EXPERT SYSTEM FOR SEISMIC RESISTANT ANALYSIS AND DESIGN OF ELEVATED WATER TANK

A DISSERTATION

submitted in partial fulfilment of the requirements for the award of the degree

of

MASTER OF ENGINEERING

in

EARTHQUAKE ENGINEERING

(With Specialization in Structural Dynamics)

By

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CANDIDATE'S DECLARATION

I here by certify that the work which is being presented in this dissertation titled **"EXPERT SYSTEM FOR SEISMIC RESISTANT ANALYSIS AND DESIGN OF ELEVATED WATER TANK"**, in partial fulfilment of the requirements for the award of the degree of MASTER OF ENGINEERING in earthquake engineering with specialisation in Structural Dynamics, submitted to the Department of Earthquake Engineering, University of Roorkee, Roorkee, India is the record of my own work carried out during the period from August 1998 to February 1999 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.

Date:

Place: Roorkee.

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This is to certify that the above statements made by the candidate are correct to the best of my knowledge.

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J. Phani Prabhatkar

(J. PHANI PRABHATKAR)

ABSTRACT

Artificial intelligence has two important applications in the field of Engineering analysis and design. They are expert systems and Neural Networks. Expert systems are computer programs that emulate the behaviour of a human expert within a specific domain of knowledge. A neural network is a computational model that is a directed graph composed of nodes and connections between the nodes which replicate the working of human brain. The ideal application of these two tools are for solving problems which require levels of expertise that is not always available and which have imprecise data.

The design codes provide the guide lines for analysis and design of civil engineering structures. The knowledge in the design codes is usually widespread and ill structured which in turn means obtaining the necessary information is a tedious job. The knowledge in the field of civil engineering design is gained through experience. So, the information available for the analysis and design is meagre and ill structured. Thus expert systems and neural networks can prove to be effective tools for civil engineering analysis and design.

In this dissertation seismic analysis and design of an elevated intze water tank has been examined in depth for the applicability of AI tools and techniques. The problem of analysis and design of intze tank has been dealt with using both the techniques of AI i.e. expert systems for replacement of decision making and neural networks for simulating analytical and design processes.

In the first part "ESETAD" expert system for elevated tank analysis and design has been developed which assists the user in step-by-step analysis and design of intze water tank. For the analysis and design of various components of tank modules have been written in C++. The knowledge bases of this package have been derived from IS:1893-1984 and IS:875-1987 and standard literature partially based on thumb rules in existence. In the second part three neural network models have been developed which are for the dimensioning, analysis and design of the intze tank.

On the basis of comparison of results from conventional procedures and artificial neural networks it has been concluded that the use of expert systems and neural networks in the field of engineering analysis and design can eliminate rigorous conventional procedures with acceptable accuracy.

CONTENTS

CHAPTER1

INTRODUCTION

1.1 GENERAL

In the past there were several computer based technologies which have provided effective tools for the development of useful large scale programs in almost every field of engineering right from the conceptual stage of a project to the execution and maintenance stage. These tools assist engineers in carrying out the projects in a systematic step-by-step procedure.

The methods of computer based technologies have been based on the laws of quantitative knowledge, which make it possible to formulate problem governing equations and to work out analytical or numerical solution techniques for them. Apart form the science of quantitative knowledge it has been found for solving large compound problems the art of qualitative knowledge is a must. The common algorithmic procedures which are used extensively for solving problems which deal with quantitative aspects of engineering suffer setback when it comes to solving problems with random or imprecise data , heuristic and ill-structured information. So, the tools that have been developed based on common algorithmic procedures are clearly not adequate to deal with all engineering problems. And there is enough evidence that at least some of them may be treated more effectively by new computer methods. It is in this context Artificial Intelligence as a computer science comes into play. One of the prominent applications of artificial intelligence is knowledge based expert systems and have generated much excitement in the engineering community.

The solution strategy of a problem depends on it's complexity, some problems require more of symbolic processing with very less arithmetic processing and others vice versa. Expert systems are used predominantly in problems where there is more symbolic processing and less arithmetic processing. Most of the professional knowledge in civil engineering originates from experience and only a small part of it is suitable enough to convert into algorithms. The design codes which provide guidelines for an engineer to design, execute and maintain civil engineering structures are a compilation of knowledge based on the long term experience of experts. The knowledge in these codes is often widespread and ill-structured.

So, the knowledge in the codes can be transferred into an easily accessible data base called knowledge base of an expert system so that a novice can come to a valid solution.

Intze tank, as we know, is an important civil engineering structure. This is usually used to satisfy water demands for capacities ranging from 200 kilo litres to 2000 kilo litres. This dissertation addresses the problem of seismic analysis and design of an intze water tank, it's staging and foundation. The intze tank container involves the problem of analysing and designing the domical roof, vertical wall, ring beams, conical dome and bottom roof dome. In the past several expert systems have been developed in the field of earthquake engineering for seismic risk evaluation earthquake resistant design of buildings, seismic hazard evaluation, dynamic structural response analysis etc.

1.2 ABOUT THE DISSERTATION

In this dissertation the prominent techniques of Artificial Intelligence i.e., expert system and neural networks have been used for the seismic analysis and design of a intze water tank. In the first part of the dissertation "ESETAD" expert system for elevated tank analysis and design has been developed For this purpose various program modules have been developed in C++ language. The modules have been interfaced with an expert system shell-EXSYS. For developing the knowledge bases IS:1893-1984 and IS:875-1987 and various standard literature have been used.

In the second part of the dissertation three neural network models have been developed. They are

1. Given the input parameters neural network for the dimensioning of the various components of tank
2. Given the input parameters neural network for the analysis of the various components of tank.
3. Given the input parameters neural network for the design of the various components of tank.

The dissertation is organised into seven chapters chapter 2 gives methods of analysis and design of intze water tank. Chapter 3 gives about the Artificial Intelligence techniques in engineering analysis and design. It gives description about expert system components and techniques involved in developing them. It also gives description of neural network models and their usage in engineering analysis and design.

In chapter 4, information about expert system development package EXSYS is given, with the instructions how to use this package to develop knowledge base of an expert system. Chapter 5 deals with the development of the knowledge base of an expert system "ESETAD" using IS:1893-1984 and IS:875-1987 as well as the development of program modules for the analysis and design of various components of intze water tank. Chapter 6 deals with the parametric study conducted to examine the effect of various seismic and wind zones on the economy of the various components of intze water tank. It also deals with development of neural network models for the dimensions, analysis and design of intze tank. Results have been discussed in detail.

In the last chapter conclusions have been given and plausible future scope of work has been discussed.

CHAPTER 2

METHODS OF ANALYSIS AND DESIGN OF INTZE TANK

2.1 GENERAL

Container of the Intze water tank has been analysed by using the membrane analysis. The column has been analysed by approximate method. Annular raft foundation has been provided which is analysed by approximate methods. Design of various elements have been carried out according to various codal provisions.

2.2 CONTAINER

2.2.1 COMPUTATION OF DIMENSIONS OF CONTAINER

Following are the economic proportions of the container of the Intze tank proposed by various experts based on experience in the engineering field.

Dimensions of the Container	Dimensions as recommended by Sushil Kumar	Dimensions as recommended by Ramamrutam	Dimensions as recommended by B.C.Punmia
H_1	0.125 D	0.16 D	0.13 D
H_2	0.667 D	0.50 D	0.667 D
D_0	0.625 D	0.60 D	0.625 D
H_3	0.1875 D	0.16 D	0.1875 D
H_4	0.125D	0.13 D	0.125 D

Where 'D' is the diameter of the Intze Tank. Given the capacity of the container the diameter of the Intze Tank can be calculated as [15].

$$V = \pi/4 \times D^2 H_2 + \pi H_3/12\left(D^2 + D_0^2 + DD_0\right) - \pi H_4^2/3\left(3R_2 - H_4\right) \qquad (2.1)$$

Where

'H_1' height of top dome in m.

'H_2' height of cylindrical wall in m.

'H_3' height of conical dome in m

'H_4' height of bottom spherical dome in m

'D_0' diameter of bottom circular beam in m

'R_2' radius bottom spherical dome in m.

Where R_2 can be calculated using the formula in terms of diameter of the tank.

$$0.125D(2R_2 - 0.125D) = D_0^2/4 \quad (2.2)$$

knowing R_2 the capacity of the tank is calculated in terms of D. And there by calculate the diameter and various dimensions of the container.

Once the dimensions of the container are known the various components of the Intze tank are analysed using the membrane analysis as follows:

2.2.2 MEMBRANE ANALYSIS AND DESIGN

2.2.2.1 TOP DOME

The meridional thrust at edge of the top dome (N_{mt}) is given by :

$$N_{mt} = W_1 \times R_1 /(1+\cos\alpha_1) \quad kN/m \quad (2.3)$$

where,

W_1 is the sum of dead load and live load on the top dome in Kn/m^2.

R_1, is radius of the top dome in m

α_1, semi central angle of top dome in radians.

Hoop tension in top dome (N_{t1}) is given by

$$N_{t1} = W_1 \times R_1[\cos\alpha_1 - 1/1 + \cos\alpha_1] \quad kN/m \quad (2.4)$$

The thickness t_1 of the top dome is assumed according IS:3370 but in any case a minimum of 80 mm need to be provided. The computed hoop stress and meridional stress in the concrete should be within the permissible limits in all elements. The area of steel can be determined as per IS: 3370. But minimum reinforcement 0.3 of the area for mild steel bars should be provided.

Horizontal thrust from top dome (R_{t1}) is given by

$$R_{t1} = N_{mt} \cos \alpha_1 \quad kN/m \tag{2.5}$$

2.2.2.2 TOP RING BEAM

The purpose of providing top ring beam is to resist the horizontal component of the meridional thrust of the top dome.

Hoop tension in the top ring beam (N_{t2}) is given by:

$$N_{t2} = R_{t1} D/2 \quad kN/m \tag{2.6}$$

2.2.2.3 CYLINDRICAL WALL

The cylindrical wall is designed to resist the hoop tension caused by the hydrostatic pressure which varies with depth of water. Hoop tension at bottom of cylindrical wall (N_{t3}) is given by :

$$N_{t3} = (\rho_w . H_2 .D) /2 \quad kN/m \tag{2.7}$$

ρ_w is the unit weight of water in kN/m^3

2.2.2.4 MIDDLE RING BEAM

The purpose of the middle ring beam is to provide a horizontal support to the conical dome.

Hoop tension in the middle ring beam is given by

$$N_{t4} = (W_{13}) (\tan \alpha_1) (D) /2 + (p_3) (H_2) (DRB) (D) /2 \quad kN/m \tag{2.8}$$

where,

W_{13} = total load transferred to the conical wall at top in kN.

H_2 = Height of cylindrical wall in m.

DRB = Assumed depth of middle ring beam in m.

2.2.2.5 CONICAL DOME

The meridional thrust in the slab of the conical dome (N_{mc}) is given by

$$N_{mc} = W_{14} / \pi D_0 . \cos\theta \quad kN \tag{2.9}$$

Hoop tension at top of conical dome (N_{t5}) is given by

$N_{t5} = [\rho_w \, (H_2) / \text{Cos}\theta + W_4 \, \text{Tan}\,\theta \,] \, (D_0/2)$ kN/m (2.10)

W_4 = weight conical dome slab in kN per square meter

H_2 = Height of cylindrical wall in m, θ is the angle of conical dome with horizontal

Hoop tension at bottom of conical dome (N_{t6}) is given by

$$N_{t6} = \left[\rho_w \left(H_2 + H_3\right) / \text{Cos}\theta + W_4 + \text{Tan}\theta\right]\left(D_0 + 2.38 H_3\right) / 2 \quad \text{kN/m} \quad (2.11)$$

where,

H_3 = height of conical dome slab in m

D_0 = Diameter at the bottom of conical dome slab in m.

Inward radial thrust from conical dome at bottom junction(R_{t2}) is given by

$R_{t2} = W_{14} / \pi D_0 \text{Tan}\theta$ kN/m (2.12)

2.2.2.6 BOTTOM DOME

The meridional thrust at edges of the bottom dome (N_{mb}) is given by

$N_{mb} = W_{15} / \pi \, D_0 \, \text{Sin}\, \alpha_2$ kN/m (2.13)

Where,

α_2 = Semi central angle of bottom dome

W_{15} = Total weight on the bottom dome

Outward radial thrust form bottom dome is given by :

$R_{t3} = N_{m2} \, \text{Cos}\alpha_2$ kN/m (2.14)

The net thrust at bottom junction from conical and bottom dome (R_t) is given by:

$R_t = R_{t2} - R_{t3}$ kN/m (2.15)

2.2.3 BOTTOM RING BEAM

The bottom ring beam is subjected to the total vertical load of the container and the water including self weight of the beam in the vertical direction. In addition it is also subjected to a radial force which is the difference of the horizontal components of the meridional thrusts from the conical shell polygon and the bottom dome. The bottom ring beam is analysed as beam curved in plan and continuous over column supports.

Bottom ring beam can be designed as singly reinforced beam when the moment of resistance of the assumed section is greater than or equal to the equivalent bending moment and designed as doubly reinforced beam when the moment of resistance of the assumed section is less than the equivalent bending moment as per IS:456-1978. The design is based on working stress method.

For the shear design, the equivalent nominal shear stress should not exceed the value of maximum shear stress given as in IS: 456-1978. If the equivalent nominal shear stress does not exceed permissible shear stress given in IS:456-1978 table 17, maximum shear reinforcement should be provided as per IS:456-1978 clause 2.5.5.1.6. If the equivalent nominal shear stress exceeds permissible shear stress given in table 17 of IS:456-1978, shear reinforcement shall be provided as per IS:456-1978 clause 4.7.4. But maximum spacing of shear reinforcement should be provided as per IS:456-1978 clause 2.5.5.1.5.

2.3 COLUMNS AND BRACES

The total forces acting on the columns of the tower, due to various causes are

1. Vertical loads due to weight of tank, water and the columns equally divided among all columns. This will cause axial thrust in each of the columns
2. Bending moments in the columns due to wind or earthquake force on the tank and the columns themselves this is critical for columns lying on the bending axis.
3. Axial forces in the columns due to wind or earthquake force on the tank and the columns.
4. This is critical for columns lying farthest from bending axis of tower.
5. Shear force in the columns due to wind or earthquake pressure.

In practice, the shear force is small and does not influence the design of column. The section adopted from other considerations is always safe in shear.

2.3.1 DESIGN OF COLUMNS

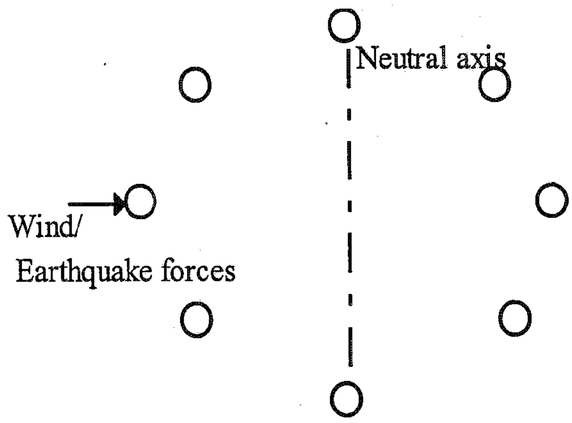
The columns are designed by analysing them with approximate methods. The following assumptions are made in the analysis

1. The braces are stiff enough to hold columns in position as well as in direction.
2. The points of contraflexure occurs at the mid points of the columns and braces

Let w be the total vertical load due to tank and it's contents above the staging. If n, be the number of columns

Total load on each column = W/n (2.16)

Add to this is the vertical force P due to wind or earthquake whichever is maximum.



$P = M\, r / \Sigma r^2$ (2.17)

where, M = Moment due to wind or earthquake force which ever is maximum about the base of columns, r is the distance from any column to the neutral axis.

Σr^2 is sum of squares of the distances form the neutral axis.

The wind force F_w is calculated by

$F_w = P\, A$ (2.18)

where, P is the basic wind pressure in N/m^2, A is the exposed area in sq.m

The vertical load to be considered for calculating seismic force

$W_e = W_0 + 1/3\ (W_s)$ (2.19)

where, W_0 is weight of the tank including weight of water, W_s is weight of the staging

The design seismic coefficient is given by

$\alpha_h = \beta\, I\, \alpha_0$ (2.20)

where, β is coefficient of soil foundation system, I is the importance factor for the structure, α_0 is seismic zone factor

By taking the value of I and β as 1.5 and 1.0 respectively, the value of α_h, can be obtained for the different seismic zones.

Thus the effective lateral load due to earthquake may be calculated as $W_{EQ} = \alpha_h.\ W_E$

The analysis can be done for empty case also. For this purpose

$W_0 = W_0$ – Weight of water in the tank.

2.4 FOUNDATION

The foundation transfers the load of the superstructure to the soil. The feasible foundations for over head tanks are raft foundations consisting of ring beam connecting to all the columns and raft slab.

2.4.1 RING BEAM

The columns of the staging are connected by a ring beam at the bottom. The design of this beam similar to the bottom ring beam. The only difference is in the loading. The ring beam is designed for the total load on the bottom ring beam plus weight of staging distributed on it's length.

2.4.2 ANNULAR RAFT SLAB

2.4.2.1 GEOMETRY

Consider a foundation which is in the form of a circular raft slab, which projects equidistant on either side of a circular ring beam which will connect all the columns at their base. Let the outer and inner diameters of the raft slab be a and b respectively.

Then Area of the slab(A) = $\pi/4\ (a^2 - b^2)$ sq.m (2.21)

A must be greater than the required area of raft slab which is calculated from bearing capacity criterion.

