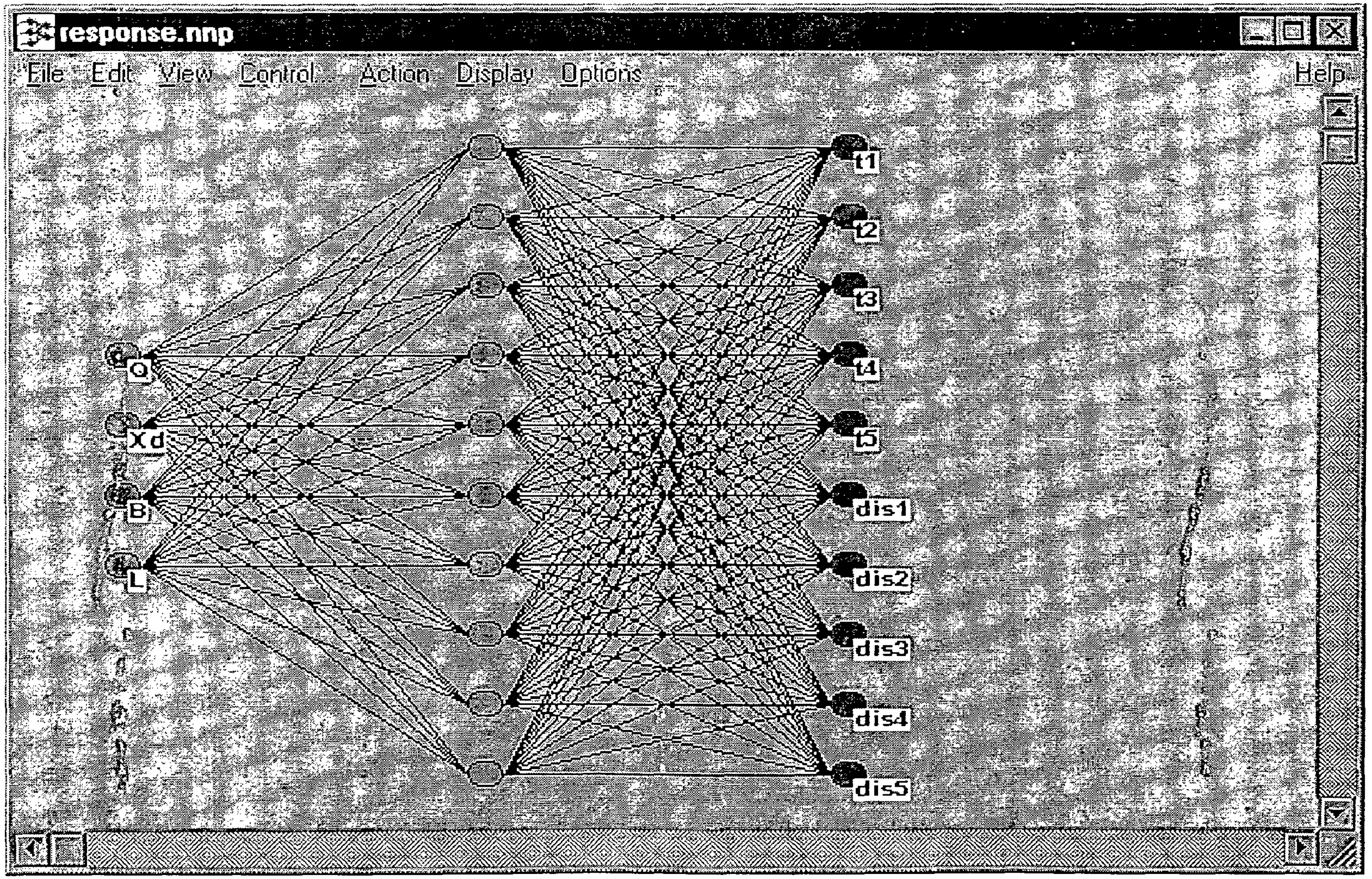


Figure 3.2 Response Net

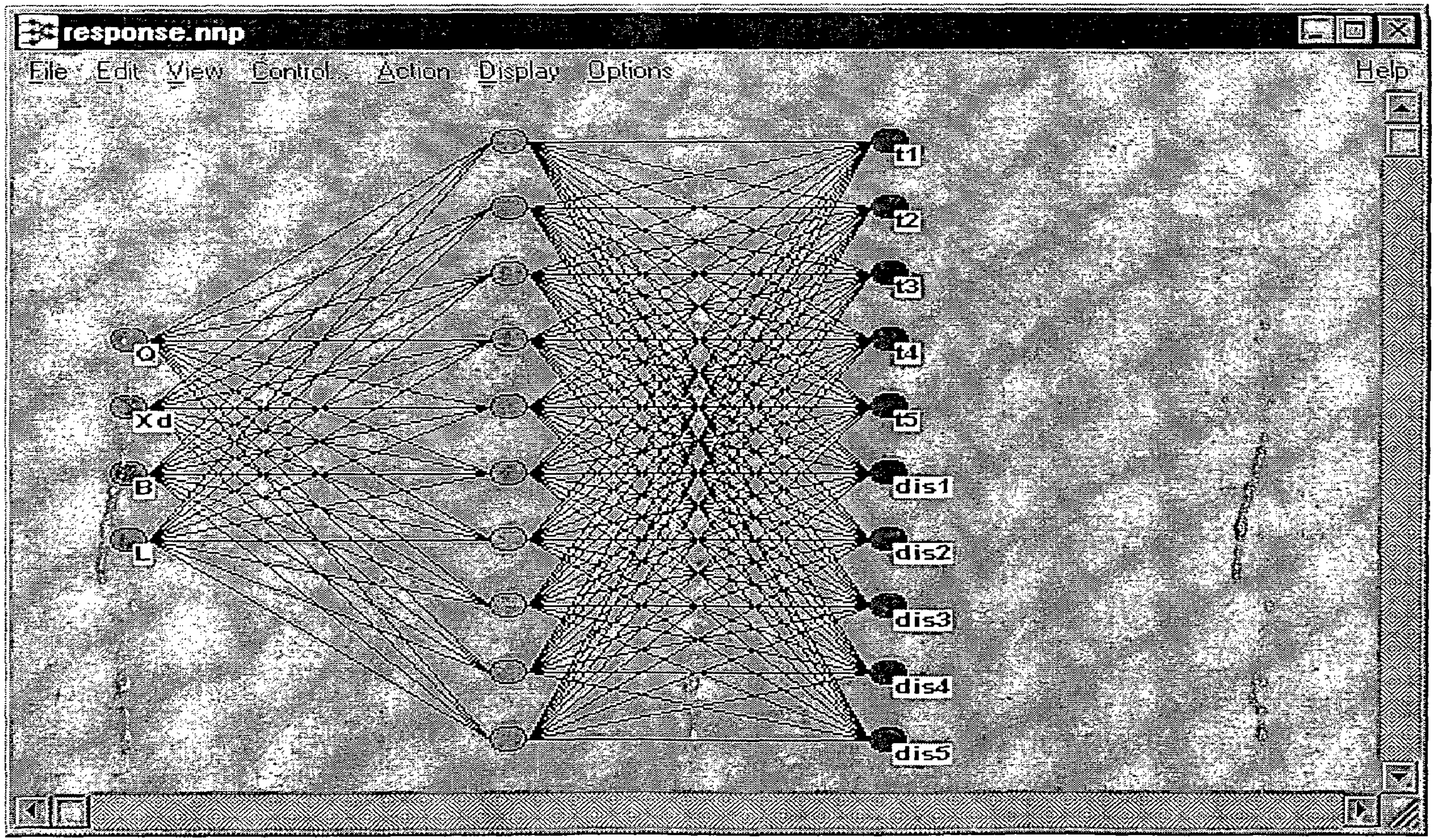


Figure 3.2 Response Net

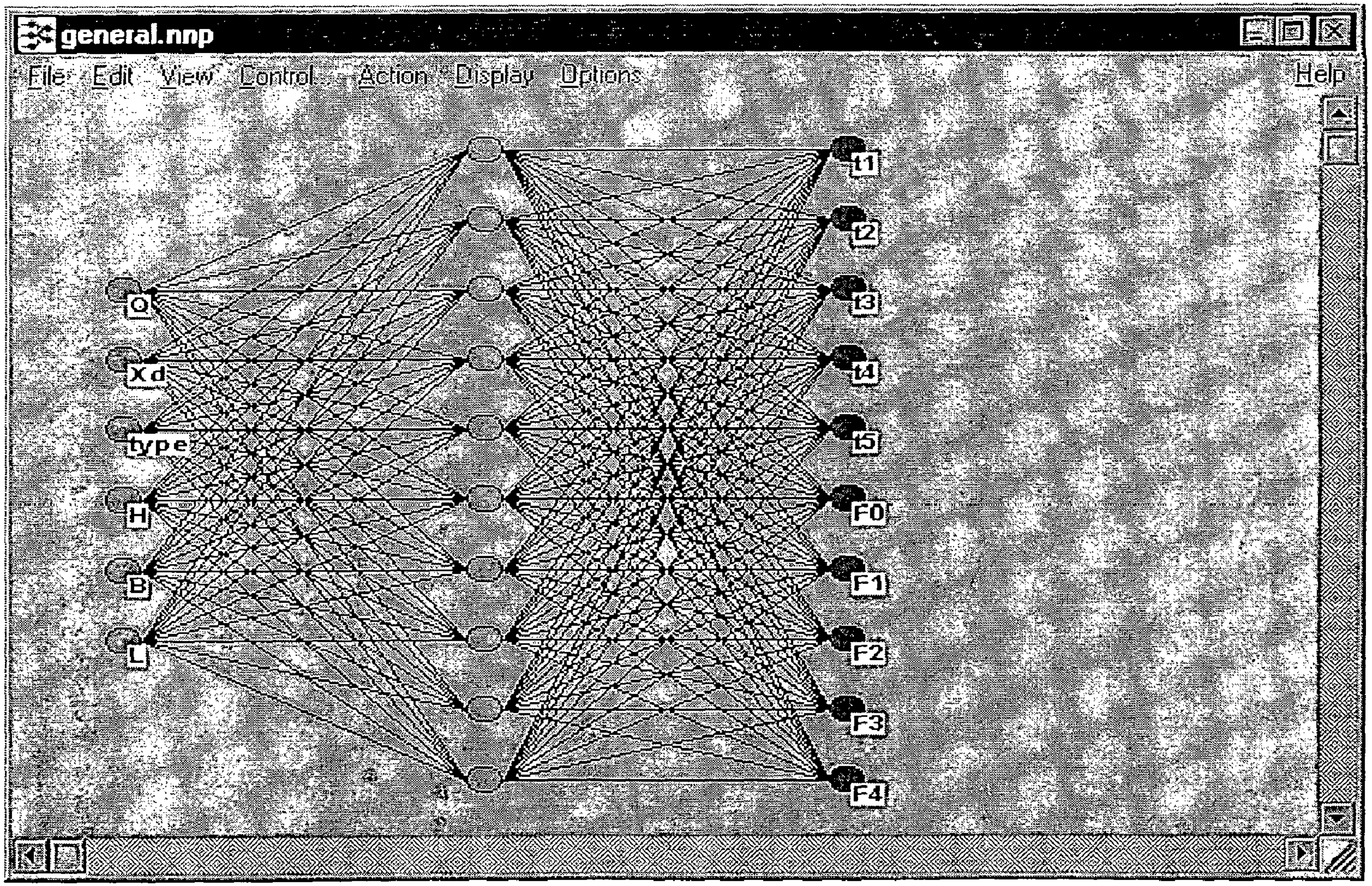


