Table of Contents

CHAPTER 4 INTERNET & ADVANCED WWW TECHNOLOGIES

CHAPTER 5 MASONRY ARCH BRIDGES & ANALYSIS METHODS

CHAPTER 6 INTELLIGENT MEXE

CHAPTER 7 CONCLUSION & RECOMMENDATIONS

ABSTRACT

In the near future internet will become the most popular method of communication. As we know communication is a very important aspect of the construction industry in the near future internet can be used as a common media for communication in construction industry. At this point as structural engineers it is important for us to know if internet can solve the communication problem between experts and non-experts in construction industry. The main aspect of this research was to investigate if internet technology will enable engineers to find the right knowledge at the right time and at the right place.

The research investigated the role of the internet as a communication media to distribute expert knowledge. The practical example for the research was to develop an expert system about masonry arch bridge analysis that is working over the internet. The expert system was developed by using Visual Basic and Active-X technology was used for web implementation. The expert system was introduced to the experts and engineers in construction industry , interviews were held with experts and non-experts. The literature review was carried out as part of the research to bridge the gap between theory and practice. The dissertation has been sectioned into 5 main parts. The first section tells about the use of computers to solve structural engineering problems, the second section deals with expert systems, the third section is about internet and advanced web technologies, the forth section deals with masonry arch bridge analysis . These four chapters can be thought as a background information for the reader to have a better understanding about the research and the fifth section covers the issues about the expert system that is developed as a part of this research.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude and thanks to my supervisors **Dr. Keith Jones** and **Mr. Robert Falconer** for their kind assistance and guidance throughout my research and for their constructive comments which have helped the development process of IMEXE. Special thanks to my parents Zuhal & Ugur Isıkdag for supporting me during my research , and I would also like to thank Miss. Mathilde Lenglet for her kind support and help during my studies in the UK.

I am grateful to all my friends and colleagues who have helped at various times in making this dissertation possible.

INTRODUCTION

1.1 GENERAL OVERVIEW

People in construction industry are now talking about internet. Today we are now familiar with Information superhighway. Most firms in construction industry use internet for general purposes like sending an e-mail or promoting their site along the world wide web.

As communication is becoming more important in the construction industry ,in the near future internet will be used for distributing knowledge and applications inside the firm between the firms and even to everyone . At this point as engineers we start to think about if internet can solve the communication problem between experts and non-experts .The main idea behind this research is to investigate if internet technology will enable engineers to find the right knowledge at the right time and in the right place. So as a researcher or as a professional we need tools that will give us the best solution in the quickest time. There are many ways of accessing the knowledge ,but internet is the one that is new and becoming more important. This work will examine the internet architecture carefully and will suggest ways to present and share the knowledge depending on current infrastructure of the internet. When we have very high hopes and try to implement our great ideas with current internet structure we always have disappointments and we usually blame the internet or emerging technologies. When we try to present the knowledge over the internet we must start from a simple application and after doing all the compatibility and efficiency criticisms ,we should continue building up a more complicated system. The main question here is if internet can be efficient enough to distribute large amounts of knowledge ,the answer is yes , when we know how to manage the internet resources . The recent technological developments in software and hardware have given us new opportunities for faster and effective distribution of the knowledge. The last important issue is selecting the platform(operating system and compatible software).The end-user should be familiar with the platform and the expert knowledge should be distributed by user friendly interface. We have to make a very careful decision on that subject because ,our decision will effect all the further research and development process and the operability of the system that will be built.

1.2 THE RESEARCH

Distributing the expert knowledge using internet is a new idea. The research will investigate the role of the internet as a communication media to distribute expert knowledge. A practical example at this research will be developing an expert system about masonry arch bridge on the internet. As well as today's technology doesn't give us a chance to develop very complicated system on the net ,but it doesn't mean that we can't develop a fully functional expert system. At this point programming languages(tools) becoming important, because that will effect the structure and reliability of the system. There are some development tools such as Java or Visual Basic ,Java is a very good programming tool but it will be very time consuming to develop an expert system using Java and Java is not easy to use as VB. The expert system shell will be developed by using Visual Basic and this will be helpful to show how a VB application can work perfectly over the internet. The system can work at a server or can be downloaded to the client and that makes the system accessible without the limitation of time and space. The idea of reaching the expert knowledge from the net is worth for research and the effects of current systems(net infrastructure or computer architecture) is taken into account during the research .Because this 2 areas(internet and AI) are now developing and somehow one day every computer will be the part of the a big network and then the technology will force us to find a way for sharing every bit of information and knowledge .In the future it may be an obligatory to use the expert system over the internet.

1.3 AIM & OBJECTIVES OF RESEARCH

1.3.1 AIM

- Making expert systems more accessible for construction industry.

1.3.2 OBJECTIVES

- To investigate the practicalities of the internet to distribute expert knowledge .
- To develop and test a model expert system on the internet .
- To examine the implication of distributing the expert knowledge via WWW to the construction industry .

1.4 METHODOLOGY OF RESEARCH

In this section I want to explain the methodology of my research depending upon my approach and I want to summarise the activities that is done during the research. Regarding traditional classification of research this research can be classified as an applied research. It can be considered as problem-solving research because in this case we are trying to find a solution to a problem that appears in reality. The construction industry used many communication channels one of them is now the internet. Internet enables everyone to exchange any kind of information and knowledge. We started to use internet more efficiently in last five years and we now have to look at the effects of internet to the construction industry on information exchanging. On information exchanging or on knowledge distributing problems occur at the stage when we want to apply the theory in practice. We now are not able to use the internet with “full-performance” ,that is caused either by internet infrastructure(the structure of internet and structure of our end user computers)or lack of knowledge (we do not know how to use the sources or we do not know how to put the knowledge effectively on the net).

We have those general(broad) problems about usage of internet in construction industry but in my research I wanted to examine if the internet will be effective on distributing the expert knowledge . My research was a problem solving research trying to find a solution to the real problem that I explained above.

My research approach can be categorised as an action research .I want to give information about the action research and then I want to explain my research programme in the light of the action research approach .

1.4.1 ACTION RSEARCH

Blaxter,Huges,Tight [1] gives basic classification about research families, approaches and techniques .