2.4.2.2 ANALYSIS OF RAFT

The raft slab is designed for the bending moment due to net upward pressure (N_{UP}) of the soil below the slab.

$$N_{UP} = \frac{T_{mlf}}{\pi . DRB} \quad N/m \qquad (2.22)$$

where, T_{mlf} total maximum load on the foundation, DRB is diameter of the ring beam

The bending moment in the raft slab is calculated by

Bending Moment = $WL^2/2$ (2.23)

L is max. projection of raft slab on either face of circular ring beam

CHAPTER 3

ARTIFICIAL INTELLIGENCE IN ENGINEERING ANALYSIS AND DESIGN

3.1 INTRODUCTION

Artificial Intelligence is a branch of computer science that is involved in simulation of human brain through software and hardware . One of the widely accepted definition of AI is that proposed by Marvin Minsky in 1968. According to him "Artificial Intelligence is the science of making machines do things that would require intelligence if done by man". The systems pertaining to AI are capable of reasoning and inference based on the existing knowledge. An artificial intelligence system is not only capable of acquiring, representing and manipulating data but it is also capable of acquiring, representing and manipulating knowledge. This ability permits an AI system to deduce new knowledge and new relationships based on the facts and concepts from the existing knowledge and to use representation and manipulation skills to solve complex problems. Some of the essential features of AI are:

- Response to situations.
- Making sense out of ambiguous or contradictory message.
- Recognise the relative importance of different elements of a situation.
- Draw distinctions between situations despite similarities which may link them.
- Find similarities between situations despite differences which may separate them.

In artificial intelligence, the program control is generally not a predefined, step-by-step procedure in which order is important. It is more of a trial and error procedure in which searches are made of a space of candidate solutions and heuristics are used to prune the combinational growth that occurs in most complex real world searches.

3.2 APPLICATIONS OF ARTIFICIAL INTELLIGENCE

Because of the versatile nature of artificial intelligence, it can be tailored to suit the needs of numerous fields, wherever there is uncertainty this technique can be applied effectively. Though algorithmic process guarantees the solution it cannot be applied to problems with uncertain and ambiguous data. On the other hand, AI may give partial or no solution. It is fit for solutions in the case of disorganised and random data. The concept of artificial intelligence can be used in various forms for different fields of interest.

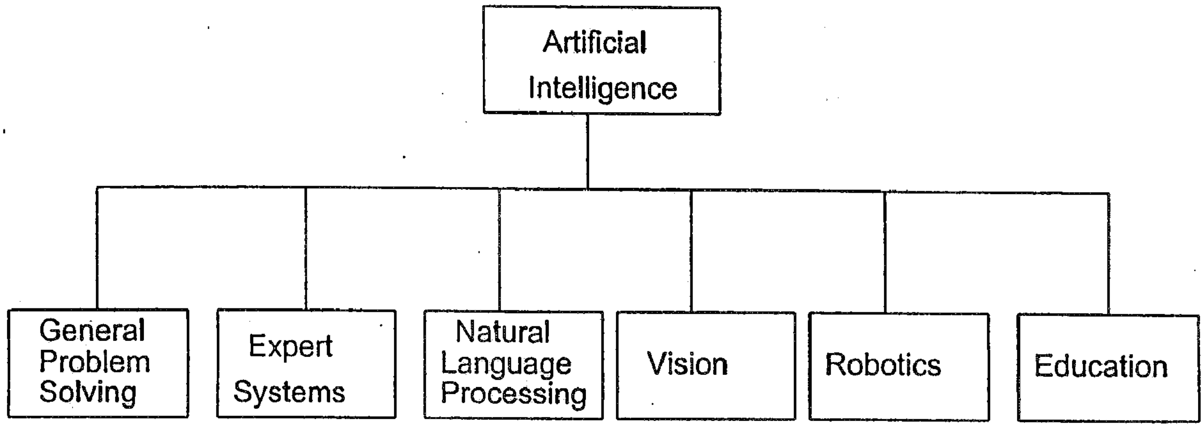


Fig 3.1 The major applications areas of artificial intelligence.

Out of these, expert systems and neural networks have wide ranging applications in the field of engineering. They are highly useful in dealing with problems with earthquake engineering given the highly uncertain nature of an earthquake event. In general, the problems where the AI techniques are highly useful are classification, diagnosis, simulation, monitoring, analysis, planning and design. It can be seen that these problems lie in the derivation-formation spectrum, with the classification type of problems in the derivation end of the spectrum and design in the formation end. The relative positions are as shown in the figure 3.2.

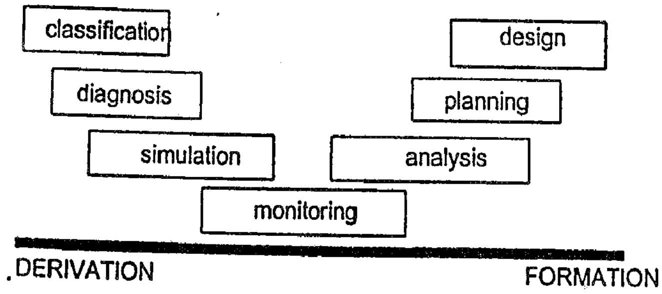


Fig 3.2 Derivation-Formation spectrum of Problem Classes

3.3 EXPERTSYSTEMS

Expert systems are arguably most successful and lucrative result of research in Artificial Intelligence. Expert systems are software programs that emulates the behaviour of a human expert within a specific domain of knowledge. The working of expert systems is like that of human experts whose expertise and training in a particular field equips them do in an efficient manner.

There is no universal, accepted definition for an expert system out of the many definitions the early definition given by Gashing et al states: "An expert system is an interactive computer program incorporating judgement, human experience, rules of thumb and other expertise to provide knowledgeable advice about a variety of tasks". The main objective of an expert system is to store the knowledge of one or more experts in the concerned field in an easily accessible database so as to permit even a tyro to reach a logical solution which would be acceptable. It essentially consists of three major components a user interface, an interface engine and a knowledge base.

3.3.1. KNOWLEDGE BASE

The most important aspect of an expert system is it's knowledge base. The efficiency of an expert system entirely depends on the knowledge base, the greater the size and quality of the knowledge base the more is the system performance in problem solving .The knowledge base contains both the declarative knowledge and procedural knowledge, the declarative knowledge has the information such as facts about objects, events and situations where as the procedural knowledge has the information about the course of action. The declarative knowledge is represented through logic, semantic networks and frames. The procedural knowledge representation includes production rules. A key element in an expert system is the software which provides the way for entering knowledge into the knowledge base and for checking, modifying and updating it. This is known as "Knowledge Interface". The creation of the software is done by a specialist "Knowledge Engineer", experienced in the creation of knowledge bases. He or She would interview experts in the subject of the knowledge base and reinterpret their answers in a form of suitable entry into knowledge base.

3.3.2. WORKING MEMORY

A collection of facts which represent the current state of the problem at hand, it consists of information input and immediate solutions generated . The working memory builds up dynamically during the solution process of a particular problem and is manipulated by the inference mechanism to determine the next step in the solution of the problem.

3.3.3 INFERENCE ENGINE

The inference engine is the software which analyses facts and draws conclusions from the relationships which exist between facts and rules and as present in the data base. The inference engine which is nothing but the implementation of one or more inference strategies , carries out search through the knowledge base either to prove hypothesis or to arrive at a conclusion. The inference strategy is generally provided by programming environment and contains no domain specific knowledge. The inferencing strategy is selected depending on the type of the problem to be solved and the kind of knowledge contained in the knowledge base. The purpose of various inferencing strategies is to arrive at a solution for the given problem, by conducting exhaustive searches through the knowledge network, implemented either in the form of rule base or a combination of rule base and semantic network. There are two basic approaches for this, 1) Blind search, 2) Heurestic search.

3.3.3.1. BLIND SEARCH

It is a collection of procedures used to search a state space. Beginning at root node operators are used to generate success or states. The search continues till a solution is found. The idea behind blind search is to examine the entire tree in an orderly manner. Starting from root node there are several procedures to reach the goal, but the procedures may be inefficient and time consuming. Hence for large problems they may totally be discarded and modified approaches like heuristic search may be applied. The different procedures for blind search are -

3.3.3.1.1. Breadth first search

A breadth first search examines all the nodes in a search tree, beginning with the root node. The nodes at each level are completely examined before moving to the next level. The process usually start at the initial state node and works downward in the tree from left to right.

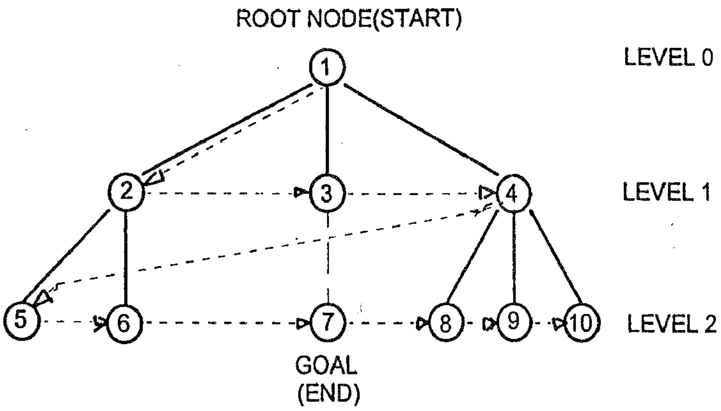


Fig 3.3 Breadth First Search

3.3.3.1.2. Depth first search

This kind of search begins at the parent or root node and works downward to successively deeper levels. The successor node is generated by the parent node and the process continues until a goal is reached or a dead end is reached. The depth first search guarantees a solution but the search may be too long. Also the search may lead through deeper sub networks though goal is at a higher level. To avoid this problem most depth first searches are accompanied with a depth limit. Such a search is known to be depth bound and allows search to specific level.

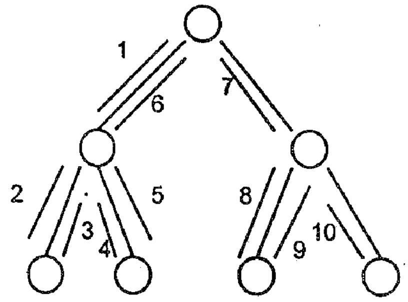


Fig 3.4 Depth First search

3.3.3.1.3. Forward and backward chaining

For a real problem it is not necessary to have single starting point. The problem may be defined in such a way that the search for a solution can begin at any one of several different entry points and there may be two or more starting points. The process of working from the initial state to goal state is known as forward chaining. A forward search process is said to be data driven and it is a kind of inferential reasoning. The process in which the search is started from goal state and work backwards towards initial state is known as backward chaining. This process is said to be goal directed and it is a kind of inductive reasoning. In practice both forward and backward chaining are used, the choice of which depends on the shape of the search space. If there are more possible outcomes than initial states, the backward chaining is faster. On the other hand if there are more initial states than goal states the forward chaining is faster. The above search techniques are used in combination with each other and the combination is chosen so as to optimise the search process for a given problem.

3.3.3.2. HEURISTIC SEARCH

A heuristic is a rule of thumb that helps the search to determine how to proceed. Actually heuristic search is a blind search that has been given some direction or guidance. The heuristics use experience and empirical knowledge to guide the search process which may lead to a faster more efficient solution.

3.3.4 USER INTERFACE

It is a language interface which allows the user to interact with the expert system, query it, obtain explanations from it and challenge it's results. It enables the interactive dialogue between the expert system and user.

3.4 KNOWLEDGE REPRESENTATION

The purpose of the knowledge representation is to organise the knowledge into a form such that all programs particularly expert systems access it for making decision, planning, recognise objects and situations, analysing scenes, drawing conclusions and other cognitive functions thus knowledge representation is central to expert system, computational vision, natural language and other areas of artificial intelligence. Knowledge representation schemes are broadly classified into declarative and procedural ones. Declarative refers to facts and assertions, while procedural refers to action.

3.4.1 RULE BASED KNOWLEDGE REPRESENTATION

In this scheme, the procedural knowledge in the form of heuristics " IF- THEN" is completely with the declarative knowledge. Each rule consists of a left - hand side called antecedent or condition and a right hand side called consequent. The two sides are separated by an arrow. The left hand side determines the applicability of the rule and the right hand side describes the actions to be taken if the conditions on the left hand side are satisfied. The general format of the knowledge represented as production rule is

IF .... THEN

ANTECEDENT.............CONSEQUENT

Because of the simplicity of this format and it's compatibility with the human thought process, this scheme has proved to be the most prevalent form of the knowledge representation and the expert systems whose knowledge has been organised using this scheme, are called production systems. The other versatile features of this scheme are modularity and modifiability.

3.4.2 FRAMES

Frames provide another method for representing facts and relationships. A frame is a table of information on a particular subject, containing individual entries called slots. Four types of slots may be incorporated into a frame, one type simply states a particular piece of information appropriate to subject. Another type a default slot will contain inevitable piece of information. A procedure attachment slot defines a routine to determine further information for the frame. Finally, a reference slot links the current frame with another which contains further relevant information.

3.4.3 SEMANTIC NETWORKS

Semantic networks features the notion of an explicit taxonomic hierarchy, a tree of lattice-like structure for categorising classes of things in the world being represented. The backbone of the hierarchy is provided by some sort of " inheritance" link between the representation object, known as "nodes". The semantic networks have the property of flexibility i.e. new nodes and links can be added and defined as and when required.

There are some difficulties with semantic networks, while they are proposed as a framework for knowledge representation there keystone construct the IS. A link has wavered considerably in its interpretation. This makes it difficult to understand what the net is really designed for and whether it was designed in a consistent manner. The difficulties also arise in the naming of the node.

3.5 DIFFERENCE OF KNOWLEDGE BASED EXPERT SYSTEMS FROM TRADITIONAL PROGRAMS

1. KBES differs form traditional programs made in FORTRAN, C, Pascal et in the sense that the knowledge of the system is separated from the algorithm that manipulates it.

2. KBES are quite transparent and friendly to the user where as the traditional programs are not. An expert system is able to tell the user why a certain information was needed or how a conclusion was reached.

3. The traditional algorithmic programs require a complete set of data to produce a unique solution, a KBES is conceptual in nature, can function with an in complete data and may produce several solutions, each with a varying degree of confidence or certainty.

4. A KBES allows the developer to check, modify and update the knowledge in the knowledge base without changing the algorithm that controls the knowledge.

3.6 ADVANTAGES OF EXPERT SYSTEMS

1. Expert systems can be used to solve problems when the problems are complex and ill-structured.

2. Expert systems are often cost effective when human expertise is very expensive not available or contradictory.

3. Expert systems can apply a systematic reasoning process with a very large knowledge base that is often much larger than a human expert retain or utilise.

4. The expert system is objective. It is not biased or prejudiced to a predetermined goal state, and it does not jump to conclusions.

3.7 DRAW BACKS OF EXPERT SYSTEM

1. Expert systems can never match intuitive human judgement.

2. They need to be considered as live systems that need amendment and maintenance.

3. They can never include common sense and emotion.

3.8 TOOLS FOR DEVELOPING EXPERT SYSTEM

The major cost associated with an expert system is usually the labour needed for development and maintenance. Computer hardware and soft ware should be carefully chosen with this in mind. Experience suggests that it is preferable to use a commercial package, if available, rather than writing one from scratch, as these tools felicitate the rapid production of a working system and also aid in the process of learning and concepts knowledge based expert system. They allow time to be spent for running and organising knowledge rather than production of inference mechanism from scratch. The software tools available for developing expert system can be divided into three classes, 1)Programming Languages: Programming languages are the translators of commands in a specified syntax.

a) General Purpose Programming Languages (GPPL)

C, FORTRAN, PASCAL, C++ etc. GPPL do not separate knowledge from the reasoning process. Although an inference mechanism can be built in these languages, it is not standard.

b) General Purpose Representational Languages (GPRL)

OPS 5, UNITS, SRLETC, offer less freedom to the user than the normal programming languages. The biggest disadvantage of these languages is their fixed control strategy. It is difficult to choose a control strategy depending on the problem.

2) Expert System Building Frame Works (Shells)

Shells are special purpose utility programs designed for certain type of applications can which the user need supping only the knowledge base. They come with a user interface, an inference mechanism and a knowledge acquisition facility. Also they are relatively in expensive, examples are EXSYS, GURU, VP, EXPERT.

A good approach can be start out by developing prototypes a shell and later switching to another tool.

3) Expert System Development Environments

Expert system development environments are meant to be complete development environments with sophisticated features seen as multiple knowledge representation techniques, integrated editors, debugging runtimes, user interface and other development facilities. However use is limited, as they require substantial investment of time to take advantage of their feature.

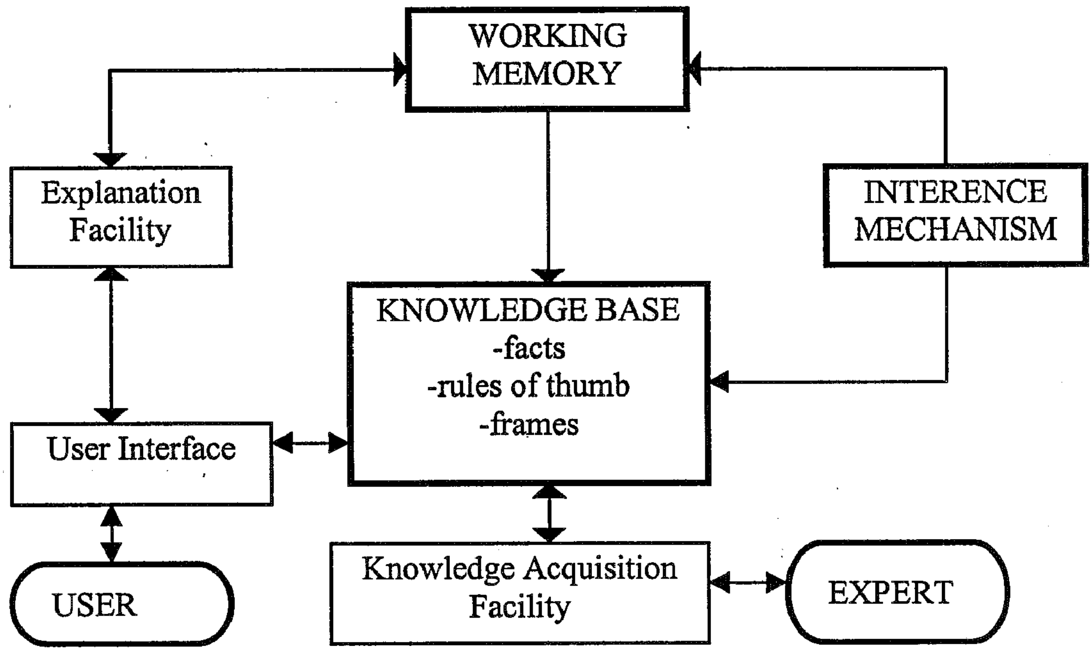


Fig 3.5 Architecture of an Expert system

3.9 NEURAL NETWORKS

A Neural Network is best defined as a set of simple, highly interconnected processing elements that are capable of learning the information presented them. These are new class of computers whose structure is similar to the biological structure of the brain and they copy the working of human brain. The human brain is built of cells called neurones. There are approximately 10^{11} neurones interconnected by approximately 10^{15} interconnections in the brain .