Figure 3.3 General Net

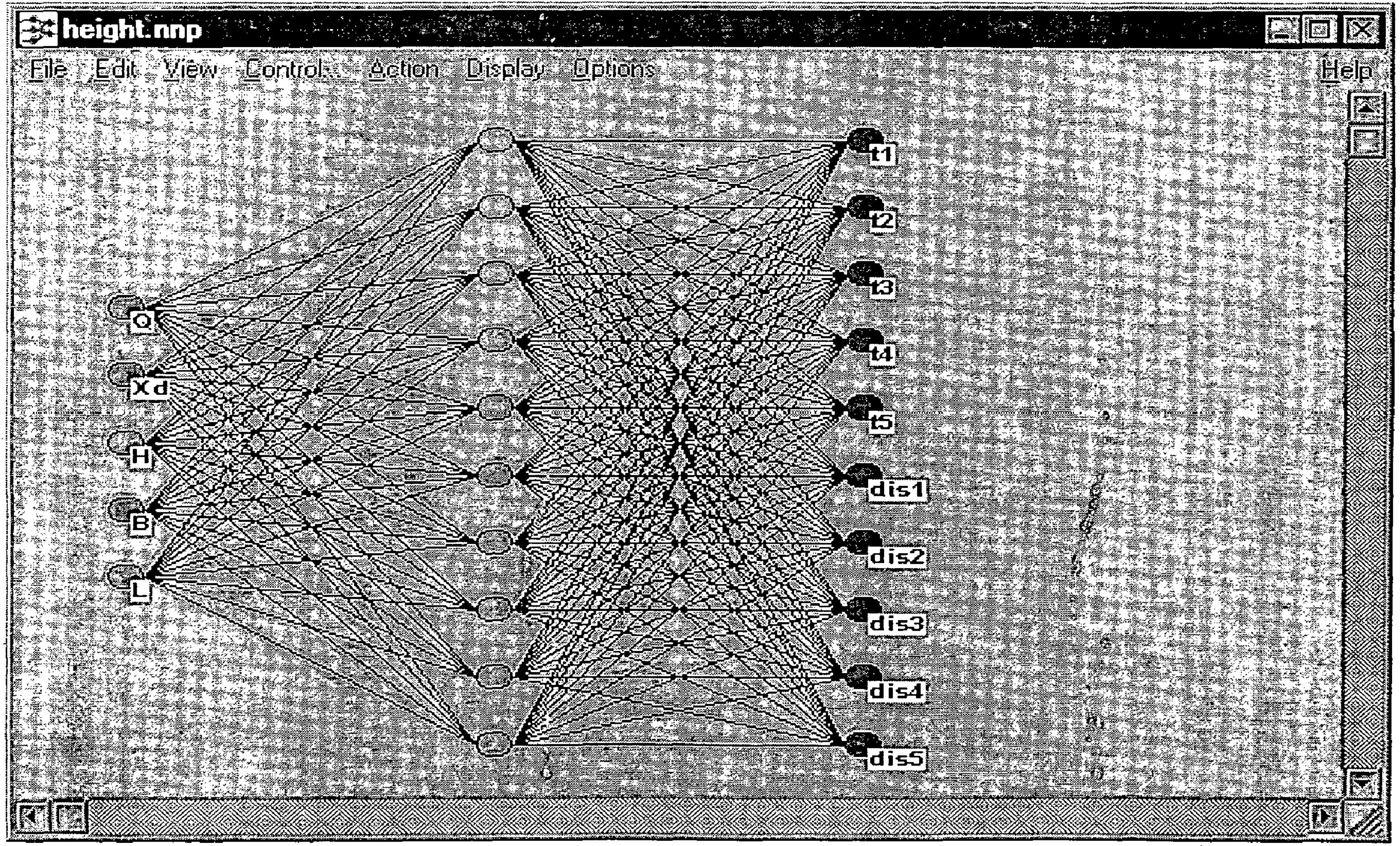


Figure 3.4 Height Net

APPENDIX

Structural Configuration

Closed rectangular or square type of structure is considered with thickness of wall as 30 cm and Inertia is calculated by considering the structure as an annulus with interior dimension equal to outer dimension minus two times the thickness of the wall considered. Mass of the structure is taken as 0.95(E)(Volume of Structure)

Stiffness of the Structure is taken as $12EI/h^3$.

Damping of the structure is taken as 2% of critical damping