Research Families

- Qualitative or Quantitative
- Deskwork or Fieldwork

Research Approaches

- Action Research
- Case Studies
- Experimental
- Surveys

Research Techniques

- Using Documents
- Interview
- Observation
- Questionnaires

"Action research aims to feed practical judgement in concrete situations and validity of the "theories" or hypothesis it generates depends not so much on "scientific" tests of truth as on their usefulness in helping people to act more intelligently and skilfully. In action research "theories" are not validated independently and then applied to practice. They are validated trough practice." [2]

Action research consists of a family of research methodologies which pursue action and research outcomes at the same time .Action research tends to be cyclic, participative and reflective. In action research similar steps tend to recur in a similar sequence(cyclic),the clients and informants are involved as partners(participative) critical reflection upon the process and outcomes are important parts of each cycle(reflective).

As I mentioned action research is cyclic ,a commonly known cycle is that of the influential model of Kemmis,S and Mc.Taggart,R [3]

Cycle Model

Cycle1	Cycle2
Plan	Plan
Act	Act
Observe	Observe
Reflect	Reflect...and goes on

1.4.2 THE PROJECT

The main objective of this research is to make expert systems more accessible for construction industry. I investigated if internet will be a practical way to distribute the expert knowledge. First step was building a knowledge base. To build the knowledge base interviews held with experts and I learned the problems and needs of the industry along that certain field. Depending on the ideas of experts the knowledge base is built. The knowledge base is dynamic and even now you can change the knowledge base. The second step was building the expert system which can answer the questions about the subject and can give advice to the engineers/architects in that area. It is very difficult to create an expert system which can find answers to all possible questions(because some questions are unpredictable or new techniques can lead us to new solutions) , but if the knowledge base is good enough and dynamic we can find answers to most of the questions. Visual Basic was used to develop the expert system, it might seem unfamiliar to use Visual Basic as a tool for expert system development ,but VB makes the expert system -easy to access- over the World Wide Web. Third step was placing the program on the internet and testing it and examining its accessibility. At the same time online questionnaires were published over the internet and answers received by e-mail. The program was introduced to the people on that field by either internet(e-mail, informing search engines, informing the other sites in the same field) or by mail. The fourth part was interviews with experts survey to gather the views of the experts and non-experts working on the field. .When these four steps completed the results were analysed and updated to the knowledge base .The fifth stage was about analysing the data. Analysing the data is very important in the research and statistical methods were used to analyse data ,some spreadsheet programs were used to help the data analysis. At this point the data analysis is done regarding cause-effect relationships between variables. On the sixth stage all the results were checked again .Finally the results are presented by a dissertation(research report) and will be put on the internet .An oral presentation(seminar) will be organised in a convenient time and place.

STRUCTURAL ENGINEERING AND COMPUTERS

2.1 INTRODUCTION

A definition of engineering is the "science by which the properties of matter and the resources of energy in nature are made useful to man". An engineer will have to study the properties and behaviour of physical systems, applying his knowledge to attain purposes useful to society.[4] Such activity can be considered as the effort to solve real physical problems. The complexities involved in dealing with all the parameters relative to the properties of a real problem will ,force the engineer to study an equivalent engineering problem which can be mathematically defined. The engineer will try to solve such a problem according to his knowledge and experience and using the computational tools at hand.

In the past , by hand computation or with the help of desk calculators , engineers were able to analyse very small discrete models which either corresponded to very simple problems , or were very rough approximations of more complex problems . The limitations of their computational capabilities had to be overcome by their experience ,engineering intuition and the adoption of very conservative safety factors. In most cases ,however, several hypothesis to simplify the problem had to be taken into account , to define a discrete model which could be solved numerically. Sometimes an inadequate simplification could result in a discrete model which could not reasonably represent the real problem. When we think of today's engineering problems , it is clear that they must be analysed using very refined discrete models , so as to closely approximate their real behaviour .Fortunately , with the help of modern computer , it is possible today to treat discrete models with up to several thousands of degrees of freedom. Thus , the need for formulating larger and more complex discrete models and the availability of computers which make feasible their analysis ,are the causes of considerable interest produced in relation to numerical methods and computer analysis techniques .

2.2 TRADITIONAL METHODS IN STRUCTURAL ANALYSIS

Before we start using the computers to analyse engineering problems we were using calculators or charts .Calculators helped us to make calculations "*faster* " and more reliable . At the same time we were using design charts that can be considered as "pre-solved problems" for possible situations. If we have a chart for a beam with uniform distributed load on it , in the chart there will the solution of the problem for load such as 1 Kn./m, then all we have to do is to multiply the results(moments , shear forces) by our load value to get the results we want.

In sixties we started to use computers in structural analysis and design to get faster, and more accurate results .Traditional languages were BASIC(Beginners All Purpose Symbolic Instruction Code)[5] and FORTRAN (Formula Translating System)[6] which are used to code our analysis problems. Parallel to the developments in the information technology our way of analysing the structures has changed. As engineers we developed new analysis methodologies considering the I.T developments. New technologies forced us to work on new methodologies and new methodologies brought us new technologies.

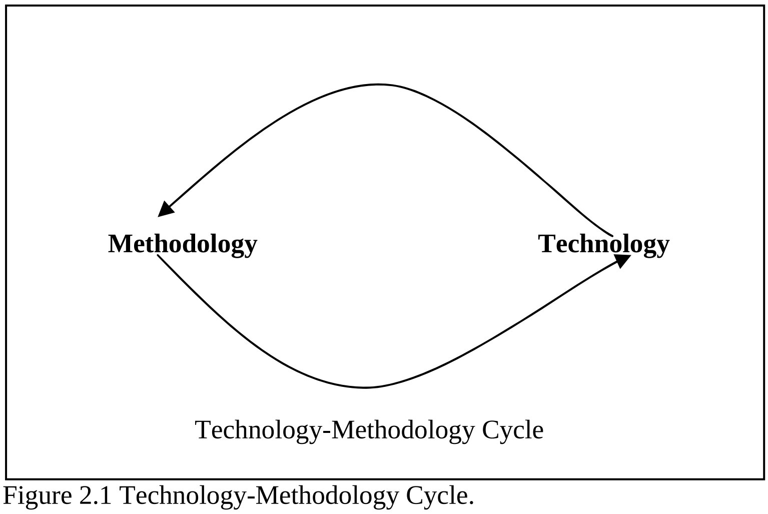

Figure 2.1 Technology-Methodology Cycle.

In order to compare and contrast those methodologies we will analyse the methodologies ,the programming tools ,programming languages, and analysis packages in chronological order.

2.2.1 ANALYSIS OF SIMPLY SUPPORTED BEAM (Example Program using Traditional Approach)

As a structural engineer ,the easiest structure to analyse is the beam below. We use very simple mathematics to find maximum bending moment and end forces of the simply supported beams .As to start with traditional analysis methods and traditional programming, we will first analyse the beam in Figure 2.2 and we will code our analysis to a simple Fortran program.