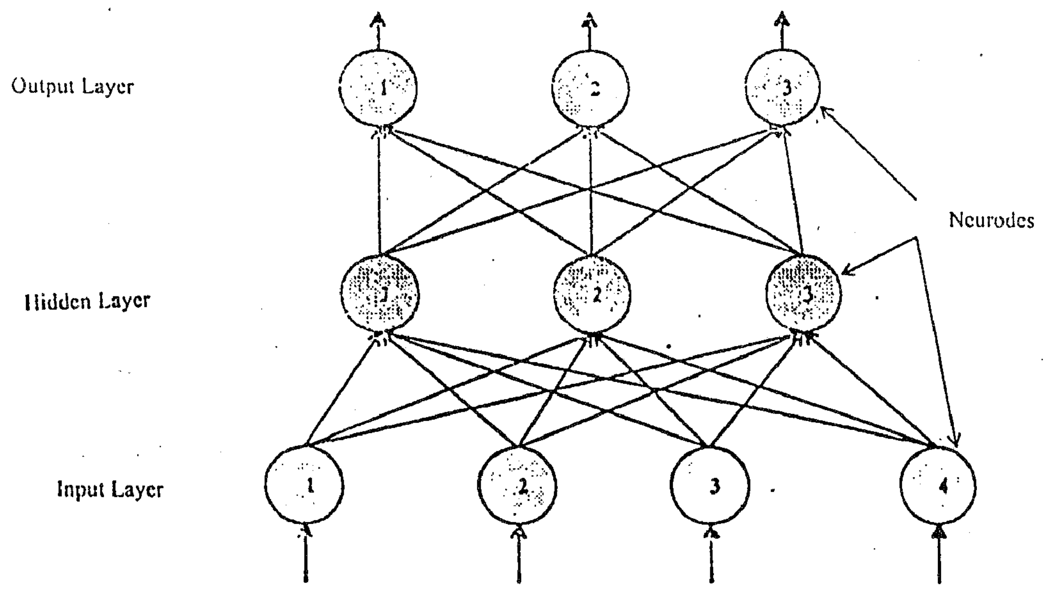


Fig 3.6 Typical neural network architecture

These neurones activate or inhibit the fixing of the other neurones whether or not a particular neurone fixes, depends on the inhibitory or excitatory inputs from all the neurones connected to it.The ability of neural network to learn and process the information classifies it as a form of Artificial Intelligence. The most exciting feature of this technology is that it can be applied effectively to problems complex and which are lacking in sophisticated theoretical models.

CHAPTER 4

EXPERT SYSTEM SHELL-EXSYS

4.1 INTRODUCTION

EXSYS is a commercially available generalised expert system development package. Expert systems are computer programs that emulate the interaction a user might have with a human expert in a particular subject area. Expert systems developed with EXSYS have the ability to ask questions on a particular subject to user. The computer will continue to ask questions till a exact solution is reached or a list of possible solutions in order of their decreasing probability of likelihood. If the user has dome queries, it can explain the rationale of the answers given by it. Expert systems can be developed EXSYS for any problem that involves a selection from among a definable group of choices where the decision is based on logical rules which have the relative probabilities of a choice being correct.

Expert systems mainly comprise of two parts knowledge base and an inference mechanism. The commercially available EXSYS expert system includes the inference mechanism for analysing the knowledge base developed by the expert system developer. The expert system developer is only required to provide the knowledge base in a particular field of usage. The EXSYS has a rule editor EDITXS which enables the expert system developer to generate knowledge base in a particular field of usage.

The input one may need to give to run a expert system is in the form of normal English language or an algebraic expression. The input is made by picking art an item or items from a list of options and there are number of choices in assigning and combining probability values.

The EXSYS programs are written in the C language producing small, fast running programs. The programs can be run with 640K RAM and one disk drive with PC-DOS. Hard disks and the full available memory of the computer may be used.

The EXSYS development package comprises five main programs:

1. EDITXS.EXE : The program for developing, editing and testing one's own expert system knowledge bases.

2. SHRINK.EXE: A utility program to compress the size of an edited knowledge base and rearrange the data in a knowledge base for rapid access.

3. FASTER.EXE: A utility program to rearrange the order of rules for maximum speed in backward chaining.

4. MERGE.EXE: A utility package to combine two knowledge bases into single knowledge base.

5. EXSYS.EXE: The runtime program for running expert system knowledge bases.

4.2 KNOWLEDGE BASE

The knowledge base of an expert system is in the form rules which can be understand easily by both the user and the computer. The set of rules formed to arrive at a solution to particular problem is called the rule based knowledge base. Rules are the way to depict knowledge by which the conclusion is reached by the program. A rule consists of 5 parts: an IF part, a THEN part, an optional ELSE part, an optional NOTE an optional REFERENCE part.

4.3 DEVELOPMENT OF EXPERT SYSTEM PACKAGE

A number of expert system languages or shells created by software engineers and developers are currently available for developing an expert system. EXSYS is a generalised expert system development package commercially available. Expert systems developed with this package will ask the user questions relevant to a subject. The user replies by choosing one or more answers from a list or by entering a numeric value. The computer will continue to ask questions until it arrives at a conclusion. The conclusion may be the selection of a single solution or a list of possible solutions arranged in order of likelihood. The computer can explain in English, now it reached its conclusion and why.

Expert systems may be developed with EXSYS for any problem that involves a selection from among a definable group of choices where the decision is based on logical rules. The rules can involve relative probabilities of a choice being correct. Any subject where a person or a group of persons having special expertise needed by others is a possible area for EXSYS.

Expert systems deal with knowledge rather than data and the files they use are called knowledge bases. The rules that the program uses are IF-THEN type rules. A rule consists of a list of IF conditions in normal English sentences or algebraic expressions and a list of THEN conditions that are mere statements or sentences about the probability of a particular choice being the appropriate solution to the problem.

If the computer determines that all of the IF conditions in a rule are true it adds the rule's THEN conditions to what it knows to be true. The computer determines what additional information it needs and how best to get that information. If possible, the computer will derive information from others rules rather than by asking the user. This ability to derive information allows the program to combine many small pieces of knowledge to reach logical conclusions about complex problems. The rule editor allows the rules to be easily modified, added or deleted.

The final goal of an expert system is to select the most appropriate solution to a problem based on the data furnished by the user. If more than one solution is possible the program will provide a list of the possible solutions arranged in order of decreasing probability.

Essentially all of the instruction necessary to run an expert system knowledge base is provided by the program and all output is in normal English. Little or no training is required to run an already developed knowledge base. There is even a knowledge base included that can help if one is having trouble running the program.

4.4 RUNNING EXPERT SYSTEMS:

EXSYS knowledge bases can be run by anyone with essentially no training other than how to start the program. However, EXSYS offers many options when requesting information about what the computer is doing and why.

All knowledge base files for EXSYS are kept in two parts: one with a RULE filename extension and one with a .TXT filename extension. Both files must be on the same disk (or

RAM disk) for the program to work. To run EXSYS place the work disk, in drive A and turn the computer on or press the Ctrl, Alt and Del keys together if the computer is already on. The screen displays the DOS prompt A>. Then type EXSYS <filename> or in this case ESTAD, without extension. If just EXSYS is entered without a filename, the program will display the title screen and ask the user for a filename in which case the user types ESTAD.

The program will always load the portion of the knowledge base contained in the .RUL file into the memory. If there is insufficient memory to run the knowledge base, the computer will indicate so. The program then checks if there is adequate memory to read the .TXT part of the knowledge base into memory. If space is adequate, the .TXT file will be read into memory and the program runs much faster. If there is insufficient memory to load the .TXT file in memory, an error message will not be given, yet the program will run correctly. The program will access the .TXT file from the disk as it is needed. In this case the disk with the knowledge base must remain in the disk drive while the program is running.

Once an acceptable filename and the knowledge base files have been loaded, the computer will ask if the user wishes instructions on how to run EXSYS. If the user has not run the program in a while, he may wish to refresh himself on the program and presses [Y]. If he does not wish the program to display instructions he presses [N] or just the [ENTER] key.

4.5 RECOVERING DATA

The computer will then ask if the user wants to recover data form a previous run stored on the disk. The EXSYS runtime program lets the user store the data he has entered up to that point, leave the program and be able to return to that point at a later time. If the data thus stored is to be recovered then [Y] is pressed. The user will then be asked for the filename of the file holding the stored input data. The program will read in the data and, after displaying the starting title screens, return to where the user left off. If he does not wish to recover stored data he presses [ENTER] or [N].

4.6 EXSYS DISPLAYS

The computer displays the subject of the knowledge base and the author. Any key may be pressed. The program may display information explaining the knowledge base the user will be running. This display is an option selected by the knowledge base author.

The program asks if the user wishes to have the rules displayed as the program determines them to be true. The default value will have been selected by the knowledge base author and will be displayed. The program runs faster if it does not have to display the rules; however, the rules show the user how the program is progressing and may help to educate the user. Regardless of the user's selection he will still be able to see the rules through the use of the "WHY" command or when the final selection of choices has been made.

4.7 INTERACTING WITH EXSYS

The computer will start asking questions relevant to the subject area of the knowledge base. This is how the program obtains the data needed to make a decision. There are two types of questions the user may be asked: multiple choice and numeric value. Multiple choice questions will display a statement ending in a verb, followed by a numbered list of possible completion of the sentence. The number or numbers of the choices is/are entered for the user's situation and [ENTER] is pressed. If more than one number is chosen, the numbers are separated by a comma or with a space. If numbers outside the range of the list are entered, the computer will re-ask the question and not get past the question until it is answered. The other type of information the user may be asked for is a numeric value. There will be an explanation of what information the program needs and a space to enter the value. A numeric value including a decimal point may be typed and [ENTER] pressed. The computer will continue asking questions till it has obtained enough information to determines that any of the IF conditions in a rule are false, it will reject the rule and go to the next appropriate rule.

4.8 RULES

Rules are the representation of the knowledge of the expert system. A rule is one or more statements in the IF part followed by one or more statements in the THEN part with a note, if necessary, to highlight some key point. The statements are plain English sentences or algebraic expressions and are just the sort of questions the computer has been asking the user. There may also be "choices" in the THEN part. Choices are the possible solutions to the problem the expert system was written for. Choices are indicated by a text statement followed by "-Probability" and either 0, 1 or a ratio. A well written rule should be easy to read. There are three main systems available in EXSYS for assigning the probability value. Only one system can be used in a given knowledge base.

4.9 0 OR 1 SYSTEM

If the value following the "probability" is a 0 or 1 the user is in this system. A value of 0 means absolutely no and eliminates the possible solution from further consideration. A value of 1 is equivalent to absolutely yes and selects that solution for

inclusion in the final list of solutions. There is no real probability in this system; only yes or no.

4.10 0 OR 10 SYSTEM

If the value following the "probability" is a ratio where the denominator is 10, the user is in this system (e.g. probability=5/10). This is the most generally useful system and the one most often encountered. In this system 0/10 is equivalent to "absolutely no" and locks the value at 0/10 regardless of any other value the choice may have rec3eived. A value of 0/10 eliminates the choice from further consideration. A value of 10/10 is equivalent to "absolutely yes" and also locks the value for the choice at 10/10 regardless of any other values the choice may have received. Values of 1 to 9 represent degrees of certainty ranging from "very probably no" to " very probably yes". The values from 1 to 9 DO NOT lock the value and are averaged to give the final value for a choice.

For example, if a choice appears in three rules that had true IF parts with values of 3/10, 8/10 and 4/10, the final value for the choice will be the average: 5/10. If the values found were 3/10, 9/10 and 0/10, the 0/10 would prevail and result in a final value of 0/10 regardless of the other values. Likewise, if the values were 1/10, 3/10 and 10/10, the 10/10 would lock the value at 10/10 regardless of the previous lower values. Values of 1-9 are averaged to a final value ONLY if not over-ridden by a 0/10 or 10/10. The first 0/10 or 10/10 prevails and will not be changed even by another 10/10 or 0/10.

4.11 0 OR 100 SYSTEM

If the ratio following "Probability =" has a denominator of 100 the user is in the 0-100 system. In this system values of 0 to 100 can be assigned but the values of 0 and 100 DO NOT lock the value. The value can be computed as an average of the probabilities or can be combined as dependent or independent probabilities. The author of the knowledge base has to select the appropriate method of combining values.

In the development of ESETAD the 0-10 system has been adopted since it is the most popular system.

4.12 ASKING ABOUT RULES

When a rule is displayed the user has the option of asking how the computer knows a condition in the IF part is true. To do this the line number of the IF condition is entered. The computer will respond with one of four responses.

1. The computer will display the rule or rules that allowed it to derive the information. A rule used for derivation will have information about the condition the user is asking about in its THEN part. The user can then keep asking how the computer knew that rule's IF conditions were true and so on. If the user asks about a condition that is an algebraic expression, the values of each of the variables in the expression will be displayed. The user may then ask how those values were derived by entering the number of the value.

2. If the user asks the program how it knows a condition is true that it did not derive, but determined by asking the user for input, the computer will respond that the user told it the information was true.

3. The user can ask for information about a condition that is several conditions down in the list and which the computer may not have yet tested.(This can occur when the user asks the computer WHY in response to its question). If this is the case, the computer will respond that it does not yet know if that condition is true or not.

4. In certain situations where the computer has just derived new information, it may tell the user that the condition the user is asking about is false and the rule will be eliminated.

5. Rules often have references for the source of the knowledge (e.g. personal observation, book, article, etc.,). If, when a rule is displayed, the user presses the computer will display the reference for the rule if one was entered by the person that developed the knowledge base. When the user has finished examining the rule, he presses [ENTER] to continue with the expert system. The computer will continue asking questions.

4.13 "WHY"

If the user wonders why the program needs to know the information it is requesting, the user can ask it by typing WHY, instead of making a selection from the list of values, and press the [ENTER] key. The program will respond by displaying the rule it is trying to determine the validity of the user may ask the program about the IF conditions or reference as described above. After the user has finished examining the rule he presses [ENTER]. The program may now have question originally asked re displayed or it may display another rule .If the latter is the case, it is because the first rule displayed was being used only to derive information needed by the second is the rule actually being tested.(One of the first rule's THEN conditions will be in the new rules IF conditions). All of the options about asking for information on the rule the are again available. The program will continue showing the rules it is using to derive information until it reaches the base rule it is trying to apply. This rule will have at least one choice in its THEN part.

The [ENTER] key is pressed to continue the program. If more than one rule was displayed, each time [ENTER] is pressed, the user will go one rule up the list being used in the derivation. The user will then be risked the question the user responded to with "WHY".

4.14 SAVING DATA WITH "QUIT"

The user has the option of storing the data he has input into the program, exiting the program, and being able to return to the same point later. This can be useful if the user needs to look up information needed by the program or if he must leave the program but does not want to lose the data he has already input. He can select to store the data by entering QUIT in response to any of the computer's requests for data. The program will then ask for the name of the file to store the data in a filename up to 8 characters but not the name of the knowledge base is entered. If a file already exists, with the name chosen, it will be erased and replaced with the new data. The user will then be asked if he wishes to return to the program or exit to DOS. The data input may also be stored by pressing [Q] when the sorted list of choices is displayed.

4.15 DISPLAY OF THE CONCLUSIONS

The program will continue asking questions until it has considered all of the possibilities the person who wrote the knowledge base put in and it will then display its results. Just prior to the display of the results, the program may display the information interpreting the meaning of the values assigned tot he choices. The inclusion of this explanation is an option available to the knowledge base author. The choice will then be displayed arranged in order by final value. The most likely first, next most likely second, etc. Only choices that received a final value greater than 0 will be displayed. These will be displayed as a statement or a statement followed by a numeric value.

The choices that are in the list will each have a probability value. This is the final value obtained by combining the values from all of the rules used that had that choice in them. ONLY the numerator will be displayed (e.g. 3 not 3/10).

This final value can be used as a confidence factor for a variety of purposes. A value of 9 or 10 should give a high confidence in the identification. A comparison of the value indicates the relative likelihood of the choices. (e.g. If the first choice gets a 9 and the second as 8, both are almost equally likely. On the other hand, if the first choice got a 9 and the second a 3, the first is much more likely than the second). The user may also find text statements with no associated numeric value displayed. These are not choices and will always appear after the list of choices regardless of there degree of certainty. If the screen has a colour card attachment such statements are displayed in a different colour from the choices. The user may also have numeric values calculated by the program displayed.