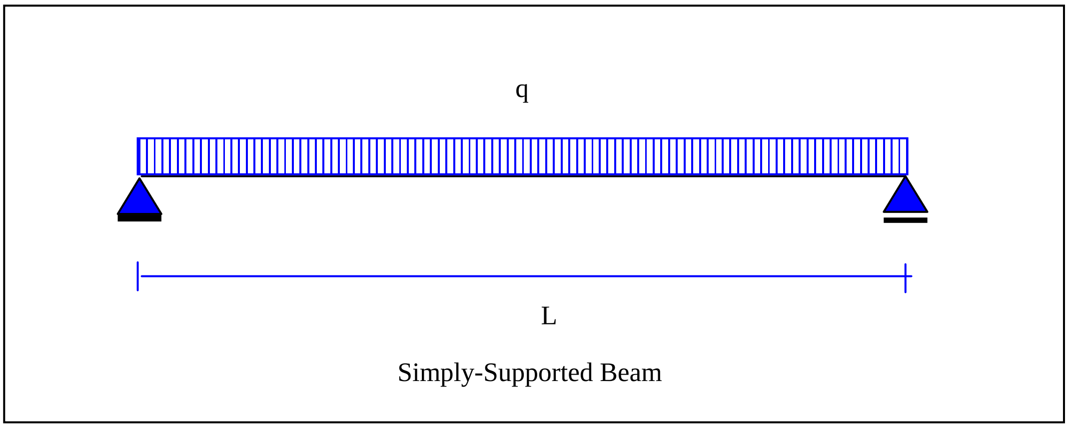

Figure 2.2 Simply Supported Beam

As we can see above ;

Q is the value for uniformly distributed load

L is the span length

The end forces for the simply supported beam with the uniform load are ;

Vl = Vr = ql/2

And the maximum bending moment for the structure is ;

Mmax = ql^2 / 8

As far as we know the mathematical expressions for the beam we can simply code it using FORTRAN programming language.

THE FORTRAN CODE

```
C     THIS PROGRAM FINDS THE VALUES FOR
C     THE MAXIMUM BENDING MOMENT AND END FORCES
C     FOR THE SIMPLY SUPPORTED BEAM UNDER UNIFORMLY
C     DISTRIBUTED LOAD

      WRITE(*,*) “Please enter the span “
      READ(*,*) l
      WRITE(*,*) “Please enter the uniformly distributed load value”
      READ(*,*) q
      V = (q * l )/2
      M = (q*(l**2))/8
      WRITE(*,*) “The end forces are :”
      WRITE(*,*)  V
      WRITE(*,*) “The maximum bending moment is :”
      WRITE(*,*) M
      END
```

The program above can be given as an example for the implementation of traditional programming with traditional analysis methods. The program finds the maximum bending moment and end forces for simply supported beam ,under uniformly distributed load . Fortran is an easy to use programming language and Fortran can be adapted easily to most of the engineering problems.

One of the advantages of solving the problems using computers is ; when the conditions of the problem change , we do not have to build up the whole code again.

Let’s consider there is a point load at the middle span of the beam (Figure 2.2).

P is the value of the point load

The end forces for the new loading condition will be :

$Vl = Vr = ql/2 + p/2$

The maximum bending moment for the new loading condition will be :

$Mmax = ql^2 / 8 + pl/4$

The new code will not be very different from the previous one :

THE FORTRAN CODE FOR THE NEW LOADING CONDITION

```
C      THIS PROGRAM FINDS THE VALUES FOR
C      THE MAXIMUM BENDING MOMENT AND END FORCES
C      FOR THE SIMPLY SUPPORTED BEAM UNDER UNIFORMLY
C      DISTRIBUTED LOAD AND A POINT LOAD AT MID SPAN

       WRITE(*,*) “Please enter the span “
       READ(*,*) l
       WRITE(*,*) “Please enter the uniformly distributed load value”
       READ(*,*) q
       WRITE(*,*) “Please enter the point load value at the mid span”
       READ(*,*) p
       V = ((q * l ) +p) / 2
       M = ((q*(l**2))/8) +((p * l )/4)
       WRITE(*,*) “The end forces are :”
       WRITE(*,*)  V
       WRITE(*,*) “The maximum bending moment is :”
       WRITE(*,*) M
       END
```

By changing the 4 lines of code we can adapt the code for the new loading condition , which is much more quicker than solving the problem again .One of the reasons that computers are vital for structural analysis is that , when the situations change, it is easier and quicker to get the accurate results with computers.

2.2.2 COMPUTATION OF BENDING STRESSES (Traditional Approach)

The computation of bending stresses requires three values the moment of inertia, the co-ordinates of neutral axis (the axis where the value of actual stress is zero) and the bending moment value for that section. If we consider a simply supported beam the calculation of the bending moment is usually a straightforward matter. The important issue is to find the moment of inertia and the co-ordinates of neutral axis , which are also called as “the properties of the section” .

It is better to look at the simple bending theory to understand the section properties.

The so-called simple(or “engineer’s”) bending theory is based upon Bernoulli’s assumption that initially plane sections remain plane after bending , and that the same elastic modulus applies whether the stress is tensile or compressive. For a length of the beam subjected to pure moment with no simultaneous axial force , considerations of equilibrium and compatibility quickly lead to the result of that the neutral axis passes through the centroid of the section. The centroid position is the first item of importance to be determined about any general cross-section and, the centroid is the origin for the axis system for which the first moments of area vanish.[7]

The unstressed or natural axis passes through the centroid and since the strains are proportional to distance form the neutral axis , so also are stresses , and the requirements of moment equilibrium lead to the result that stresses are inversely proportional to the second moment of area(moment of inertia) of the section. If the moments of area of a simple shape about its own principal centroidal axes is known , then the parallel axis theorems can be used to compute the relevant properties of a complex cross-section which the simple element forms a part. Most beam cross sections can be idealised into a collection of rectangles , triangles and circles.

The rectangular beam will be taken as an example and we will code a program to find the section properties and bending stresses for the given section. The moment of inertia for the rectangular beam is:

$Ixx = Iyy = bh^3/12$

Neutral Axis Ordinate is:

$Nao = y/2$

The moment of inertia values (of any shape) can be calculated by using $Ixx = \int y^2\, dA$ and $Iyy = \int x^2\, dA$ equations and the co-ordinates of the natural axis (of any shape) can be calculated by using $\int xdA = 0$ $\int ydA = 0$ equations.

Assuming that we know the value for the bending moment of the section ,the code for Basic programming language will be as follows:

THE BASIC CODE (Microsoft© Quick Basic)

```
REM  THIS PROGRAM CALCULATES THE VALUES
REM  OF BENDING STRESS FOR RECTANGULAR BEAM
REM  MI= Moment of Inertia NAO = Ordinate value for neutral axis
REM  H GHT/DPTH = Section height/depth
REM  STR= The stress value for the section

5    CLS
10   PRINT  ″Please enter the value for section height .″
20   INPUT HGHT
30   PRINT ″Please enter the value for section depth .″
40   INPUT DPTH
50   PRINT ″Please enter the value for bending moment.″
60   INPUT BNMNT
70   MI=((HGHT^3)*DPTH) / 12
80   NAO= HGHT/2
90   STR= (NAO * BNMNT)/MI
100  PRINT ″The bending stress for the section is: ″
110  PRINT STR
120  END
```

The program is coded in Basic language , which is also a common used language like Fortran and it is also used in Mac's as well as PCs. Basic is a straightforward programming language and easy to use for mathematical and non-mathematical applications.

Many engineering structures are composed of a series of individual members which are connected together at a number of points. Such structures are called ‘skeletal’ structures, the points at which the individual members are connected are being referred to as ‘node points’ .Engineers have long appreciated that the analysis of these skeletal structures can be carried out by first considering the behaviour of each individual element independently and by then assembling the elements together in such a way that equilibrium of forces and compatibility of displacements are satisfied at each nodal point. An example of such a process is the analysis of a continuous beam by slope deflection method, where the relationship between the moments and rotations within each individual span of the beam is first established , the spans then being combined together such that equilibrium of moments and compatibility of rotations are satisfied at the points of interconnection.

When a structure comprised of many members , such as a continuous beam containing many spans or a multi-storey frame containing many bays the traditional methods (like slope-deflection method) can become very laborious and can involve the solution of a large number of simultaneous equations .Because of this in the past much research effort has been devoted to developing analytical techniques , based on a physical appreciation of the structural behaviour , which would reduce the amount of work required to complete an analysis , and would not require the direct solution of many simultaneous equations. A prime example of such a technique is the Hardy Cross moment distribution method , in which , instead of setting up simultaneous equations explicitly as in slope-deflection method , the solution is accomplished in series of convenient steps.[8] After we started to use computers effectively in structural analysis , it has been realised that the solution of a large number of simultaneous equations no longer posed an insurmountable problem and this prompted a return to fundamental methods of analysis. These methods ,since they involve a number of repetitive steps are particularly suitable for automatic computation and they have been formulated to take maximum advantage of the capabilities of a digital computer .These so-called “matrix methods” for analysing structures(including deep beams , plates and slabs subjected to bending , dam walls) have been established for a number of years.

The finite element method represents the extension of matrix methods for skeletal structures to the analysis of continuum structures. In the finite element method the continuum is idealised as a structure consisting of a number of individual elements connected only at nodal points. It is only in this idealisation that the method differs from the standard matrix method. The finite element method is extremely powerful since it enables continua with complex geometrical properties and loading conditions to be accurately analysed. The method involves extensive computations but , because of the repetitive nature of these computations, it is ideally suited for a solution using a computer.

2.3 THE CONCEPT OF THE FINITE ELEMENT ANALYSIS

Upon reflection at the present time ,many years after the term ‘finite element’ was first used , the introduction of the method can be seen to have been of great significance in the evolution of engineering analysis. As engineers have gained an increasing awareness of the potential of the method and also as larger and faster computers have become commonly available , the interest in the application and the development of the method has grown rapidly. In 1961 ten papers were published about finite elements, but by 1976 the cumulative total of publications was in excess of 7000 and this number has increased greatly since then as the research effort has expanded into new fields. The finite element method was originally developed as a tool for the analysis of the structural systems .The developments of the method have ranged far beyond the limits of structural analysis to encompass complex geo-technical and fluid flow problems. Time dependent problems involving vibrations , structural response to earthquakes creep effects in concrete have been solved. The finite element method originated as a logical development of the techniques of matrix analysis that had been applied for some time to structures composed of discrete members. In this early work , a physical model was created ,which was capable in many cases of giving good answers to engineering problems that are difficult to solve. The realisation of the great potential of the new tool led to the rapid development of new elements for different applications, and this development continued on a rather ad hoc basis for some time with solution convergence characteristics are being determined largely on a trial and error basis. In time the method was placed on a sounder mathematical footing and the concept was generalised in terms of the solution of a variational problem by minimisation of a functional. This had the great advantage of enabling convergence criteria to be established on a rational basis and also of indicating other possible fields of application for the method. In parallel with the application of the method to an ever-widening field ,efforts have been devoted to developing new types of elements and improving existing elements. All efforts until today enabled us to use today's modern engineering analysis software. At the following section we will look at today's analysis programs in detail.

2.4 ANALYSIS SOFTWARE OF TODAY

In this section some examples about the finite element analysis and design programs will be given in order to explain the level of technology that is used now in 1999.

2.4.1 SAP 90

Sap 90 is a commonly used tool in USA for static analysis, dynamic analysis, second order analysis ,and finite element analysis. SAP 90 [9] is a DOS based straightforward analysis package Data is entered by creating a data file and the program is capable of reading the data file and then the software calculates member forces, member displacements and can give the results either on graphical format or as a text file. The data input is fairly easy ,but because SAP90 is a DOS based program, sometimes the input operation become laborious. To make things more clear we may look at an example problem of a truss fixed at both ends .The input data file of the truss can be seen below.

SAP90 INPUT FILE

SYSTEM	: Plane Truss Fixed At Both Ends
L=1	: The number of loading conditions (=1)
JOINTS	: Number of the node -The co-ordinates of the node
1 X=0 Y=0	
2 X=0 Y=1	
3 X=1.20 Y=0	
4 X=1.20 Y=0.80	
5 X=2.4 Y=0	
6 X=2.40 Y=0.6	
7 X=3.6 Y=0	
8 X=3.6 Y=0.4	
9 X=4.8 Y=0	
10 X=4.8 Y=0.6	
11 X=6 Y=0	
12 X=6 Y=0.8	
13 X=7.2 Y=0	
14 X=7.2 Y=1	
RESTRAINTS	:The fixity of supports Fx,Fy,Fz,Mx,My,Mz
1 R=1,1,1,1,1,1	
13 R=1,1,1,1,1,1	
FRAME	
NM=1 NL=1	:The number of different (materials/loading)
1 A=1 I=100 E=30E6	:Section properties of the appropriate section
1 WL=0,-100	:The value of local weight over members
1 1 2 M=1 LP=1,0	
2 1 3 NSL=1	:Definition of the member -Identification of the load
3 3 4	:Eg: Member 3 starts at node 3 and ends at node 4
4 3 5 NSL=1	
5 5 6	
6 5 7 NSL=1	
7 7 8	
8 7 9 NSL=1	
9 9 10	
10 9 11 NSL=1	
11 11 12	
12 11 13 NSL=1	
13 13 14	
14 2 4	
15 4 6	
16 6 8	
17 8 10	
18 10 12	
19 12 14	

After inputting the data ,the program checks the data for errors and if there is none it calculates the forces, moments, displacements of the structure.