There will be text statement followed by a number. Like the text statement described above, the display of variable ALWAYS comes after the list of choices and is a different colour. When the final sorted list of choices is displayed, the user has several options. In the initial display, only choices that received a value greater then zero will be displayed. The user has the option of having all choices that were found in rules, even those with a final value of zero, displayed by pressing the [A] key. If the user has pressed the [A] key to have all choices displayed and would prefer to only see the ones with values greater then zero the [G] is pressed. If no rules in the knowledge base applied to a choice, it has no value and even the [A] key will not display it.

4.16 ASKING HOW A CONCLUSION WAS REACHED

The user can ask the computer how it arrived at its final value for a specific choice or why a statement is displayed. If the line number for any choice or statement is entered, the computer will respond by displaying all of the rules it used to determine the value of that choice or statement. The user again has all of the options in requesting more information about each of the rules as discussed above. If the user wishes to learn why a choice not displayed was eliminated by being given a probability value of 0, [A] is pressed to have all choices displayed. Then the line number of the choice in question is entered.

4.17 CHANGING THE SORT CRITERIA

If the knowledge base being used is based on the system that uses choice vales form 0-100, the user has the option of changing the way the final value of the choices is calculated. To change the sorting criteria [S] is pressed. If the knowledge base is not based on choice values from 0-100, the computer will respond that there is on alternate sorting criteria for the data. If it is based on the 0-100 system the user will be given the option of selecting average value [A] or combining the data as a dependent probability[I].

4.18 CHANGING AND RERUNNING THE DATA

EXSYS provides a very easy way to test and analyse the effect the user's input had on the final list of choices. He can change one or more of his answers, while holding the remainder constant, rerun the data and see what effect the changes have on the final outcome. The current value for the choices can be saved for comparison with the new value.

To change the data [C] is pressed. The user will be asked if he wishes to save the current values for comparison with the new ones he will be calculating . The program will then display a list of all of the information he provided by answering questions. The number of the statement he wants changed is entered and the program will risk that question. The question is answered with the new values that he wishes to try. The computer will return to the display of all of the information that the user told it.

Statements are [R] to return to the data. If due to the changes, the program now needs more information it will ask for it. The rules will not be displayed during the rerun. The program will then display the new list of choices. If the user opts to have the previous values saved for comparison, they will be displayed in parenthesis. The user can change the data again in almost the same way. The only difference is that when he presses [C] he will be given 3 options.

1. Keep the original values for comparison.

2. Keep the most recently calculated values for comparison.

3. Do not keep any comparison data.

The ability to change and rerun the data allows expert system models to be built and tested and to see if an answer that the user was not sure of its vital to the final outcome, or really has little effect.

4.19 STORING THE RESULTS

The user can store the input provided to reach the calculations by pressing [Q]. This is the same as using the QUIT option when entering data. The data input will be stored in a disk file and the user will be able to return directly to this point. This is particularly useful if the user wants to experiment with the "change and rerun" command.

4.20 PRINTING THE RESULTS

The user may wish to save a printed copy of the results of the run. To do this he presses [P]. He will then be asked if he wishes to have the data he told the computer also printed. If he presses [Y] he will have both the final sorted list of choices printed along with all of the data he provided the computer in answer to its questions.

4.21 EXITING THE PROGRAM

When the user has finished examining the choices he presses the [D] key. He will then be given the option of running the program again with either the same or a different knowledge base file.

The program can fully explain how it arrived at its conclusion. If the user disagrees with the computer's rules, it may indicate a problem or error in the rules. To correct this, the user should contact the person that wrote the knowledge base or if the user wants to try changing it himself, he can edit the rules with EDITXS.

4.22 DIRECTING EXSYS OUTPUT TO A FILE

It is possible to direct the output from the runtime program, EXSYS.EXE, to a disk file. When this option is used, the program will automatically write the results of the run to the disk file, along with the data input by the user, and exit to DOS. This allows EXSYS to be combined in a series of operations controlled by a batch file. Potentially, with all data needed by EXSYS can be provided by an external program, EXSYS can be used to analyse the data and write it to a disk and another program could read and use the EXSYS results.

There are several differences between the way EXSYS normally runs and the way the program runs when the option to direct the output to a file is selected

1. The program will NOT pause for the user to press a key except when user input of data is required.
2. If an external program provides all input needed; EXSYS will not require any user action and will complete its analysis and write the results to the disk .
3. The title screens and results will be displayed on the screen but will flash by very quickly.
4. The user will be able to ask what rules were used to determine the conclusions or perform a "Change and rerun". If the user is asked for input he will be able to ask the program "WHY" the data is needed.
5. The program will automatically drop back to DOS once the results are written to the file.

To direct output to a file, the command

OUT=<filename>is added to the line when EXSYS is called. For example :

EXSYS<filename>OUT=<output filename>

The rule filename is the name of the knowledge base. Output file name is the name of the file that EXSYS will write the results to (OUT=MUST BE IN CAPITALS).

CHAPTER 5

ARTIFICIAL INTELLIGENCE IN ANALYSIS AND DESIGN OF INTZE TANK

5.1 INTRODUCTION

The problem of analysis and design of Intze tanks has been dealt with in two parts with regard to the application of AI tools and techniques. The first part consists of the interfacing and implementation of expert system shells with conventional program. The second part examines the possibility of applying artificial neural networks to replicate and thus do away with conventional programs and practices.

The first part relates to the following tasks inherent in the analysis and design as per conventional practices i.e.

(a) Preliminary dimensioning of the tank

(b) Analysis for forces as per conventional practices in accordance with applicable BIS (Bureau of Indian Standards) codes of practice IS:1893-1984 and IS:875-1987.

(c) Design for forces as obtained from (b) again in accordance with relevant and applicable BIS (Bureau of Indian Standards) codes of practice IS:456-1978.

The main analytical /design module "ESETAD" with which the expert systems have been interfaced has been developed in C++. In the second part three artificial neural networks have been developed for the following purposes.

(a) Preliminary dimensioning of the tank

(b) Estimating of design forces in various components of intze tank.

(c) Estimating Reinforcement in various components of intze tank.

5.2 ESETAD: EXPERT SYSTEM FOR ELEVATED TANK ANALYSIS AND DESIGN

The ESETAD is a knowledge based tool for the analysis and design of intze water tank. The ESETAD is designed to:

1) Estimate preliminary dimensions of the intze tank.
2) Estimate the seismic factor, wind pressure coefficients and other forces relevant to analysis and design of various components of intze tank.
3) Check the stability of the tank under the action of various forces.
4) Carryout the design of various components of the Intze Tank.

The "ESETAD" mainly consists of two parts.

(i) Knowledge Bases

(ii) Modules written in C++ which carryout the analysis and design of different components of the intze Tank.

5.2.1 KNOWLEDGE BASES OF 'ESETAD'

The knowledge Bases of "ESETAD" have been developed with the use of Expert System development package "EXSYS". May consist mainly of three modules, They are

1) Dimensioning Module
2) Wind code module
3) Seismic Code module

5.2.1.1 DIMENSIONING MODULE :

This module contains knowledge about the kind of Tank to be used based on the capacity and it contains knowledge about economic proportions of the intze tank based on the recommendations given by the different experts [19][16][15]. Based on the recommendations given by different experts [19][16][15] thumb rules have been developed for the economic proportions of the Tank based on the capacity. The various recommendation of experts for the economic proportions of the intze tank are shown in table 5.2.

Table 5.1 Thumb rules for different types of Tanks

Capacity (in kilolitres) (Q)	Shape	Place of Construction
Q < 100	Rectangular	Under ground or on the ground
100 < Q <300	Circular	Under ground or on the ground
Q > 300	Intze	At a height of 15 m or above from the ground.

It is found that for storing large volumes of water, water tanks either circular or rectangular with flat floor slabs works out to an uneconomical design. It is mainly on account of very thick floor slab. Intze tank is best suitable under such circumstances. In this module questions will be asked regarding capacity of Tank. Based on the capacity of the Tank it will give the type of tank to used. If the tank to be used is to intze type then the diameter of the tank is calculated as follows

. First [Diameter] will be set to zero. If the capacity is greater than 300 kilolitres then diameter is calculated by the expression.

[diameter] = ([capacity/0.548] * * 0.333)

Then it will display [diameter] is given the value [diameter] + ([Capacity/0.548] ** 0.333)

The various dimensions given in the Table 5.3 are calculated and displayed accordingly.

Where,

H_1 is Height of top dome in m, H_2 is Height of cylindrical wall in m, D_0 Bottom circular beam in m, H_3 is Height of Conical dome in m, H_4 is Height of bottom spherical dome in m.

Table 5.2 Recommendations of different experts on economic proportions of tank

Dimension	Recommended by Sushil Kumar	Recommended by Ramamrutam	Recommended by B.C.Punnima
H_1	0.125D	0.16D	0.13D
H_2	0.667D	0.50D	0.667D
D_o	0.625D	0.60D	0.625D
H_3	0.1875D	0.16D	0.1875D
H_4	0.125D	0.13D	0.125D

Table 5.3 Economic Proportions based on the above three criteria

Dimensioning	Economic Proportions
H_1	0.138D
H_2	0.611D
D_o	0.616D
H_3	0.1783D
H_4	0.126D

5.2.1.2 SEISMIC CODE MODULE

In this module seismic forces are calculated using seismic co-efficient method. For this purpose knowledge has taken from seismic code IS : 1893-1984. This module is used to determine the seismic factors like zone factor and importance factors.

α_h is Horizontal seismic co-efficient and is calculated by the expression.

$$\alpha_h = \beta I \alpha_o$$

Where, β = a co-efficient depending upon the soil-foundation systems.

I = a co-efficient depending upon the Importance of a structure.

α_o = basic Horizontal Seismic co-efficient.

In this module rules have been developed to store the knowledge described above – when the system takes information from the user it estimates the values of different seismic co-efficients.

5.2.1.3 WIND CODE MODULE

The wind load on a structure depends on the design wind pressure. One intensity of wind pressure depends on wind velocity. One magnitude of wind velocity varies with geographical location of the structure and is different in various zones.

The wind load, W_L acting Normal to a structure circular in plan.

$W_L = C_f \, . \, A. \, P_d$

C_f = Force coefficient

A = Surface Area of the Structure

P_d = Design wind pressure

The design wind pressure at any height above mean ground level is shall be obtained from the following expression

$P_d = 0.0006 \, (V_d)^2 \ \text{kN/m}^2$

Where V_d is the design wind speed in m/sec and it is obtained from the following expression

$V_d = (K_1.K_2.K_3) \, V_b$

Where,

K_1 = risk coefficient (probability factor)

K_2 = terrain, height and structure size factor, and

K_3 = topography factor

V_b = basic wind speed in m/s

This module is used to determine various coefficients which are used in calculating the wind loads. The rules in this module have been framed using the knowledge of the wind code IS: 875-1987. One rules have been framed to determine zone in which the structure is located and determines basic wind speeds in each zone. After finding out the basic wind speeds it determines the risk co-efficient (K_1) and further it uses the rules to determine the terrain, height and structure (K_2). K_3 value is furces 1 for simplicity.

In order to determine K_2 the terrain is classified into following categories.

a) Category 1 : The exposed open terrain with few or no obstruction and in which the average height of any object surrounding the structure is loss than 1.5m above ground surface. It is to note that open sea coasts and flat plains having no trees are included in this category.

b) Category 2 : the open terrain with scattered obstructions having heights usually between 1.5m to 10m above ground surface. It is to note that air fields, open park lands and undeveloped sparsely built-up outskirts of tourn and suburbs are included in this category.

c) Category 3 : The terrain's having numerous closely spaced obstructions. It is to note that well wooded areas, and shurbs, terms and industrial are as full or partially developed are included in this category.

d) Category : The terrain with numbers high size and closely spaced structures. It is to note that large city centres are included in this category.

The force co-efficient depends on the height to breadth ratio of the structure. Depending on the height to Breadth ratio of structure the force co-efficient varies for structure circular in plan. Rules have been framed for the following data to determine the force co-efficient.

Table 5.4 Height to breadth ratio of structures circular in plan

Height/Breadth (HB)	C_f
HB < 2	0.7
2 < HB ≤ 5	0.8
5 < HB ≤ 10	0.9
10 < HB ≤ 20	1.0
20 < HB ≤infinity	1.2

In this module the system will ask questions regarding the terrain and height/breadth ratio of the structure and uses the knowledge above to determined K_2 and C_f.

5.2.2 ANALYSIS AND DESIGN MODULES

They are total 10 modules which carryout analysis and design of different components of Intze tank.

1) TOP DOME MODULE

This module carries out the Dimensioning, analysis and designed top dome. The information from this module is put in a data file.

2) TOP RING BEAM MODULE

This module carries out the dimensioning, analysis and design of top ring beam taking some data through a data file from top done module.

3) CYLINDRICAL WALL MODULE

This module carries out the dimensioning, Analysis and Design of Cylindrical wall taking some data though a data file from top ring beam modules.

4) BOTTOM RING BEAM MODULE

This module carries out the dimensioning, Analysis and design of bottom ring beam taking some data through a data file from cylindrical wall module.

5) CONICAL DOME MODULE

This module carries out the dimensioning, analysis and design of conical bone taking some data through a data file from bottom ring beam module.

6) BOTTOM SPHERICAL DOME MODULE

This module carries out the dimensioning, Analysis and design of bottom spherical done taking same data through a data file from conical done module.

7) BOTTOM CIRCULAR BEAM MODULE

It carries out the dimensioning, Analysis and Design of Bottom circular Beam taking data from previous modules through a data file.

8) COLUMN MODULE

It carries out the dimensioning, Analysis and design of columns taking data frame previous modules through a data file.

9) BRACING MODULE

If carries out the dimensioning, Analysis and design of Bracings taking data from previous modules through a data file.

10) FOUNDATION MODULE

It carries out the dimensions, Analysis and design of foundation taking data from previous modules through a data file.

11) GRAPHICS MODULE

It gives the working drawings of all the members of the container of the Intze tank.

5.3 NEURAL NETWORK STUDY

The Intze tank has been analysed and designed by creating neural network models. The neural network analyses of the tank were carried out using a neural planner program. Neural planner is a neural network system for microsoft windows. It allows to produce multilayered neural networks using a simple graphical editor or create standard three layer networks from training files. There are also facilities for producing, training, testing and interrogating files in the neural planner. The neural planner can learn from training files, self test using testing files and be interrogated by interrogating files.

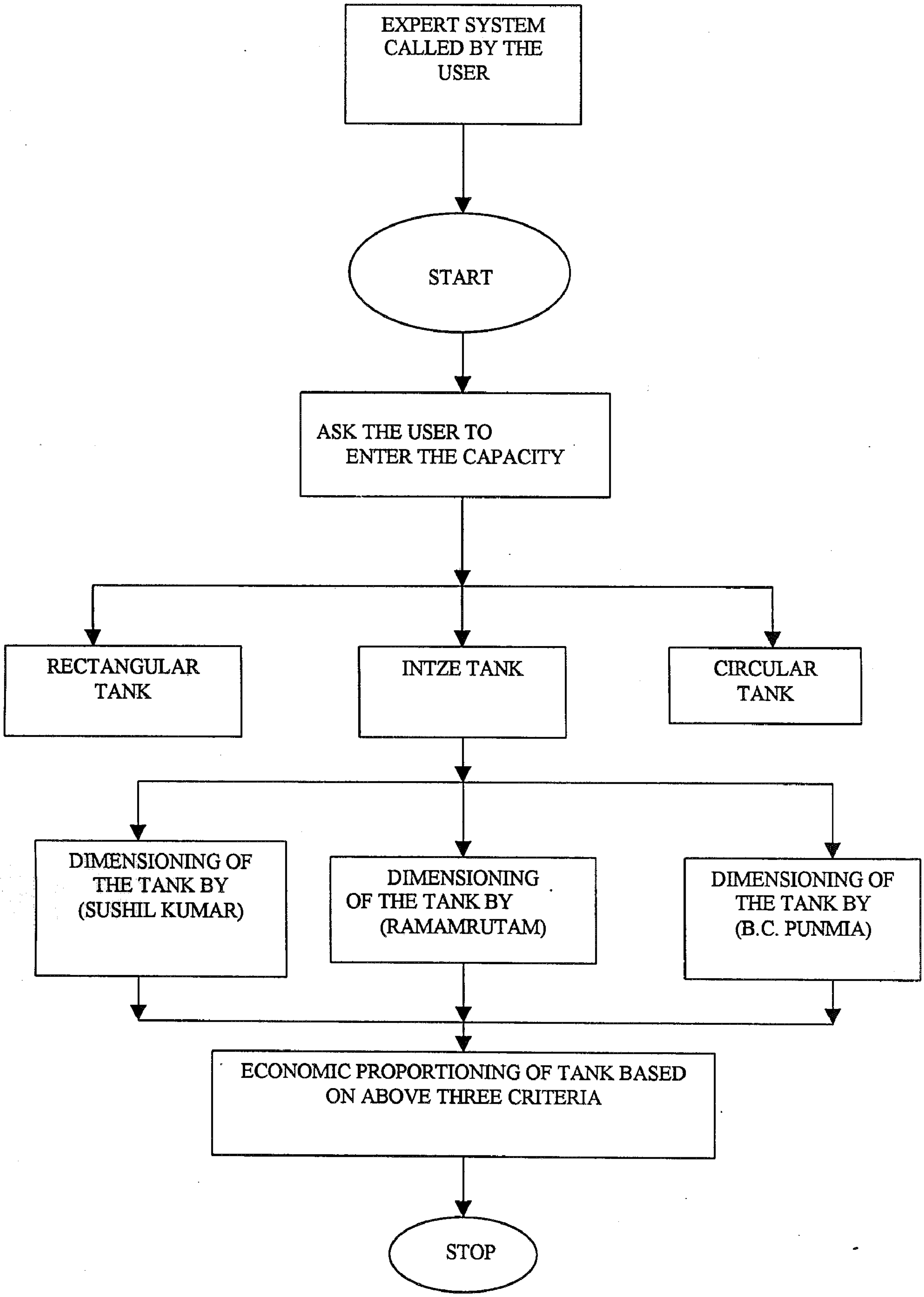


Fig. 5.1 Flow chart for economic proportions of the intze tank

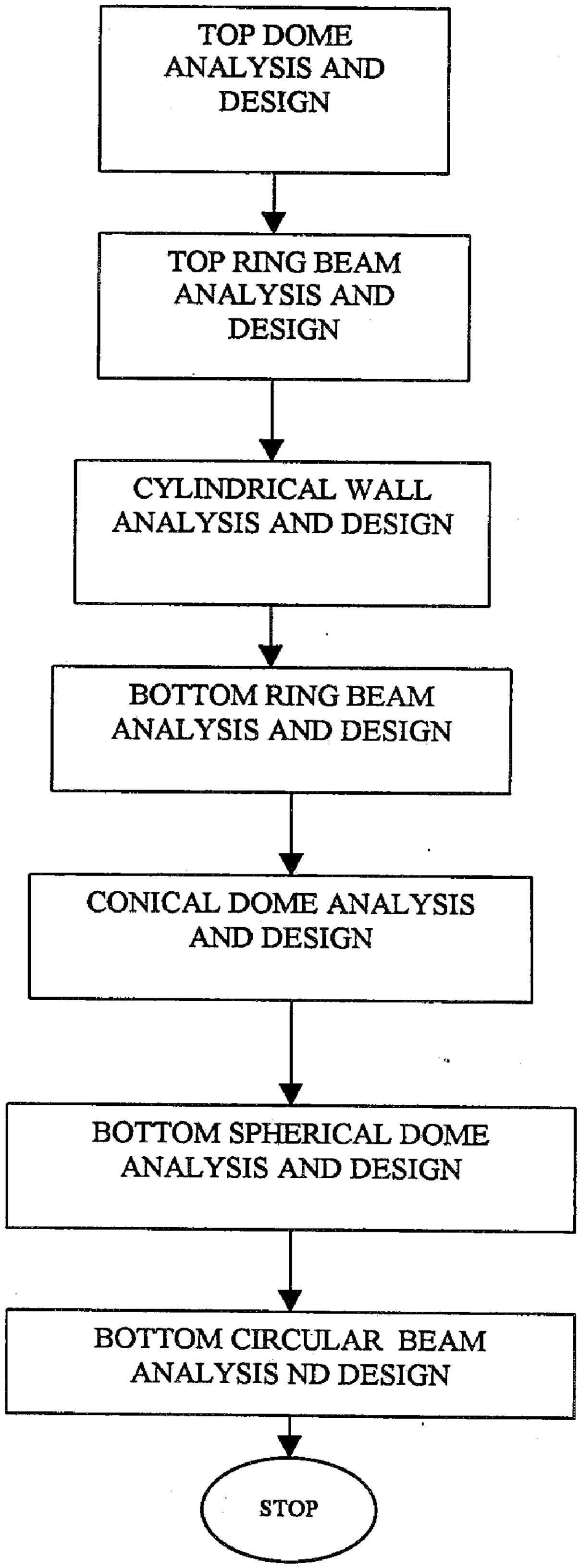


Fig. 5.2 Flow chart for analysis and design of superstructure

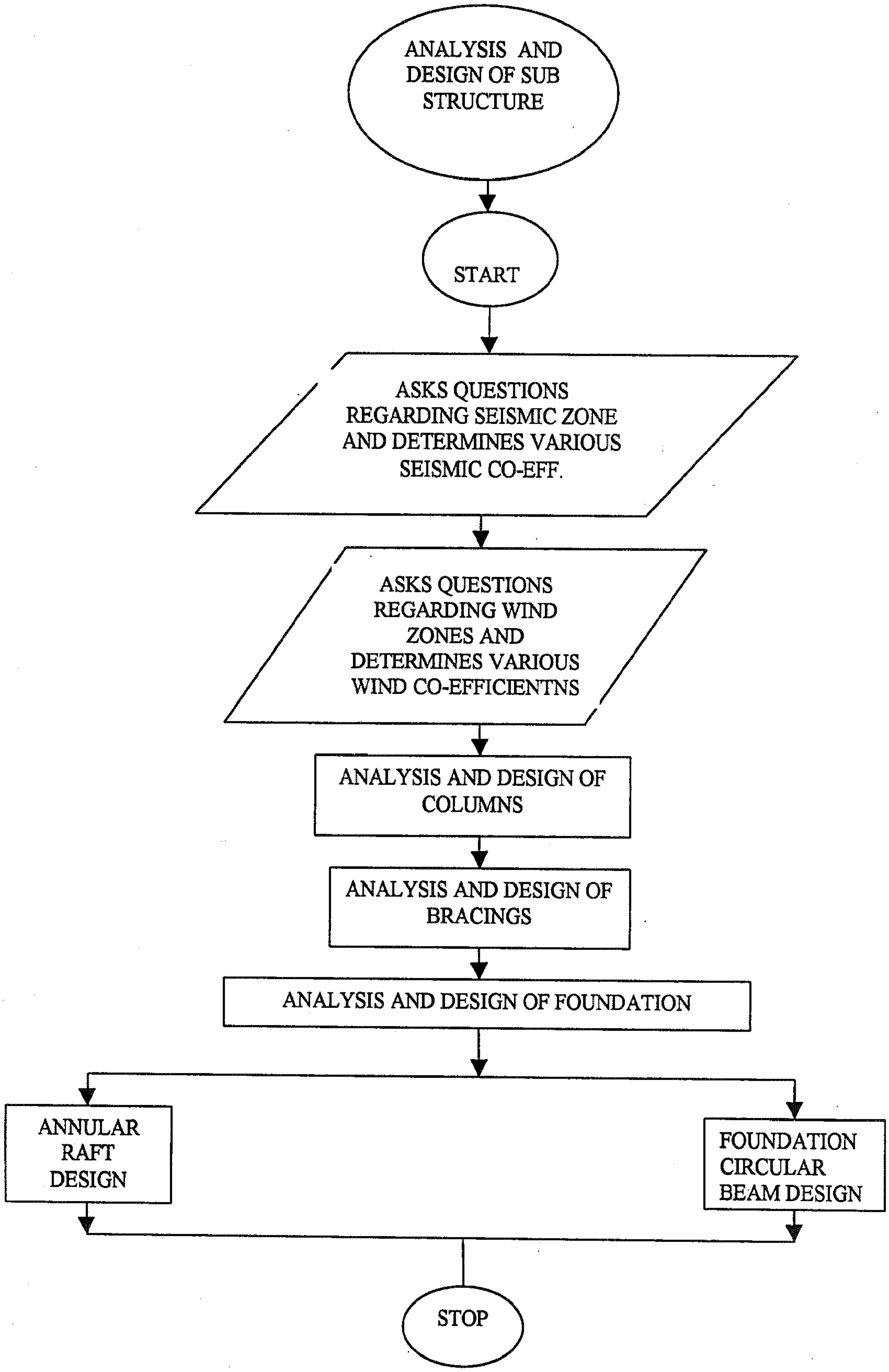


fig. 5.3 Flow chart for analysis and design of substructure

A sample problem of intze tank has been solved using the sotware package ESETAD. The out put of the sample problem is presented in the following lines.

PLEASE MENTION THE CAPACITY OF THE WATER TANK YOU WANT:

(1) Small capacity (Capacity is less than 100 kL)
(2) Medium capacity (capacity is in between 100 kL and 300 kL)
(3) Large capacity (capacity is greater than 300 kL)

3

PLEASE GIVE THE CAPACITY IN KILOLITRES
1500

PLEASE MENTION THE HEIGHT STAGING YOU WANT TO

(1) Low Height (Height of staging is of the order of 15mt)
(2) Medium Height (Height of staging is of the order of 20mt)
(3) High Height (Height of staging is of the order of 25mt)
(4) I don't Know

2

STRUCTURE IS

1. An Important Structure
2. Not An Important Structure
3. 1 Don't Know

1

THE SOIL IS

1. Hard Soil
2. Medium Soil
3. Soft Soil
4. I Don't Know

4

THE BUILDING IS NEAR TO

1. Ajmer, Aurangabad, Bangalore, Bhilai, Chitrgaurad, Hyderabad, Jhansi, Jodhpur, Kurnoor, Mysore, Raipur, Rourkela, Sironj
2. Allahabad, Bhopal, Jaipur, Jamshedpur, Madras, Madurai, Nagpur, Nellore, Pondicherry, Ranchi, Thanjavur, Tiruchirapalli, Udaipur, Visakhapatanam
3. Agra, Ahmadabad, Asansol, Barailly, Bhatinda, Bhubaneshwar, Bikaner, Dokaro, Bombay, Burdwan, Calcutta, Coimbatore, Cuttack, Duragapur, Gaya, Jabalpur, Kanpur, Lucknow,Manglore, Nasik, Panjim, Patiala, Pune, Rajkot, Surat, Trivandrem, Vadodara, Varanasi, Vijayawada.
4. Almora, Ambala, Amristar, Bahraich, Barauni, Chandigarh, Darjeelling, Dehradun, Delhi, Gangtok, Gorakhpur, Ludhiana, Monghyr, Moradabad, Nainital, Patna, Pilibhit, Roorkee, Simla
5. Bhuj, Darbhanga, Gauhati, Imphal, Jorhat, Kathmandu, Kohima, Mandi, Sadiya, Stinagar, Tezpur

4

THE TERRAIN CATEGORY IS

1. Category 1 (The Exposed Open Terrain With Few Or No Obstructions)
2. Category 2 (Terrain With Scattered Obstructions Of Height Between 1.5m To 10m)
3. Category 3(The Terrain Having Numerous Closely Spaced Obstructions E.G. Thorn And Industrial Areas Full Or Partially Developed)
4. Category 4 (Full Developed City Like Delhi)
5. I Don't Know

1

THE STRUCTURE HAVING

(1) Very Low Height/Breadth Ratio (in the order of less than 2)

(2) Low Height/Breadth Ratio (in between 2 and 5)

(3) Medium Height/Breadth Ratio (in between 5 and 10)

(4) High Height/ Breadth Ratio (in between 10 and 20)

(5) Very High Height/Breadth Ratio (in between 20 and infinity)

(6) I Don't Know

6

ANALYSIS OF THE TANK

TOP DOME

Meridional Stress : 0.28 N/Sq. mm

Hoop stress : 0.30 N/Sq. mm

TOP RING BEAM

Hoop Tension : 1.82×10^5 N

CYLINDRICAL WALL

Maximum Hoop Tension at the base : 4.2×10^5 N

BALCONY BEAM

Hoop Tension : 873477 N

CONICAL DOME

Maximum Hoop Tension : 758015N

Meridional Thrust : 469720N

BOTTOM SPHERICAL DOME

Meridional Stress : 1.18 N/ Sq. mm

Hoop Stress : 0.52 N/ Sq. mm

BOTTOM CIRCULAR BEAM

Support Moment : 6.565 x 10^5 Nm, Mid span moment : 2.984 x 10^5 Nm.

Maximum Torsional Moment : 4.773x10^4 Nm, Maximum shear 9.95x10^5 N

STAGING ANALYSIS

Column height = 20.0 m, Column diameter = 0.80 m

No. of Bracings = 4

Bracing width = 0.60 m, Bracing depth = 0.6m

ANALYSIS OF COLUMNS

Panel	Axial load in N	Leeward Column		Column at bending axis	
		Wind thrust in N	Earthquake thrust in N	Wind moment in N-m	Earthquake moment in N-m
1	2031160	16875	179100	31725	242144
2	2058119	19786	185076	37197	242144
3	2091052	23426	191053	44040	242144
4	2129683	25778	197030	48462	242144
5	2174102	28522	203007	53924	242144

FOUNDATION ANALYSIS

RAFT SLAB

Bending Moment at the support of the Raft Slab 103588 Nm

CIRCULAR BEAM OF RAFT FOUNDATION

Support Moment : 739969 N-m

Mid span moment : 336350N-m

Torsional moment : 56059 N-m

DESIGN OF INTZE TANK

DESIGN OF TOP DOME

Thickness = 100mm, Top Dome Height = 1750 mm

Top Dome Radius = 14000 mm

Circumferential Reinforcement :

Provide 8 mm dia bars @ 167mm c/c

Meridional Reinforcement :

Provide 8 mm dia bars @ 167 mm c/c

DESIGN OF TOP RING BEAM

Width = 414 mm, Depth = 310 mm, Provide 6 bars of 20 mm dia as main reinforcement, Provide 8 mm dia twolegged stirrups @ 202 mm c/c as distribution steel.

DESIGN OF CYLINDRICAL WALL

Cylindrical wall Radius = 7000 mm, Cylindrical wall height = 6000 mm

Provide a thickness of 200 mm at the top of the wall,. Provide a thickness of 353 mm at the bottom of the wall

Hoop Reinforcement (0n each face)

Provide 12mm dia @ 92 mm c/c at the top of the wall, Provide 12mm dia @ 82 mm c/c at one third height from top of the wall, Provide 16mm dia @ 110 mm c/c at the base of the wall

Distribution steel (on each face)

Provide 8 mm dia 4-legged stirrups 150 mm c/c,

DESIGN OF BOTTOM TOP RING BEAM

Width = 1000 mm, Depth = 600mm

Provide 25mm dia @ 162 mm c/c as main reinforcement, Provide 10 mm dia four legged stirrups 284 mm c/c

DESIGN OF CONICAL DOME

Thickness = 500 mm, Height = 2500 mm

Hoop reinforcement (on each face)

Provide 25 mm dia @ 148 mm c/c

Distribution Steel (On each face)

Provide 12mm dia @ 158 mm c/c

DESIGN OF BOTTOM SPHERICAL DOME

Thickness = 300 mm, Radius = 8750 mm, Height of Bottom Dome = 1750 mm

Circumferential Reinforcement :

Provide 12mm dia @ 100 mm c/c

Meridional Reinforcement:

Provide 12 mm dia @ 100 mm c/c

DESIGN OF LOWER RING BEAM GIRDER:

Width = 650 mm, Depth = 1300 mm, Radius = 5000mm

Reinforcement for support Moment :

Provide 25 mm dia bars 10nos

Reinforcement for mid span moment:

Provide 3 nos of 25 mm dia bars

Side Face Reinforcement

Provide 4 bars of 12mm dia on each face

DESIGN OF BRACINGS:

Provide 25mm dia 50 mm c/c both at top and bottom, Provide 8 mm dia 4- legged stirrups @ 198 mm c/c

DESIGN OF RAFT SLAB

Inner radius of the raft slab = 4 m, Outer radius of the raft slab = 7m, Depth of the raft slab is 442 mm

Provide 25 mm dia @ 218 mm c/c as circumferential reinforcement in raft slab, Provide 8 mm dia @ 250mm c/c as radial reinforcement

DESIGN OF RING BEAM FOUNDATION

Width = 800 mm, Depth = 1600mm, Radius = 5.00 mt

Reinforcement for support moment :

Provide 25mm dia bars – 9 in number

Reinforcement for Mid span moment :

Provide 25 mm dia bars 4 in number

Side face reinforcement :

Provide 4 bars of 12mm dia on each face

Distribution Reinforcement

Provide 12 mm dia 6- legged stirrups @ 130 mm c/c near, Supports and increase it to 230mm c/c near mid span

DESIGN OF COLUMNS

Design of panel number 1

Provide 32mm dia bars 8 in number as main steel

Provide 10mm dia lateral pies @ 480mm c/c

Design of Panel number 2 :

Provide 32mm dia bars 8 in number as main steel

Provide 10 mm dia lateral ties @ 480 mm c/c

Design of panel number 3 :

Provide 32 mm dia bars 8 in number as main steel

Provide 10mm dia lateral ties @ 480 mm c/c

Design of Panel number 4:

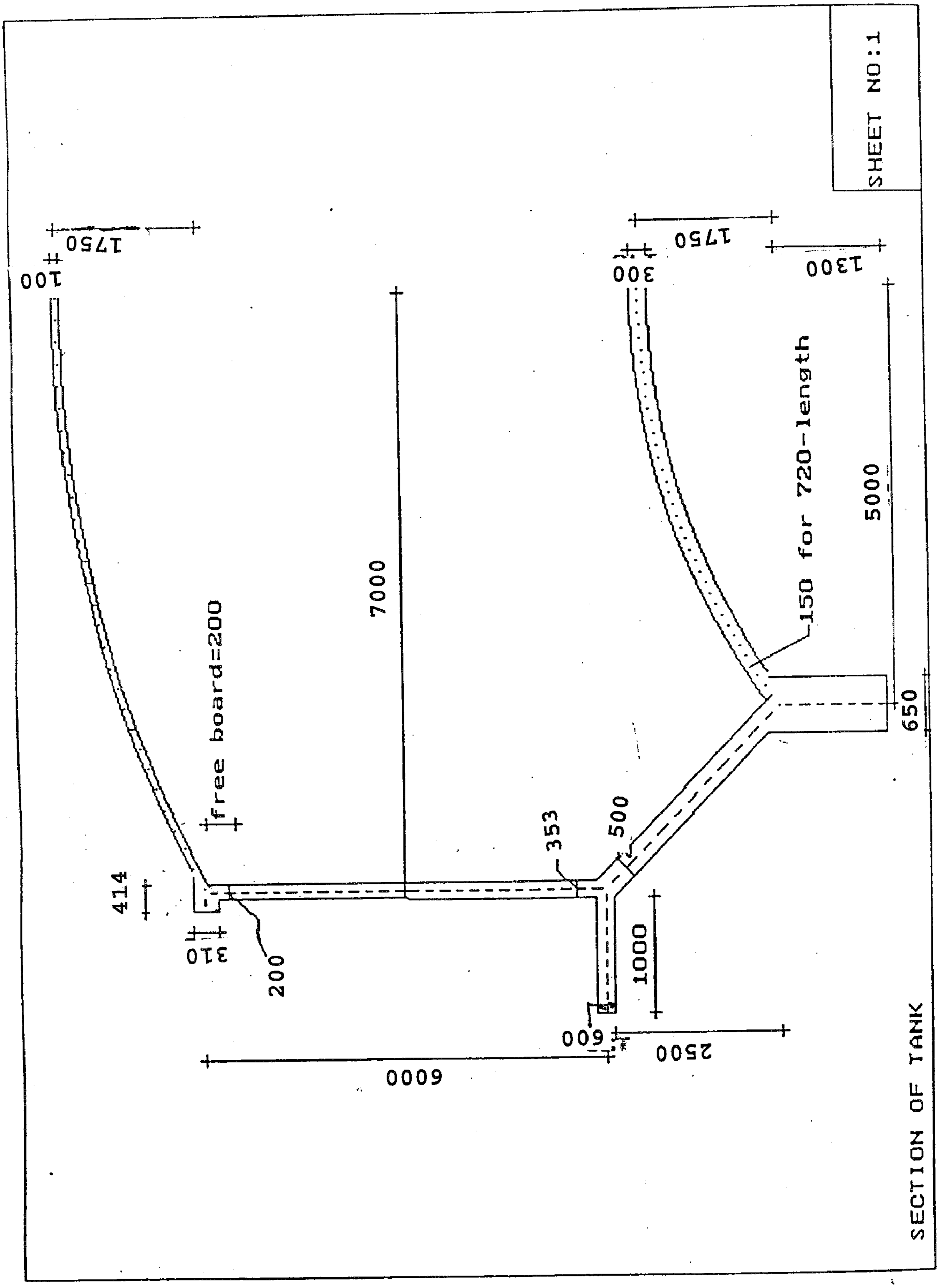
Provide 32mm dia bars 8 in number as main steel

Provide 10mm dia lateral ties @ 480mm c/c

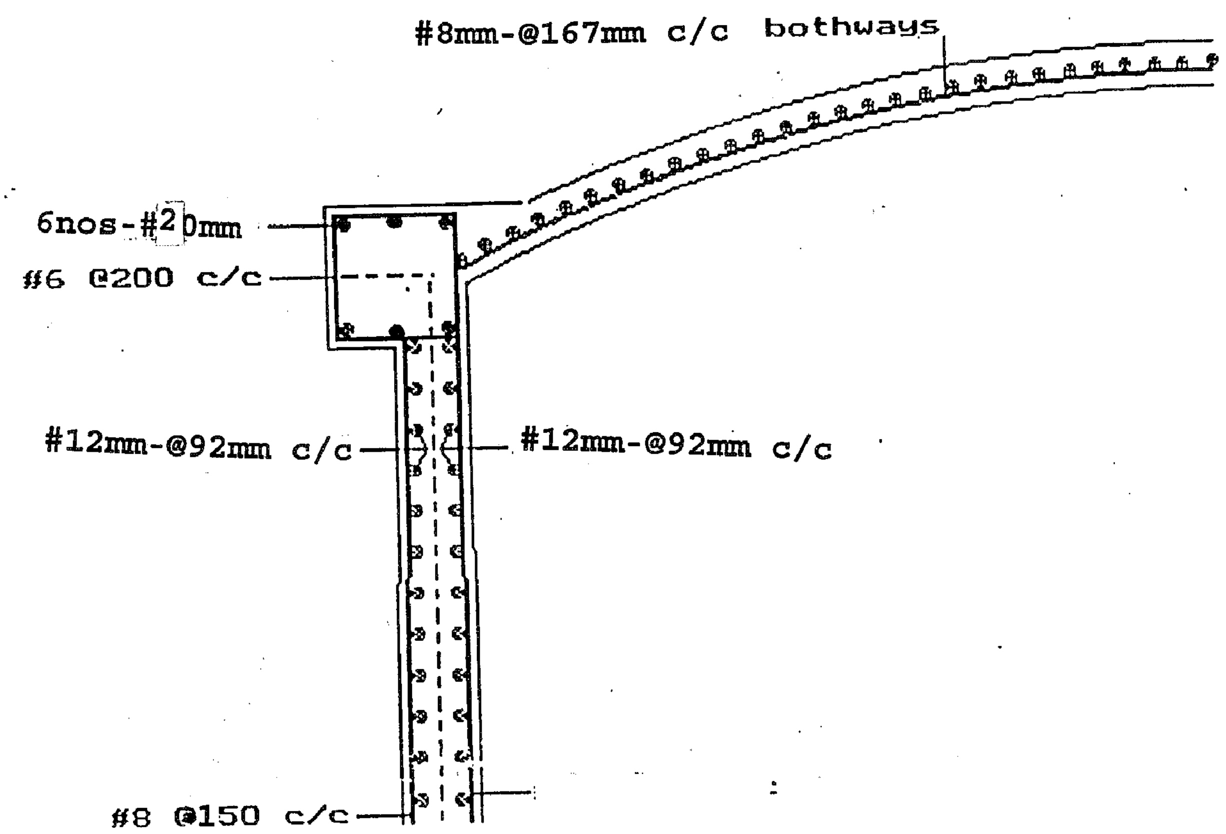
Design of panel number 5

Provide 32 mm dia bars 8 in number as main steel

Provide 10mm dia lateral ties @ 480 mm c/c



SHEET NO:1
1750
100
1750
300
1300
7000
150 for 720-length
5000
650
free board=200
414
310
200
353
500
1000
600
2500
6000
SECTION OF TANK

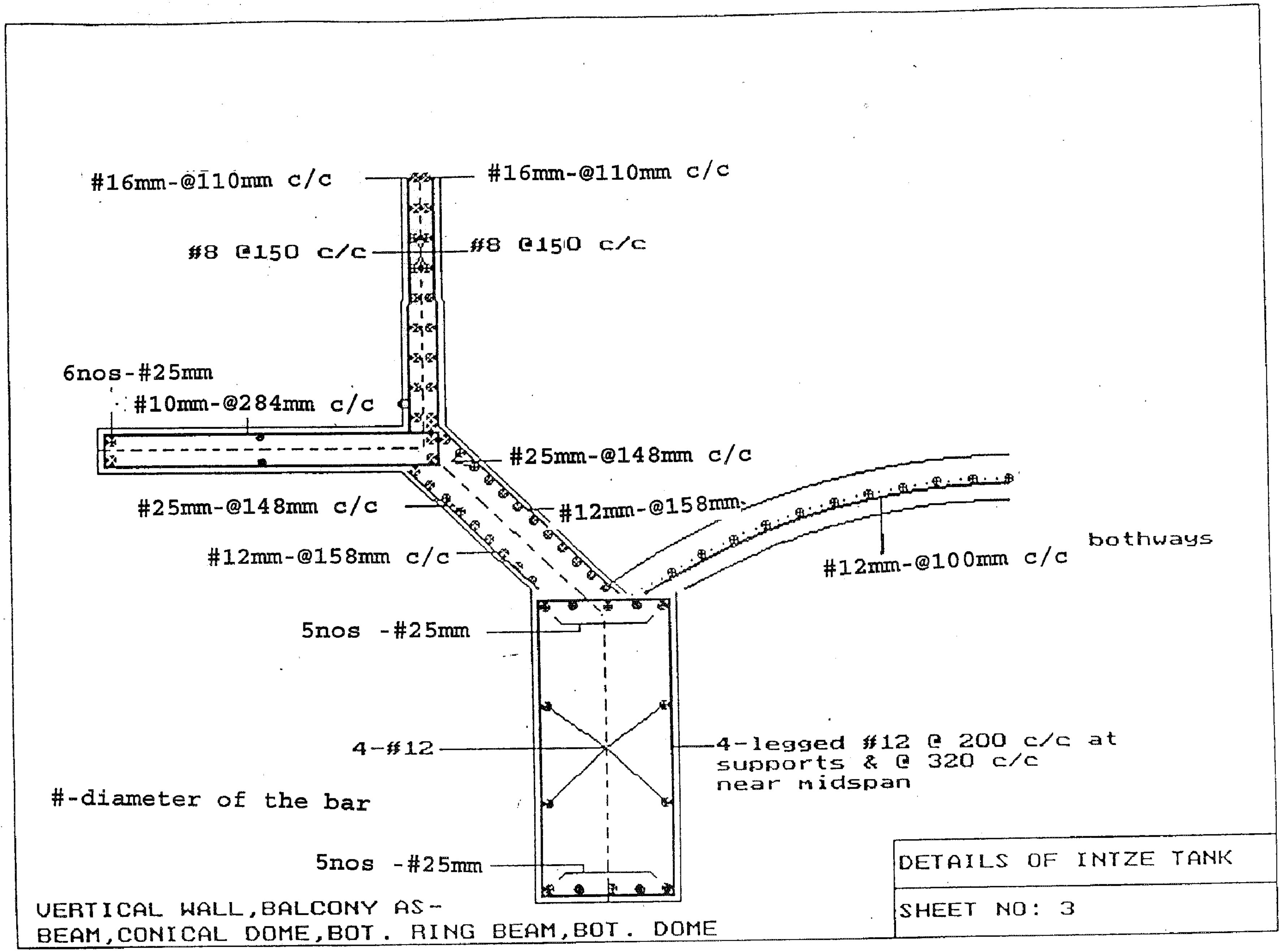


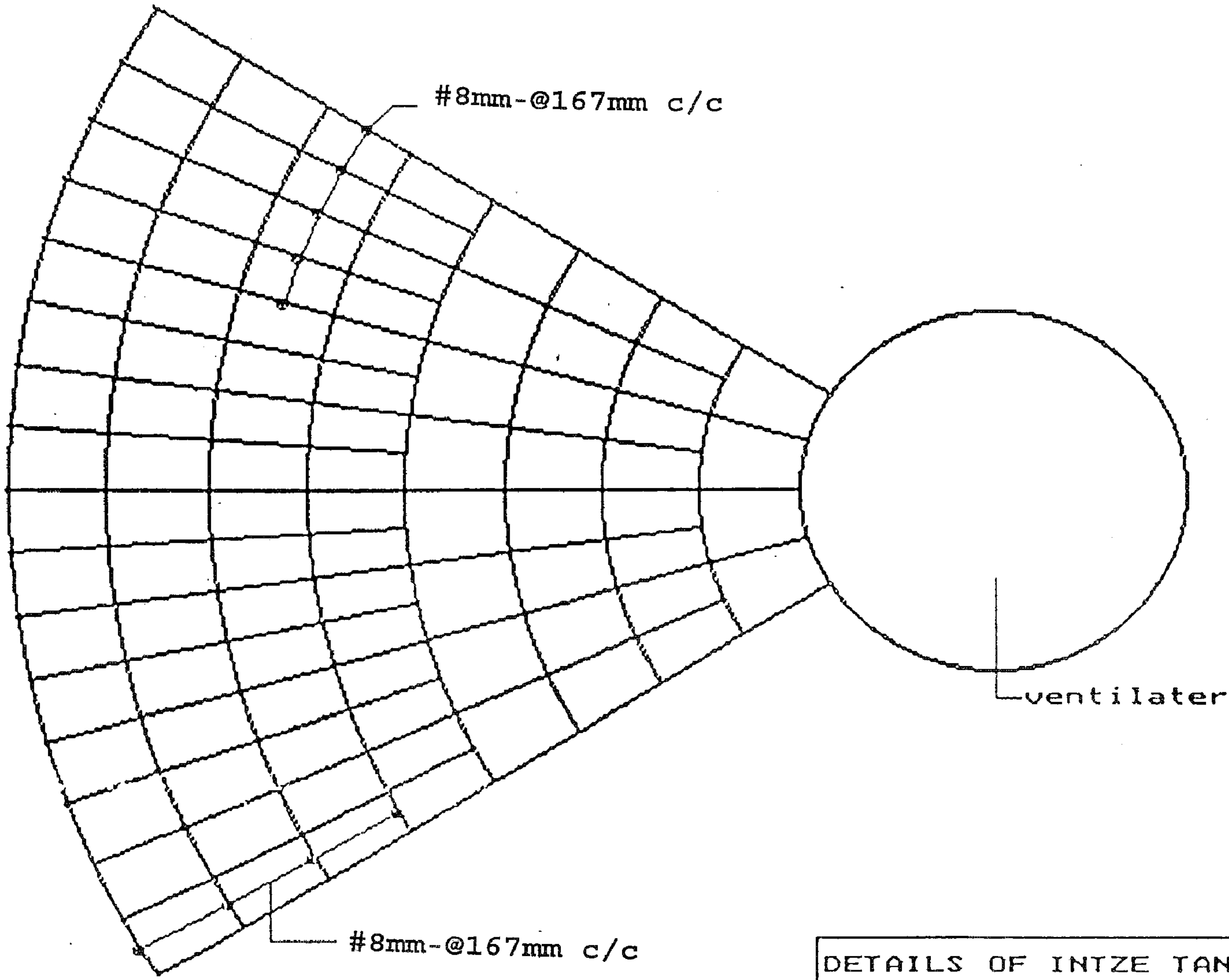
#-diameter of the bar

TOP DOME,TOP RING BEAM,
VERTICAL WALL

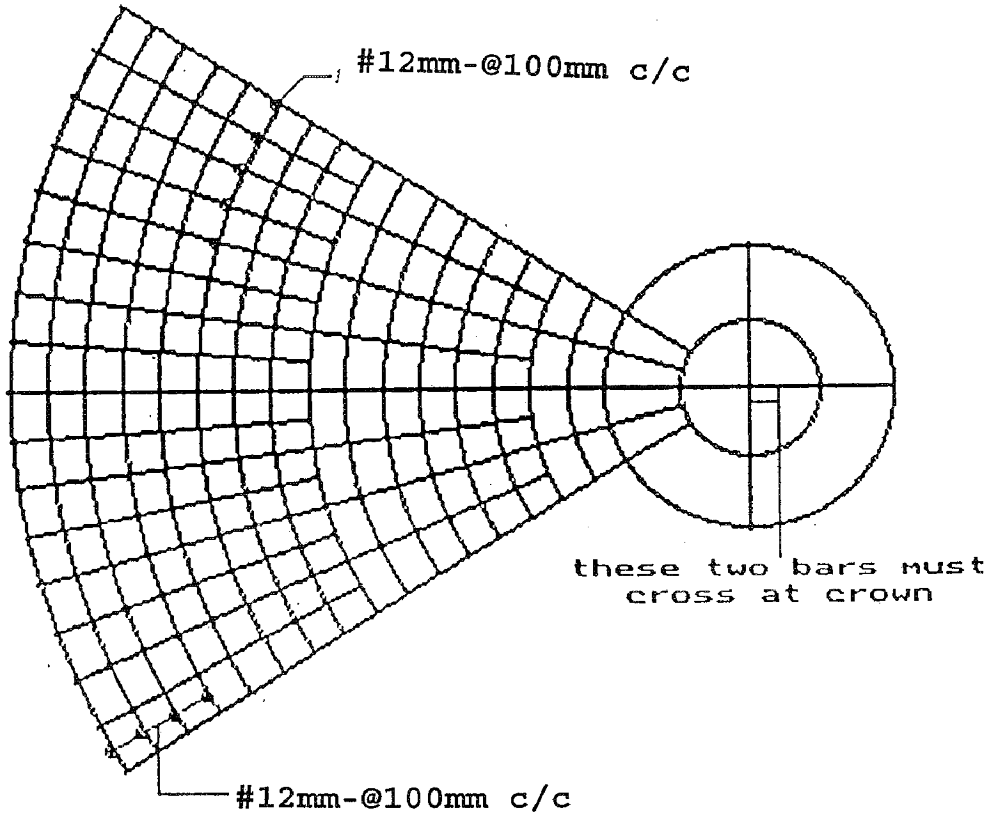
DETAILS OF INTZE TANK

SHEET NO: 2


#16mm-@110mm c/c
#16mm-@110mm c/c
#8 @150 c/c
#8 @150 c/c
6nos-#25mm
#10mm-@284mm c/c
#25mm-@148mm c/c
#25mm-@148mm c/c
#12mm-@158mm
#12mm-@158mm c/c
bothways
#12mm-@100mm c/c
5nos -#25mm
4-#12
4-legged #12 @ 200 c/c at
supports & @ 320 c/c
near midspan
#-diameter of the bar
5nos -#25mm
VERTICAL WALL,BALCONY AS-
BEAM,CONICAL DOME,BOT. RING BEAM,BOT. DOME
DETAILS OF INTZE TANK
SHEET NO: 3



PART PLAN OF TOP DOME



DETAILS OF INTZE TANK

SHEET NO: 5

PART PLAN OF BOT. DOME

CHAPTER 6

RESULTS AND DISCUSSION

6.1 INTRODUCTION

In order to elicit the scope of the application of the program that has been developed for the analysis and design of Intze Water Tank, a parametric study has been conducted. The study involved the observation of variation of sizing, forces and design of various components of Intze Tank according to the variation of parameters like seismic zone, wind zone, capacity of the tank and height of staging. In order to do away with the conventional program three neural network models have been developed for the sizing, analysis and design of Intze Tank.

6.2 PARAMETRIC STUDY

Table 6.1 shows list of values in which for the same capacity and height of staging, the seismic zone and wind zone are varied. Its been observed that when wind zone I (considered to have the maximum basic wind pressure) is coupled with seismic zone I the wind force is governing the design of columns and braces. But in all other cases it is the seismic force which is governing the design. We can observe from the table 6.6 for the seismic zone V the dimensions and percentage of steel in columns and bracings are maximum.