The output can be read from a text file or can be seen graphically using the program Saplot.

The text output for first 4 elements can be seen below ,because the problem is analysed in 2 dimensions we can see the results for 1-2 plane which is a two dimensional plane. Every element has 2 ends which is indicated by letters i and j and - DIST END I – shows the position of the force/moment depending on its distance from the i end of the element.

```
F R A M E   E L E M E N T   F O R C E S

   ELT LOAD    DIST          1-2 PLANE       AXIAL
    ID COND    END I       SHEAR      MOMENT   FORCE
     1 --------------------------------------------
          1    .000                            -.868
               .000        .376     -60.346
              1.000        .376     -59.970
              1.000                            -.868


     2 --------------------------------------------
          1    .000                            -.492
               .000     359.132    -355.141
              1.200     239.132       3.817
              1.200                            -.492


     3 --------------------------------------------
          1    .000                            -.649
               .000       -.695      80.112
               .800       -.695      79.556
               .800                            -.649

4 --------------------------------------------
          1    .000                             .203
               .000     238.482     -76.296
              1.200     118.482     137.883
              1.200                             .203
```

The graphic output is also easy to understand and we can see undeformed shape , deformed shape and member forces diagrams in colour output in a DOS prompt. The graphical output module (SAPLOT) is also capable to give the animated view of the deformed shape. SAP 90 is one of the most popular structural analysis programs, this was a brief explanation of SAP90

Other popular programs are QSE and Prokon for structural analysis and ANSYS & LUSAS for finite element analysis.

EXPERT SYSTEMS & ES APPLICATIONS IN CONSTRUCTION INDUSTRY

3.1 INTRODUCTION

Expert systems originate from the branch of computer science called artificial intelligence. The field of AI itself encompasses many subfields – search , problem solving , machine learning ,and theorem proving among them[10]–our focus however is on the expert system technology derived from AI research. Expert systems can be defined as a computer program that contains heuristic knowledge and performs a task normally done by experts. Let's now look at the other definitions of expert systems ,Stefik et al in a tutorial on the organisation of expert systems says that they are:

"*problem solving programs that solve substantial problems generally conceded as being difficult and requiring expertise. They are called knowledge based because their performance depends critically on the use of facts and heuristics used by experts*" [11]

A formal description has been prepared by the British Computer Society's Specialist Group on Expert Systems is as below :

"An Expert System is regarded as the embodiment within a computer of knowledge based component from an expert skill in such a form that the machine can offer intelligent advice about a processing function. A desirable additional characteristic , which many would regard as fundamental , is the capability of the system on demand to justify its own line of reasoning in a manner directly intelligible to the enquirer. The style adopted to attain these characteristics is rule-based programming."[12]

We can notice that an expert system is a system which contains a base of expert knowledge about a specific domain or domains ,and uses this knowledge in a human like intelligent manner .Such systems should have the ability of being modified and updated as further knowledge is acquired , be able to communicate with the user to request more information , tell the user why the information is required and say how it decided on any recommendations or decisions.

3.2 THE BASICS OF EXPERT SYSTEMS

An expert system is a computer program that will provide advice in a selected specialist field .The user will answer questions and will be led towards one or more recommendations. The questions are likely to be phrased in the jargon of the specialist field and the user will have the opportunity of asking the program how it arrived at its conclusion. Three key features of expert systems distinguish them from conventional computer programs which could , in a limited sense, behave in the manner described above.

1.) The central element of an expert system is a representation of an expert's knowledge about the specialism in a form comprehensible to man and computer.
2.) That knowledge is continuously searched by sophisticated methods when the system is striving to solve a user's problem
3.) The user can be given an explanation of how an answer was arrived at from the very same knowledge statements used to obtain the answer.

How knowledge can be represented in a suitable form is still a matter for research, but whatever form is adopted the outcome is that an expert's knowledge can be stored in a computer file on a hard disc or on a CD. Such files are often called "knowledge bases" and the limited field of specialism is called "knowledge domain" and the person who builds the knowledge base is called "knowledge engineer"[13]

On my research I have come across many different models, defining the structure of the expert systems I will mention one of these structure definitions here .The definition by CICA in the report Expert Systems and Construction Industry.

3.2.1 EXPERT SYSTEMS STRUCTURE

Expert Systems are substantially different from conventionally programmed systems ; one of the major reasons why they are different is that their structure is constructed of three main elements

i) The Knowledge Base

ii) The Knowledge Manager(Inference Engine)