Table 6.6 shows the effect of increase in the capacity of Tank and increase in the height of staging on the dimensions of various components of the intze Tank. It can be observed from the table 6.2 that variation in the dimensioning of various components of Tank for an increase of 500 Kilo litres is meager. From that we can infer, that for small increase say 50 Kilo litres in capacity the dimensions and design remains more or less same. The variation in the height of staging has no effect on the design of the super structure. But the dimensions of the substructure i.e. foundation are effected to some extent.

6.3 NEURAL NETWORK MODELLING OF THE STUDY

In this study three Neural network models have been developed.

1) Given the input parameters the capacity of the tank, the height of staging, wind pressure and horizontal seismic co-efficient it will give the dimensioning of the various components of the tank.
2) Given the input parameters the capacity of the tanks, the height for staging, wind pressure and horizontal seismic coefficient it will the design of various components of the tank.
3) Given the input parameters the capacity of the Tank, the height of staging, wind pressure and horizontal seismic co-efficient it will the design of various components of the tank.

6.3.1 THE TRAINING DATA

For each Neural Network Model a total of 105 cases of data are considered for the work. Out of which 55 cases are considered for the training the neural network, 24 cases for the testing and 25 cases for interrogation of the network. The details of interrogation network data are Shown in the Table 6.3 to 6.5. The Neural Network analysis were carried out with a learning rate $\eta = 0.5$, and the momentum factor $\alpha = 0.6$. These optimal values of learning rate were determined through trial and error.

6.3.2 ANALYSIS OF THE DATA

For the sake of convenience three neural network models were trained for the same no of input variables it is found that the models were found to converge in a similar manner. The success rates of the neural network models have been given in the table 6.2. The success rates of neural networks indicate that common algorithmic procedures of analysis and design of intze tank can be replaced with neural networks of acceptable accuracy. The results indicate that the neural network has been successful in learning the relationship between input and output data. One results from the training phase suggest that although the neural network models were not explicitly trained for these data, they were capable of generalization and gave reasonable predictions. Once the neural network has been trained given the input data

Table 6.1 Parametric Study

Item	Input parameters				Output Parameters					
	Capacity in KL	Height of staging in mt	Seismic zone	Wind zone	B.M. due to E.Q. force in Column in N-M	B.M. due to wind force in column in N-M	% of steel in column of 32mm diameter bars	% of Steel in bracing of 25 mm diameter bars	Size of column in mm x mm	Size of Bracing in mm x mm
CASE 1	1500	20	I	I	48428.8	53974.8	0.08	0.05	800x800	600x600
CASE 2	1500	20	I	II	48428.8	45646.4	0.06	0.05	650x650	600x600
CASE 3	1500	20	II	I	59257.6	53974.8	0.08	0.09	800x800	600x600
CASE 4	1500	20	III	I	193640	53974.8	0.08	0.17	800x800	600x600
CASE 5	1500	20	IV	I	242144	53974.8	0.08	0.21	800x800	600x600
CASE 6	1500	20	V	I	387460	53974.8	0.10	0.33	950x950	600x600
CASE 7	1500	20	II	II	59257.6	45646.4	0.08	0.09	800x800	600x600
CASE 8	1500	20	III	II	193640	45646.4	0.08	0.17	800x800	600x600
CASE 9	1500	20	IV	II	242144	45646.4	0.08	0.21	800x800	600x600
CASE 10	1500	20	V	II	387460	45646.4	0.10	0.33	950x950	600x600
CASE 11	1500	20	I	III	48428.8	40307	0.06	0.05	650x650	600x600
CASE 12	1500	20	II	III	59257.6	40307	0.08	0.09	800x800	600x600
CASE 13	1500	20	III	III	193640	40307	0.08	0.17	800x800	600x600
CASE 14	1500	20	IV	III	242144	40307	0.08	0.21	800x800	600x600
CASE 15	1500	20	V	III	387460	40307	0.10	0.33	950x950	600x600
CASE 16	1500	20	I	IV	48428.8	36115	0.06	0.05	650x650	600x600
CASE 17	1500	20	II	IV	59257.6	36115	0.08	0.09	800x800	600x600
CASE 18	1500	20	III	IV	193640	36115	0.08	0.17	800x800	600x600
CASE 19	1500	20	IV	IV	242144	36115	0.08	0.21	800x800	600x600
CASE 20	1500	20	V	IV	387460	36115	0.10	0.33	950x950	600x600
CASE 21	1500	20	I	V	48428.8	29002	0.06	0.05	650x650	600x600
CASE 22	1500	20	II	V	59257.6	29002	0.08	0.09	800x800	600x600
CASE 23	1500	20	III	V	193640	29002	0.08	0.17	800x800	600x600
CASE 24	1500	20	IV	V	242144	29002	0.08	0.21	800x800	600x600
CASE 25	1500	20	V	V	387460	29002	0.10	0.33	950x950	600x600

Table 6.2 Success rates of Neural Networks

Model	No. of input Variables	No. of hidden nodes	No. of output Variables	Efficiency	Success rate
M1	7	14	28	95	96
M2	7	18	21	96	97
M3	7	14	51	95	95

TABLE- 6.3 SIZING NEURAL NETWORK

INPUT PARAMETERS							TOP DOME				TOP RING BEAM		
q	hc	bc	nc	s.c	w.c	w.p	ttd	rtd	alpha	dit	btrb	dtrb	hcw
500	15	250	8	0.144	0.7	1184	100	10	0.523	10	297	222	4
500	15	250	8	0.018	0.7	1060	100	10	0.523	10	297	223	4
500	15	250	8	0.036	0.7	1060	100	10	0.523	10	297	222	4
500	20	250	8	0.144	0.7	1340	100	10	0.523	10	297	223	4
500	20	250	8	0.018	0.7	1184	100	10	0.523	10	297	222	4
500	20	250	8	0.036	0.7	1184	100	10	0.523	10	297	222	4
500	25	250	8	0.018	0.7	1184	100	10	0.523	10	297	222	4
500	25	250	8	0.036	0.7	1184	100	10	0.523	10	297	222	4
500	25	250	8	0.072	0.7	1184	100	10	0.523	10	297	222	4
1000	15	250	8	0.018	0.7	1184	100	11	0.523	11	313	236	5
1000	15	250	8	0.036	0.7	1184	100	11	0.523	11	312	236	5
1000	15	250	8	0.072	0.7	1184	100	11	0.523	11	311	235	5
1000	20	250	8	0.018	0.7	1184	100	11	0.523	11	318	240	5
1000	20	250	8	0.036	0.7	1184	100	11	0.523	11	317	239	5
1000	20	250	8	0.072	0.7	1184	100	11	0.523	11	315	237	5
1000	25	250	8	0.144	0.7	1340	100	11	0.523	11	324	243	5
1000	25	250	8	0.018	0.7	1184	100	11	0.523	11	320	240	5
1000	25	250	8	0.036	0.7	1184	100	11	0.523	11	319	239	5
1500	15	250	8	0.144	0.7	1340	100	12	0.523	13	369	283	6
1500	15	250	8	0.018	0.7	1184	100	12	0.523	13	367	283	6
1500	15	250	8	0.036	0.7	1184	100	12	0.523	13	368	283	6
1500	20	250	8	0.144	0.7	1340	100	14	0.523	13	403	303	6
1500	20	250	8	0.018	0.7	1184	100	14	0.523	13	394	297	6
1500	20	250	8	0.036	0.7	1184	100	14	0.523	13	395	298	6
2000	20	250	8	0.072	0.7	1340	100	16	0.523	16	484	363	6

TABLE 6.3 SIZING NEURAL NETWORK CONTINUED

CYLINDRICAL WALL		RING BEAM		CONICAL DOME		BOTTOM DOME				CIRCULAR BEAM		
tcwt	tcwb	bbtrb	dbtrb	tcd	hcd	bdcd	tbsd	rbsd	beta	dbdcd	bbbrb	dbbrb
96	169	701	400	500	1	7	300	6	0.521	7	650	1300
96	169	701	400	500	1	7	300	6	0.521	7	650	1300
96	169	701	400	500	1	7	300	6	0.521	7	650	1300
96	169	701	400	500	1	7	300	6	0.521	7	650	1300
96	169	700	400	500	1	7	300	6	0.521	7	650	1300
96	169	700	400	500	1	7	300	6	0.521	7	650	1300
96	169	700	400	500	1	7	300	6	0.521	7	650	1300
96	169	700	400	500	1	7	300	6	0.521	7	650	1300
96	169	700	400	500	1	7	300	6	0.521	7	650	1300
135	240	919	400	500	1	8	300	7	0.521	9	650	1300
134	237	915	400	500	1	8	300	7	0.521	9	650	1300
131	232	907	400	500	1	7	300	7	0.521	9	650	1300
136	240	933	400	500	1	8	300	7	0.521	9	650	1300
133	237	928	400	500	1	8	300	7	0.521	9	650	1300
129	229	919	400	500	1	8	300	7	0.521	9	650	1300
129	229	943	400	500	1	8	300	7	0.521	9	650	1300
126	223	929	400	500	1	8	300	7	0.521	9	650	1300
125	221	926	400	500	1	8	300	7	0.521	9	650	1300
191	338	995	400	500	2	9	300	8	0.521	10	650	1300
193	340	995	400	500	2	9	300	8	0.521	10	650	1300
192	339	995	400	500	2	9	300	8	0.521	10	650	1300
194	346	997	400	500	2	10	303	8	0.521	10	650	1300
196	347	997	400	500	2	10	302	8	0.521	10	650	1300
197	347	997	400	500	2	10	302	8	0.521	10	650	1300
225	397	1000	400	500	2	12	398	10	0.521	10	650	1300

TABLE 6.3 SIZING NEURAL NETWORK CONTINUED

COLUMN	BRACING		ANNULAR RAFT FOUNDATION				
dc	wbr	dbr	odcd	idcd	wf	df	drs
650	402	401	12	6	800	1600	304
650	402	401	12	6	800	1600	304
650	402	401	12	6	800	1600	304
650	402	401	12	6	800	1600	304
650	401	401	12	6	800	1600	304
650	401	401	12	6	800	1600	304
650	402	401	12	6	800	1600	304
650	402	401	12	6	800	1600	304
650	402	401	12	6	800	1600	304
651	440	431	14	6	800	1600	311
651	439	430	14	6	800	1600	310
651	436	429	14	6	800	1600	310
651	445	440	14	6	800	1600	322
651	443	439	14	6	800	1600	321
651	440	437	14	6	800	1600	320
652	450	459	14	6	800	1600	365
651	444	451	13	6	800	1600	353
651	442	450	13	6	800	1600	352
655	530	523	15	6	800	1600	409
654	527	519	15	6	800	1600	403
654	528	521	15	6	800	1600	405
666	582	582	15	6	800	1600	453
658	570	581	15	6	800	1600	450
658	573	583	15	6	800	1600	451
827	688	683	15	6	800	1600	460

TABLE 6.4 FORCE NEURAL NETWORK

INPUT PARAMETERS							TOP DOME		TOP BEAM	C.WALL	C.DOME	BOTTOM DOME	
q	hc	bc	nc	s.c	w.c	w.p	hsttd	msttd	ktrb	mhtcw	mhtcd	mstbsd	hstbsd
500	15	250	8	0.144	0.7	1340	.200	0.215	22288	201291	387305	0.575	0.036
500	15	250	8	0.018	0.7	1340	.200	0.215	22324	201416	387386	0.575	0.036
500	20	250	8	0.036	0.7	1340	.201	0.216	23284	202545	388588	0.585	0.036
500	20	250	8	0.144	0.7	1184	.200	0.215	22587	201589	387701	0.578	0.036
500	20	250	8	0.018	0.7	1184	.200	0.215	22726	201781	387910	0.579	0.036
500	25	250	8	0.036	0.7	1184	.201	0.216	23187	202328	388570	0.582	0.036
500	25	250	8	0.018	0.7	1184	.201	0.216	23485	202703	388995	0.585	0.036
500	25	250	8	0.036	0.7	1184	.201	0.217	24349	203783	390197	0.591	0.036
1000	15	250	8	0.072	0.7	1184	.233	0.271	111628	342856	549740	0.1002	0.041
1000	15	250	8	0.018	0.7	1184	.226	0.26	107286	346435	551998	0.1	0.04
1000	15	250	8	0.036	0.7	1184	.217	0.242	98488	351708	555476	0.1007	0.04
1000	20	250	8	0.072	0.7	1184	.267	0.313	129241	326815	544031	0.1051	0.041
1000	20	250	8	0.018	0.7	1184	.266	0.312	128890	327549	544562	0.1052	0.041
1000	20	250	8	0.036	0.7	1184	.260	0.307	127005	329478	545396	0.1053	0.041
1000	25	250	8	0.072	0.7	1340	.272	0.321	136521	326068	543843	0.1077	0.042
1000	25	250	8	0.144	0.7	1184	.272	0.318	132992	329142	548377	0.1061	0.042
1000	25	250	8	0.018	0.7	1184	.273	0.319	133491	329774	549051	0.1063	0.042
1500	15	250	8	0.036	0.7	1340	.210	0.273	89010	414189	713296	0.119	0.047
1500	15	250	8	0.144	0.7	1184	.211	0.266	94255	413111	717502	0.1189	0.048
1500	15	250	8	0.018	0.7	1184	.210	0.261	91712	416442	721231	0.1189	0.048
1500	20	250	8	0.036	0.7	1340	.279	0.35	173533	424780	757121	0.119	0.054
1500	20	250	8	0.144	0.7	1184	.277	0.347	155363	422136	747634	0.119	0.053
1500	20	250	8	0.018	0.7	1184	.272	0.345	155975	423441	751140	0.119	0.053
2000	20	250	8	0.036	0.7	1340	.340	0.36	253837	478500	863681	0.119	0.06

TABLE 6.4 FORCE NEURAL NETWORK CONTINUED

BOTTOM CIRCULAR BEAM			COLUMN					BRACING	FOUNDATION			
tdlbbrb	nbmbbrb	pbmbbrb	tmbbrb	mmc	vlc	spcw	spceq	mbr	tmlf	nbmf	pbmf	tmf
265068	170702	78895	16515	15989	959892	14604	8408	46163	8447	212139	97315	16021
265075	170847	78926	16525	16807	960063	14509	8408	49861	8436	212616	97491	16047
265187	173337	80023	16678	37150	965075	14332	8408	106079	8647	218394	100242	16285
265103	171686	79398	16594	15806	960495	13726	8408	46852	8544	214764	98665	16125
265120	172081	79566	16616	15906	960771	13721	8408	47578	8574	215600	99085	16170
265173	173303	80114	16677	16021	961805	13845	8408	48322	8685	217789	100314	16296
265212	174101	80417	16721	16166	962364	13849	8408	49346	8741	219325	101106	16379
265334	176314	81176	16840	16750	963985	13926	8408	52802	8882	223368	103156	16598
351764	361952	111614	23805	28098	1008434	19229	8420	116883	12556	404058	190896	32190
365175	350159	111094	22770	29328	1002355	19884	8443	117029	12523	384630	185861	32194
401404	324292	109625	20830	35270	993793	21051	8603	120225	12657	342394	179876	32262
332105	402448	115417	28945	26922	1043265	16380	8408	118169	13362	477032	216306	32196
333949	401473	115506	28893	27379	1042077	16388	8408	119898	13360	476073	215376	32212
340028	395638	115627	28453	30175	1038930	16556	8408	128128	13342	468786	210514	32101
338953	398814	118015	30424	465509	1264518	17302	8428	532300	13490	495576	216821	32417
335360	412249	117683	29937	27327	1049244	16599	8408	117515	13517	494470	222646	32813
336373	413545	117992	30108	27887	1050280	16608	8408	119127	13536	497169	223435	32918
506985	497091	287899	55926	576454	1089787	15194	160354	924274	19713	701105	349836	63606
506974	486813	273985	54518	91158	990786	15608	11683	163643	19676	745734	330937	60713
506979	480829	274117	53068	101160	989714	16223	14053	161569	19676	722445	335762	61377
506979	644657	325511	63118	585383	1882967	16668	101071	821404	20827	926667	385021	65718
506958	642924	315570	62628	98969	1047797	16531	8476	176590	20417	926881	386952	64893
506969	638181	319746	62626	111405	1046947	16947	8541	171112	20549	926418	384679	64860

TABLE 6.5 DESIGN NEURAL NETWORK

INPUT PARAMETERS							TOP DOME		TOP RING BEAM		
q	hc	bc	nc	s.c	w.c	w.p	phitd	std	ntrb	phitrb	strb
500	15	250	8	0.144	0.7	1340	8	167	3	20	388
500	15	250	8	0.018	0.7	1340	8	167	3	20	388
500	15	250	8	0.036	0.7	1340	8	167	3	20	388
500	20	250	8	0.144	0.7	1340	8	167	3	20	388
500	20	250	8	0.018	0.7	1184	8	167	3	20	388
500	20	250	8	0.036	0.7	1184	8	167	3	20	388
500	25	250	8	0.018	0.7	1184	8	167	3	20	387
500	25	250	8	0.036	0.7	1184	8	167	3	20	387
500	25	250	8	0.072	0.7	1184	8	167	3	20	387
1000	15	250	8	0.018	0.7	1184	8	167	6	20	224
1000	15	250	8	0.036	0.7	1184	8	167	6	20	224
1000	15	250	8	0.072	0.7	1184	8	167	6	20	226
1000	20	250	8	0.018	0.7	1184	8	167	6	20	224
1000	20	250	8	0.036	0.7	1184	8	167	6	20	224
1000	20	250	8	0.072	0.7	1184	8	167	6	20	227
1000	25	250	8	0.144	0.7	1340	8	167	6	20	233
1000	25	250	8	0.018	0.7	1184	8	167	6	20	224
1000	25	250	8	0.036	0.7	1184	8	167	6	20	224
1500	15	250	8	0.144	0.7	1340	8	167	6	20	232
1500	15	250	8	0.018	0.7	1184	8	167	6	20	224
1500	15	250	8	0.036	0.7	1184	8	167	6	20	224
1500	20	250	8	0.144	0.7	1340	8	167	6	20	229
1500	20	250	8	0.018	0.7	1184	8	167	6	20	222
1500	20	250	8	0.036	0.7	1184	8	167	6	20	222
2000	20	250	8	0.072	0.7	1340	8	167	8	20	141