iii) The Situation Model(The Context

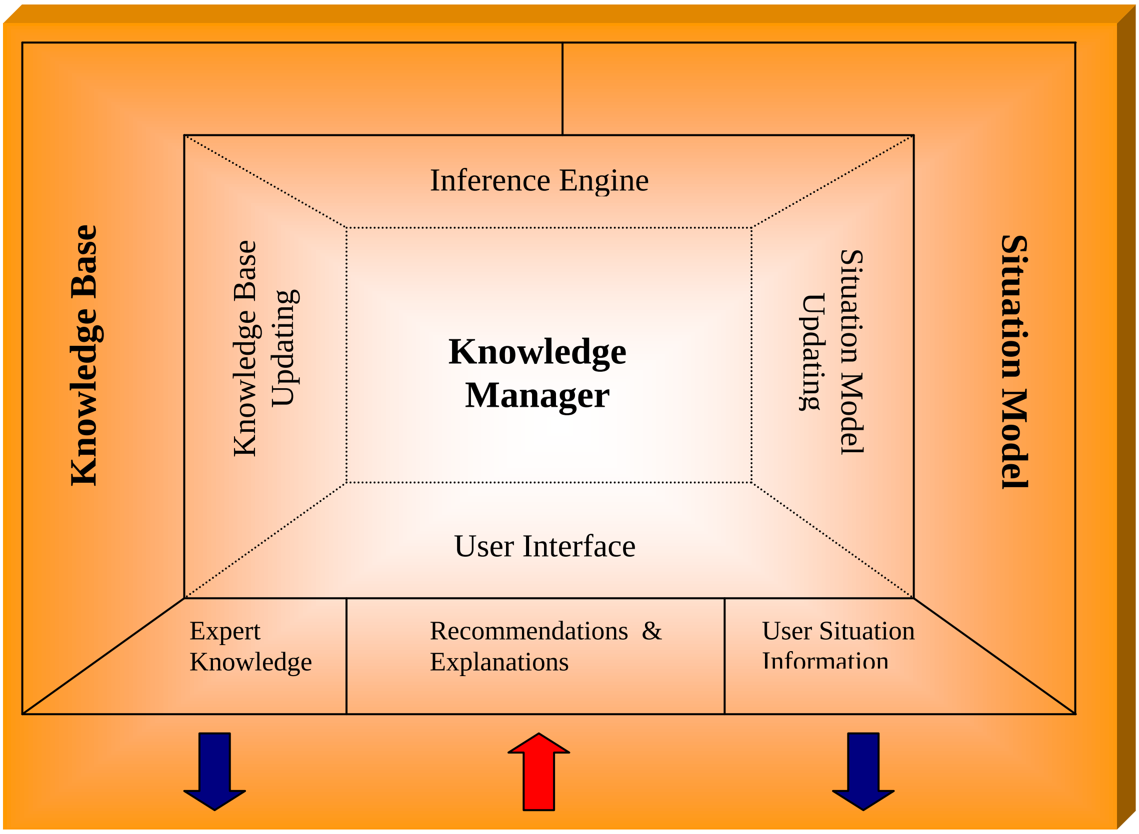

Figure 3.1 Architecture of an Expert System

Which is shown in Figure 3.1.Because of the modular design of the system within the main structure of the knowledge base , the knowledge manager and the situation model , each structured separately , within the overall system , it is easier to modify ,additions to or deletion from any module without effecting the structures of other modules.

The Knowledge Base:

It contains the expert knowledge about the specific domain considered by the system. If a system is to be efficient it must contain all the information required to be able to make correct decisions in the domain under consideration. Knowledge can be held in different forms such as production rules ,or using other techniques that will be mentioned on the next section.

The Knowledge Manager (Inference Engine)

It is responsible for the effective management of the expert system .It must know how to operate the knowledge base and decide what rules should be implemented or which route should be taken to arrive at a decision It must also be able to build and modify the knowledge base and be able explain how and why it came to any decisions. It has been characterised as having four basic parts[14]

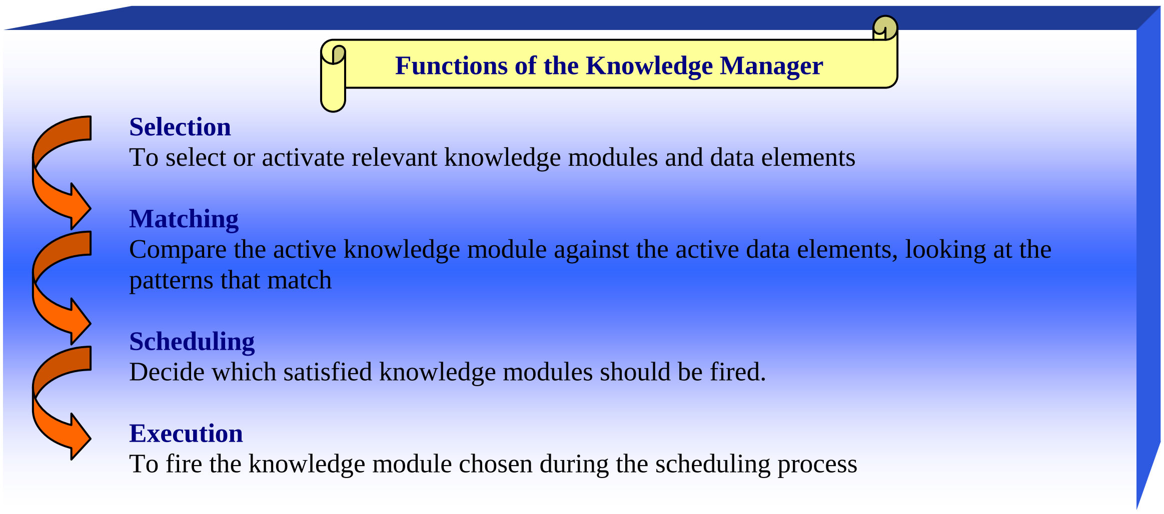

Figure3.2 Functions of Knowledge Manager

- Selection
- Matching
- Scheduling
- Execution.

The Situation Model(The Context):

Information and data about a particular situation are entered into the situation model by the system user via the knowledge manager. This is the initial base of knowledge about a particular situation which can then be compared with the knowledge base in a attempt to match rules and provides an answer.

The base of the information stored will change as the system consultation proceeds because of 2 reasons:

1.)When the data is compared with the knowledge base the system may be able to make certain conclusions from the information supplied. These conclusions are returned to and alter the situation model.

2.) At various stages during a consultation the system may require more information from the user to enable a decision to be made. This information is input via the knowledge manager, and it will than be added to and thus modifying the situation model.

Some expert systems are being created to assist with the interface between the user and large database systems, or between the user and extensive or complicated monitoring systems. In such cases there would be a link between the knowledge base and the database or monitoring system.

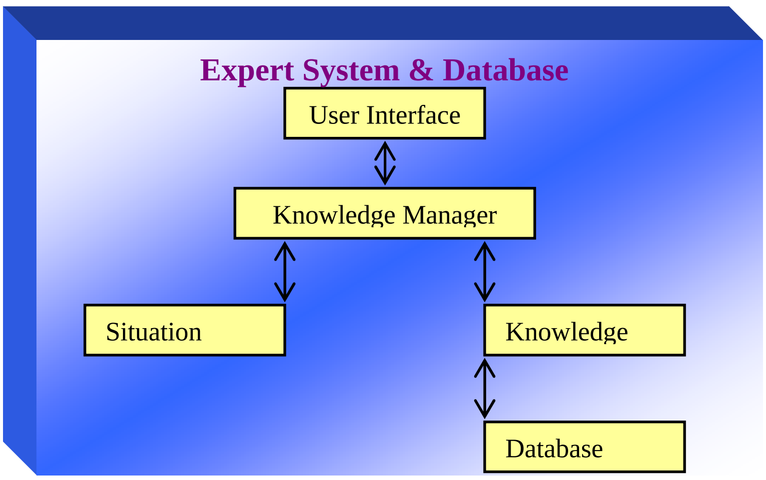

Figure 3.3 Expert System & Database Interaction

There are various differences between the traditional programs ,the table below shows the main differences between them.

Traditional Programs	Expert Systems
Representation and use of data	Representation and use of knowledge
Knowledge and control integrated	Knowledge and control separated
Algorithmic (Repetitive) process	Heuristic (Inferential) process
Effective manipulation of large databases	Effective manipulation of large knowledge bases
Programmer must ensure uniqueness and completeness	Knowledge engineer inevitably relaxes uniqueness and completeness restrained
Midrun explanation impossible	Midrun explanation desirable and achievable
Oriented toward numerical processing	Oriented toward symbolic processing

Table 3.1 Traditional Programs vs. Expert Systems

There are three major steps to develop an expert system (which will be explained in detail in this chapter) are knowledge acquisition ,knowledge representation and building the expert system.

3.3 KNOWLEDGE ACQUISITION

In general knowledge is obtainable from books ,from examples and from people. If knowledge can be satisfactorily represented on a paper it may well be not an appropriate topic for an expert system. Books and reports are our most common of knowledge and many will , at least, provide a starting point for the knowledge acquisition task .Extracting knowledge from many examples is a possibility which has attracted artificial intelligence researchers .The principal sources of knowledge with which we will be concerned are human experts and so we consider a task of eliciting their knowledge.

Much has been written of the difficulty of this task , and certainly it certainly is not easy. The underlying problem in knowledge elicitation is communication between one or more experts and one or more interviewers. We will look at both parties shortly , but it is best to keep in mind certain basic ideas.

i)The objective is to convert the expert’s knowledge to the form used by a computer program.

ii)Analysis of the knowledge to accomplish this conversion will go in parallel with the knowledge elicitation iii)Experts apparently solve problems by working through a set of sequential steps. We need to get at the reasoning that lies behind these steps.

iv)Knowledge elicitation and the creation of an expert system is an iterative process.

It may not be necessary for the interviewer to know how to code the chosen shell ,but it is certainly important that he understands the principles of rules and interfacing. If he does not prepare the final knowledge base , another communication gap with the programmer must be bridged. Achieving objective (i) will be easier if the interviewer does the coding too , as will the ongoing analysis of the overall form of the system. It is very helpful to establish at an early stage the general flow and to start identifying intermediate stages(sub-goals).Item(iii) represents a paradox which will probably always trouble knowledge elicitation .Experts are good at solving problems - that is why we go to them – and they do this by following a procedural sequence of questions and deductions. If we were able to capture their knowledge in conventional programs, this forward chaining procedural sequence would be fine and life would be easy. But it is just because an expert’s knowledge can not easily be represented by conventional programs that we use expert system technology and are forced to look behind the external manifestation of expert’s thinking and made to capture the true basis of the reasoning behind it. Of course rules and backward chaining are a poor simulation of human reasoning , but it is all we have and we must try to represent the expert’s thinking by these means. And so paradox is to take the ‘case study’ procedural appearance of an expert’s way of working and turn it into rules which , when searched , will lead to a similar , if not identical , set of questions and deductions.

The task of knowledge acquisition & knowledge elicitation and the build-up of a knowledge base is an iterative process, and the experts and the interviewers must be quite aware of this from the start. A method for proposed method for knowledge elicitation consists of following steps:

- Unstructured general interviews
- Interviews focused on one general topic
- Use of past problems
- Demonstration and discussion of prototype
- Discussion of knowledge base with expert.

The unstructured interview should be aimed at educating the interviewer and establishing the scope of the system by defining the list of goals. The expert should be allowed to do this in his manner ,even if it seems rambling to the interviewer. This is the time when a good relationship can be built up between interviewer and the expert , a ‘chemistry’ which will play dividends when ground needs to be retraced or delicate questions to be put about the standing of a rule. The focused interviews can merge into the first general interviews , but it may be best to make clear to the expert that the transition has occurred. The interviewer should now concentrate discussion on one goal at a time and be concerned about the symptoms and rules which confirm that goal alone. Experts who have tried to train others are more likely to have thought out how they work and how their knowledge can be communicated. Even so, getting them to think in terms of rules will not be easy , particularly if there are many intermediate stages between the symptoms and the goal. Demonstrations of early prototypes to the expert must be heavily qualified by disclaimers of the depth of knowledge. Non-computer experts can easily be over-swayed in their reactions to a system by the quality of the screen displays ,particularly by the lack of polished graphics. The final suggestion is about the discussion of knowledge base with expert. The purpose of knowledge elicitation is to extract knowledge analyse it and represent it for a particular shell. If we can close the loop and put the final knowledge base before the expert for his blessing, we have surely got as close as possible to our objective. Knowledge diagrams illustrating the links established by the rules between the questions and the goals will help by providing an overall view of the knowledge and will help in these discussions. The knowledge acquisition and elicitation is the fundamental and most important step for developing a successful expert system. It is the most time consuming part and tiring part of the all work for the expert as well as the knowledge engineer. The successful development of the knowledge base will lead us to a good expert system. The second step of our development process is the representation of the knowledge. Now the knowledge should be put into the order that the computer will understand .

3.4 KNOWLEDGE REPRESENTATION

"Knowledge representation refers to the method we use to represent domain knowledge in a way recognisable to the computer in a knowledge-based expert system"[15]

Expert systems are defined as computer programs that contain heuristic knowledge and perform a task normally done by an expert. The most important difference between conventional programs and expert systems is expert systems are build upon a knowledge base. The vital issue at building a knowledge base is how we represent the knowledge. In the light of that idea we can argue that knowledge representation is critical to expert system development. There are five common types of knowledge representation logic, rules ,frames ,objects and neural nets.(There are other knowledge representation paradigms exist but the choice for inclusion of the five representations will be mentioned here is determined by their popularity among applications within the engineering community.)

Symbolic logic is a representational formalism for expressing knowledge reasoning about such knowledge and deducing logically consistent facts from data and existing knowledge. Formal logic systems have existed since the time of Aristotle ;however using a calculus to represent and manipulate knowledge(in place of mathematical relationships) originates from Leibnitz and is perfected by Russell and White's *Principia Mathematica* [16]

In a manner similar to proving theorems in mathematics from axioms and other theorems symbolic logic can be used to deduce facts about the world in which it reasons about.