TABLE 6.5 DESIGN NEURAL NETWORK CONTINUED

		CYLINDRICAL WALL								BOTTOM RING BEAM	
dphitrb	dstrb	phicw	scw	phicwo	scwo	phiswt	scwt	dphicw	dscw	nbtrb	phibtrb
8	281	16	229	12	195	12	163	10	412	7	25
8	281	16	229	12	195	12	163	10	412	7	25
8	281	16	229	12	195	12	163	10	411	7	25
8	281	16	228	12	195	12	163	10	409	7	25
8	281	16	229	12	195	12	162	10	412	7	25
8	281	16	229	12	195	12	162	10	412	7	25
8	280	16	224	12	194	12	161	10	411	7	25
8	280	16	224	12	194	12	161	10	411	7	25
8	280	16	222	12	194	12	161	10	409	7	25
8	211	16	102	12	87	12	76	10	149	15	25
8	211	16	102	12	87	12	76	10	148	15	25
8	212	16	102	12	87	12	76	10	135	14	25
8	211	16	102	12	87	12	76	10	149	15	25
8	211	16	102	12	87	12	76	10	147	15	25
8	213	16	102	12	87	12	76	10	132	14	25
8	216	16	101	12	87	12	76	10	126	14	25
8	211	16	102	12	87	12	76	10	148	15	25
8	211	16	102	12	87	12	76	10	146	15	25
8	215	16	101	12	87	12	76	10	126	14	25
8	211	16	102	12	87	12	76	10	149	15	25
8	211	16	102	12	87	12	76	10	148	15	25
8	214	16	101	12	86	12	76	10	126	15	25
8	210	16	102	12	87	12	76	10	148	15	25
8	210	16	102	12	87	12	76	10	146	15	25
8	170	16	96	12	81	12	72	10	125	39	25

TABLE 6.5 DESIGN NEURAL NETWORK CONTINUED

			CONICAL DOME				BOTTOM CIRCULAR BEAM				
sbtrb	dphibtrb	dsbtrb	phicd	scd	dphicd	dscd	nsbbrb	nmbbrb	sphibbrb	Mphibbrb	dphibbrb
183	10	252	25	142	12	432	3	2	25	25	12
183	10	252	25	139	12	432	3	2	25	25	12
183	10	252	25	137	12	432	3	2	25	25	12
183	10	252	25	135	12	432	3	2	25	25	12
183	10	252	25	140	12	432	3	2	25	25	12
183	10	252	25	140	12	432	3	2	25	25	12
183	10	250	25	135	12	430	3	2	25	25	12
183	10	250	25	135	12	430	3	2	25	25	12
183	10	250	25	133	12	429	3	2	25	25	12
171	10	182	25	130	12	155	9	3	25	25	12
171	10	182	25	130	12	156	9	3	25	25	12
170	10	182	25	130	12	156	9	3	25	25	12
171	10	182	25	130	12	155	9	3	25	25	12
171	10	182	25	130	12	156	9	3	25	25	12
170	10	182	25	130	12	157	8	3	25	25	12
170	10	182	25	130	12	158	8	4	25	25	12
171	10	182	25	130	12	155	9	3	25	25	12
171	10	182	25	130	12	156	9	3	25	25	12
170	10	182	25	130	12	158	8	4	25	25	12
171	10	182	25	130	12	155	9	3	25	25	12
171	10	182	25	130	12	155	9	3	25	25	12
169	10	182	25	130	12	155	8	4	25	25	12
170	10	182	25	130	12	154	9	3	25	25	12
170	10	182	25	130	12	154	9	3	25	25	12
41	10	180	25	130	12	110	14	6	25	25	12

TABLE 6.5 DESIGN NEURAL NETWORK CONTINUED

				COLUMN				BRACING			
sbbrbc	sbbrbpc	nsfbbrb	phisfbbrb	phic	dphic	nbc	vsc	nbbr	phibr	dphibr	sbr
237	350	4	12	32	10	6	480	4	25	10	143
236	350	4	12	32	10	6	480	6	25	10	44
235	350	4	12	32	10	6	480	11	25	10	28
234	350	4	12	32	10	6	480	18	25	10	27
236	350	4	12	32	10	6	480	4	25	10	153
236	350	4	12	32	10	6	480	4	25	10	145
229	349	4	12	32	10	6	480	4	25	10	161
228	349	4	12	32	10	6	480	4	25	10	147
224	349	4	12	32	10	6	480	8	25	10	33
141	260	4	12	32	10	6	480	5	25	10	205
141	260	4	12	32	10	6	480	5	25	10	202
140	260	4	12	32	10	6	480	8	25	10	99
141	260	4	12	32	10	6	480	5	25	10	205
141	260	4	12	32	10	6	480	5	25	10	198
140	260	4	12	32	10	6	480	10	25	10	58
140	262	4	12	32	10	8	480	26	25	10	27
141	260	4	12	32	10	6	480	5	25	10	203
140	260	4	12	32	10	6	480	6	25	10	191
140	262	4	12	32	10	8	480	26	25	10	27
141	260	4	12	32	10	6	480	5	25	10	205
141	260	4	12	32	10	6	480	5	25	10	200
140	261	4	12	32	10	8	480	26	25	10	27
140	259	4	12	32	10	6	480	5	25	10	204
140	259	4	12	32	10	6	480	6	25	10	195
139	227	3	12	32	10	11	480	21	25	10	27

TABLE 6.5 DESIGN NEURAL NETWORK CONTINUED

FOUNDATION									
nfsm	phifsm	nfmm	phifmm	nsff	phinsff	phidf	sdff	phirsf	srsf
3	25	2	25	1	25	10	169	25	284
3	25	2	25	1	25	10	169	25	284
3	25	2	25	1	25	10	169	25	284
3	25	2	25	1	25	10	168	25	284
3	25	2	25	1	25	10	169	25	284
3	25	2	25	1	25	10	169	25	284
3	25	2	25	1	25	10	168	25	282
3	25	2	25	1	25	10	167	25	282
3	25	2	25	1	25	10	167	25	282
3	25	4	25	1	25	10	104	25	184
3	25	4	25	1	25	10	104	25	184
3	25	4	25	1	25	10	102	25	183
3	25	4	25	1	25	10	104	25	184
3	25	4	25	1	25	10	104	25	183
3	25	4	25	1	25	10	100	25	183
3	25	4	25	1	25	10	95	25	183
3	25	4	25	1	25	10	104	25	183
3	25	4	25	1	25	10	104	25	183
3	25	4	25	1	25	10	95	25	183
3	25	4	25	1	25	10	104	25	183
3	25	4	25	1	25	10	104	25	183
3	25	4	25	1	25	10	95	25	183
3	25	4	25	1	25	10	104	25	183
3	25	4	25	1	25	10	103	25	183
3	25	5	25	1	25	10	76	25	175

TABLE- 6.6 PARAMETRIC STUDY OF DIMENSIONS

INPUT PARAMETERS							TOP DOME				TOP RING BEAM		
q	hc	bc	nc	s.c	w.c	w.p	ttd	rtd	alpha	dit	btrb	dtrb	hcw
500	15	250	8	0.036	0.7	1060	100	10	0.523	10	297	222	4
500	20	250	8	0.144	0.7	1340	100	10	0.523	10	297	223	4
1000	15	250	8	0.072	0.7	1184	100	11	0.523	11	311	235	5
1000	20	250	8	0.018	0.7	1184	100	11	0.523	11	318	240	5
1000	25	250	8	0.036	0.7	1184	100	11	0.523	11	319	239	5
1500	15	250	8	0.144	0.7	1340	100	12	0.523	13	369	283	6
1500	20	250	8	0.144	0.7	1340	100	14	0.523	13	403	303	6
2000	20	250	8	0.072	0.7	1340	100	16	0.523	16	484	363	6

TABLE- 6.6 PARAMETRIC STUDY OF DIMENSIONS CONTINUED

CYLINDRICAL WALL		RING BEAM		CONICAL DOME		BOTTOM DOME				CIRCULAR BEAM		
tcwt	tcwb	bbtrb	dbtrb	tcd	hcd	bdcd	tbsd	rbsd	beta	dbdcd	bbbrb	dbbrb
96	169	701	400	500	1	7	300	6	0.521	7	650	1300
96	169	701	400	500	1	7	300	6	0.521	7	650	1300
131	232	907	400	500	1	7	300	7	0.521	9	650	1300
136	240	933	400	500	1	8	300	7	0.521	9	650	1300
125	221	926	400	500	1	8	300	7	0.521	9	650	1300
191	338	995	400	500	2	9	300	8	0.521	10	650	1300
194	346	997	400	500	2	10	303	8	0.521	10	650	1300
225	397	1000	400	500	2	12	398	10	0.521	10	650	1300

TABLE- 6.6 PARAMETRIC STUDY OF DIMENSIONS CONTINUED

COLUMN	BRACING		ANNULAR RAFT FOUNDATION				
dc	wbr	dbr	odcd	idcd	wf	df	drs
650	402	401	12	6	800	1600	304
650	402	401	12	6	800	1600	304
651	436	429	14	6	800	1600	310
651	445	440	14	6	800	1600	322
651	442	450	13	6	800	1600	352
655	530	523	15	6	800	1600	409
666	582	582	15	6	800	1600	453
827	688	683	15	6	800	1600	460

LIST OF SYMBOLS FOR THE INPUT PARAMETERS OF THREE NEURAL NETWORKS

q	Capacity of the Tank in kilolitres
hc	Height of columns in m.
nc	No. of Columns
bc	Bearing capacity of the soil in kN/m^2
s.c	Horizontal seismic coefficient
w.c	Force coefficient of wind
w.p	Basic wind pressure in N/m^2

LIST OF SYMBOLS FOR SIZING NEURAL NETWORK

ttd	Thickness of top dome in mm
rtd	Radius of top dome in m.
alpha	Angle of top dome in radians
dit	Diameter of the tank in m.
btrb	Breadth of top ring beam in mm
dtrb	Depth of top ring beam in mm
hcw	Height of cylindrical wall in m.
tcwt	Thickness of cylindrical wall at top in mm.
tcwb	Thickness of cylindrical wall at bottom in mm
bbtrb	Breadth of bottom ring beam in mm
dbtrb	Depth of bottom ring beam in mm
tcd	Thickness of conical dome in mm
hcd	Height of conical dome in m.
bdcd	Bottom diameter of conical done in m.
tbsd	Thickness of bottom spherical dome in mm
rbsd	Radius of bottom spherical dome in mm
beta	Angle of bottom spherical dome in radians
dbdcd	Diameter of bottom circular Beam in m

bbbrb	Breadth of bottom circular beam in mm
dbbrb	Depth of bottom circular beam in mm
dc	Diameter of the column in mm
wbr	Width of bracing in mm
dbr	Depth bracing in mm
odcd	Outer diameter of the annular raft foundation in m.
idcd	Inner diameter of the annular raft foundation in m.
wf	Width of foundation in mm
df	Depth of foundation in mm
drs	Depth of raft slab in mm

LIST OF SYMBOLS FOR FORCE NEURAL NETWORK

hsttd	Hoop stress in top dome in N/Sq. mm
msttd	Meridional stress in Top Done in N/Sq. mm
ktrb	Hoop tension in top ring beam in N
mhtcw	Maximum Hoop tension at the base of cylindrical wall in N.
mhtcd	Maximum hoop tension in conical dome in N
hstbsd	Hoop stress in bottom spherical dome in N/sq. mm
dlbbrb	Total design load on bottom circular beam in N/m
nbmbbrb	Support moment in bottom circular beam in Nm
pbmbbrb	Mid span moment in bottom circular beam in Nm
tmbbrb	Torsional moment in bottom circular beam in Nm
mmc	Maximum moment in the column in Nm
vlc	Total vertical load on the column in N
spcw	Shear per column due to wind in N
spceeq	shear per column due to Earthquake in N
mbr	Maximum moment in bracing in Nm
tmlf	Total maximum load on foundation in N
nbmf	Support moment in the ring beam of foundation in Nm
pbmf	Mid span moment in the ring beam of foundation in Nm
tmf	Torsional moment in the ring beam of foundation in Nm

LIST OF SYMOLS FOR THE DESIGN NEURAL NETWORK

phitd	Diameter of the bars in mm in the top dome
std	Spacing of bars in mm in top dome
ntrb	No. of bars of main reinforcement in top ring beam
phitrb	Diameter of the bars in mm for main reinforcement in top ring beam.
strb	Spacing of bars in mm for main reinforcement in top ring beam.
dphitrb	Diameter of the bars in mm for distribution reinforcement in top ring beam.
phicw	Diameter of the bars in mm for main reinforcement at the base of cylindrical wall.
scw	Spacing of bars in mm for main reinforcement at the base of cylindrical wall.
scwo	Spacing of the bars in mm for main reinforcement at the one third height from the top of cylindrical wall.
phicwt	Diameter of bars in mm for main reinforcement at one third height from the top of cylindrical all.
dphicw	Diameter of the bars in mm for distribution reinforcement in cylindrical wall.
nbtrb	No. of bars reqd for main reinforcement bottom ring beam.
phibtrb	Diameter of the bars in mm for main reinforcement in bottom ring beam.
sbtrb	Spacing of bars in mm for main reinforcement in bottom ring beam
dphibtrb	Diameter of bars in mm for distribution reinforcement in bottom ring beam.
dsbtrb	Spacing of bars in mm for distribution reinforcement in bottom ring beam.
phicd	Diameter of the bars in mm for main reinforcement in conical dome.
scd	Spacing of the bars in the mm for main reinforcement in conical dome.
dphicd	Diameter of the bars in mm for distribution reinforcement in conical dome.
dscd	Spacing of the bars in mm for distribution reinforcement in conical dome
nsbbrb	No. of bars for support moment in bottom circular beam
nmbdrb	No. of bars for mid span moment in bottom circular beam
sphibbrb	Diameter of bars in mm for support moment in bottom circular beam
mphibbrb	Diameter of bars in mm for mid span moment in bottom circular beam
dphibbrb	Diameter of bars in mm for distribution reinforcement in bottom circular

	beam.
sbbrbc	Spacing of the bars in mm for support moment in bottom circular beam
nsfbbrb	No. of bars for the side face reinforcement in the bottom circular beam.
phisfbbrb	Diameter of the bars in mm for side face reinforcement in bottom circular beam.
phic	Diameter of the bars in mm for main reinforcement in column
dphic	Diameter of the bars in mm for distribution reinforcement in column.
nbc	No. of bars for the main reinforcement in the column
vsc	Spacing of bars of distribution reinforcement in column
nbbr	No. of bars for the main reinforcement in the bracing
phibr	Diameter of the bars in mm for main reinforcement in the bracing
dphibr	Diameter of the bars in mm for distribution reinforcement in the bracing
sbr	Spacing of the bars in mm of distribution reinforcement in the bracing.
nfsm	No. of bars for the support moment in the foundation ring beam.
phifsm	Diameter of the bars in mm for the support moment in the foundation ring beam
nfmm	No. of bars for the mid span moment in the foundation ring beam.
phifmm	Diameter of the bars in mm for mid span moment in the foundation ring beam.
nsff	No. of bars for side face reinforcement in the foundation ring beam
phinsff	Diameter of the bars in mm for distribution reinforcement in the foundation ring beam
phidf	Diameter of the bars in mm for distribution Reinforcement in the foundation Ring beam
sdff	Spacing of bars in mm for distribution reinforcement in the foundation ring beam
phirsf	Diameter of the bars in mm for the main reinforcement in the raft slab.
srsf	Spacing of the bars in mm for the main reinforcement in the raft slab.

CHAPTER 7

CONCLUSIONS AND SCOPE FOR FUTURE STUDY

7.1 CONCLUSIONS

1. The techniques of artificial intelligence provide an effective alternative for the common algorithmic solutions
2. The user interface in "ESETAD" incorporating expert systems could be so designed that a lay person with the simple knowledge of capacity and height of staging is able to arrive at a safe and economic design of Intze Water Tank.
3. Expert system act as an effective tool, for transferring ill-structured information and the information gained through long term experience of experts in a specific domain of knowledge, into easily accessible knowledge base.
4. The parametric study conducted indicates the satisfactory performance of the expert systems. The results indicate that the seismic force is governing the design of columns and braces in all cases except the case in which seismic zone I is coupled with wind zone I.
5. Expert system like "ESETAD" acts as a powerful tool to augment common algorithmic solution. The main power lies in the simplicity of the usage and expandability of the knowledge bases.
6. Neural nets provide a method that is simple, less expensive, fast and as reliable as the other conventional methods.

7. The sizing, force and Design Neural Networks for the dimensioning, analysis and design of Intze tank provide a powerful tool for replacing traditional algorithmic solutions.

7.2 SCOPE FOR FURTHER STUDY

The emerging role of AI techniques in augmenting or replacing procedures and practices of conventional analysis and design, is beginning to be better appreciated. The powerful tools which constitute the range of AI methodologies and concepts can easily be interfaced with conventional programs producing acceptable results with nominal, incomplete and imprecise inputs. While an attempt has been made in this dissertation to demonstrate the interfacing of expert systems with conventional programs with satisfactory results, there is still ample scope for the following.

1) The continuity analysis of the tank has not been carried out and can easily be incorporated in the software.

2) To be a more comprehensive package, based on capacity the software for the design of rectangular and circular tanks can also be incorporated.

3) Neural networks can be interfaced with conventional programs for analysis and design of intze tank according to traditional methods.

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