There are two wildly used formal logic systems today: propositional logic and first order predicate logic. In brief ,propositional logic involves manipulating boolean expressions using connectives into well formed formulas. These well formed formulas are manipulated using inference rules to infer newly deduced expressions from existing ones and establish the truth or falsity of a particular expression based on the boolean values of its preceding or component expressions. The inference rules are usually straightforward such as “If a structural element is a beam , then it is one-dimensional” .If “a structural element is a beam” is a true expression then propositional logic deduces that “the structural element is one dimensional”. FOL (First Order Predicate Logic) extends propositional logic considerably by introducing the concept of and language for representing members of a classes of objects. Variables may be quantified and related. FOL following to take place:

“all horizontal elements are beams”

“A2 is a horizontal element”

therefore *“A2 is a beam”*

This type of representation is found useful in engineering applications, and many expert systems have been developed using this type of knowledge representation.

Rules are the best understood Knowledge Representation paradigm because of their utility and foundations in conventional programming ,and their analogue in human behaviour.[17]

A rule consists of a left hand side where the conditions or antecedents are stated and a right hand side where the actions or consequents are stated. As engineers we often think of events in terms of being casual relationships. In structures for example , a 2-D frame always sways away from its stiffer side.

Frames were introduced as a knowledge representation paradigm to effectively represent common-sense knowledge. A frame is a data structure for representing stereotypical and hierarchical information ,such as a building or a beam. Each frame contains information(a record) about the salient properties associated with objects that are of that class. For example when we are defining a specific beam (A2 e.g) that specific beam inherits the properties of the generic class of beams.

Objects are data structures very similar to frames .Object-oriented programming originated with an ALGOL simulation. An object is a self contained entity , encompassing the frame characteristics of hierarchy , class ,attributes and their values and inheritance. However objects and OOP extend the notion of frames by combining the properties of procedures and data. Objects communicate directly with one another via message passing ; this is a contrast to frame-based systems , where procedures are attached to frames for communication purposes.

A neural network is a network of simple processing units (often called nodes or artificial neurones) .Each node represents a specific concept and an indescribable part of a larger concept. Nodes are either input units , output units or hidden units and each node contains one piece of information : its current level of activation. Neural nets are capable of and specifically geared toward self organisation and learning. Thus the neural network concept is not a Knowledge Representation formalism in the same sense as logic , rules , frames or objects; neural nets are being developed to interpret patterns. At the following section different types of knowledge representation will be explained .

3.4.1 RULE BASED KNOWLEDGE REPRESENTATION (PRODUCTION RULES)

In production systems knowledge and information is stored in the knowledge base by using production rules **.**These production rules are individually statements of the form:

Precondition (pc) >> Conclusion(con)

each statement having a precondition and a conclusion. Groups of knowledge may be represented in production rules

$$pc_1,pc_2,\text{...........}pc_n \;>>\; con_1\text{...........}con_n$$

A rule would be applied or fired either when the preconditions are satisfied and there are some conclusions or when for a certain conclusion preconditions are satisfied leading to some further sub-goal. The knowledge manager chooses which of the applicable production rules in the knowledge base is to be applied and ends the computation when a terminal condition in a knowledge base is satisfied. Rules do not ‘call’ other rules it is the job of the knowledge manager to control which rule to be accessed. Communication between the production rules in the knowledge base and the situation model thus occurs through and controlled by the knowledge manager. There are two production systems the first forward chaining , looks at the rules as a simple condition statement :

IF Condition is true THEN execute Action

The alternative , backward chaining ,chooses rules where the conclusion satisfies the situation model and then looks at the precondition to produce further sub-goals which are then in turn considered to see whether the situation can be proven. We will look both in detail now.

3.4.1.1 FORWARD CHAINING PRODUCTION SYSTEM

Let’s consider a rule in a knowledge base of an expert system about earthquake damage diagnosis ;

Condition : IF There is a short column failure in the building

Action :THEN Write “Damage at the column is caused by shear forces”

The knowledge manager looks at the knowledge base to see which rules have their situation satisfied , selects one of them and fires it by performing the corresponding action. If the situation model showed that there is a short column in the structure then the condition of the rule is satisfied ,and it fires the corresponding action in this case the ES gives a message mentioning the damage is caused by shear forces. However if there is not any short column in the structure then the condition will not be satisfied and the knowledge manager will consider other rules. This is known as a forward chaining, or a data driven inference system. The actions when fired may change the contents of the situation model, new facts may be added ,existing facts modified removed or replaced or the system may ask user for more information. The process is completed until the final goal is achieved or until no further rules are available.

3.4.1.2 BACKWARD CHAINING PRODUCTION SYSTEM

Backward chaining method uses a different method of interpretation. If the condition of a rule was satisfied by the knowledge base , with this method , using that rule would be a step forward towards satisfying the situation model. If not then the condition itself could yield further or sub-goals to be achieved. The same rules are interpreted thus:

IF an Action is to be established

THEN try to establish the Condition

Let’s look at a rule in a knowledge base of the expert system again:

Condition : IF There is a damage at the column is caused by shear forces

Action :THEN Write “There is a short column failure in the building”

In this situation in order for the rule to be fired it would be necessary to satisfy the condition, but in backward chaining systems just satisfying one condition is not enough, all the conditions must be satisfied to fire the rule. In other words the expert system will not conclude that there is a short column failure in the building just knowing that there is a damage caused by shear forces .All other additional conditions like:

Condition : IF The height of the column is shorter than 1 metre.

Action :THEN Write “There is a short column failure in the building”

should be satisfied for the expert system to conclude that there is a short column failure in the building. One of the most well known expert systems MYCIN uses a backward chaining selection process.

The table below indicates the differences between both chaining production systems.

FORWARD CHAINING	BACKWARD CHAINING
Planning, Monitoring ,Control	Diagnosis
Present to Future	Present to Past
Antecedent to Consequent	Consequent to Antecedent
Data Driven, bottom-up reasoning	Goal Driven, top-down reasoning
Work forward to find what solutions follow from the facts	Work backward to find facts that support the hypothesis
Breadth-first search facilitated	Depth-first search facilitated
Antecedents determine search	Consequents determine search
Explanation not facilitated	Explanation facilitated

Table 3.2 Forward Chaining vs. Backward Chaining

3.4.2 SEMANTIC NETWORKS

During the latter part of 1960s consideration began on the representation of knowledge in the form that subsequently became known as semantic network representation schemes ; one such relationship is shown below:

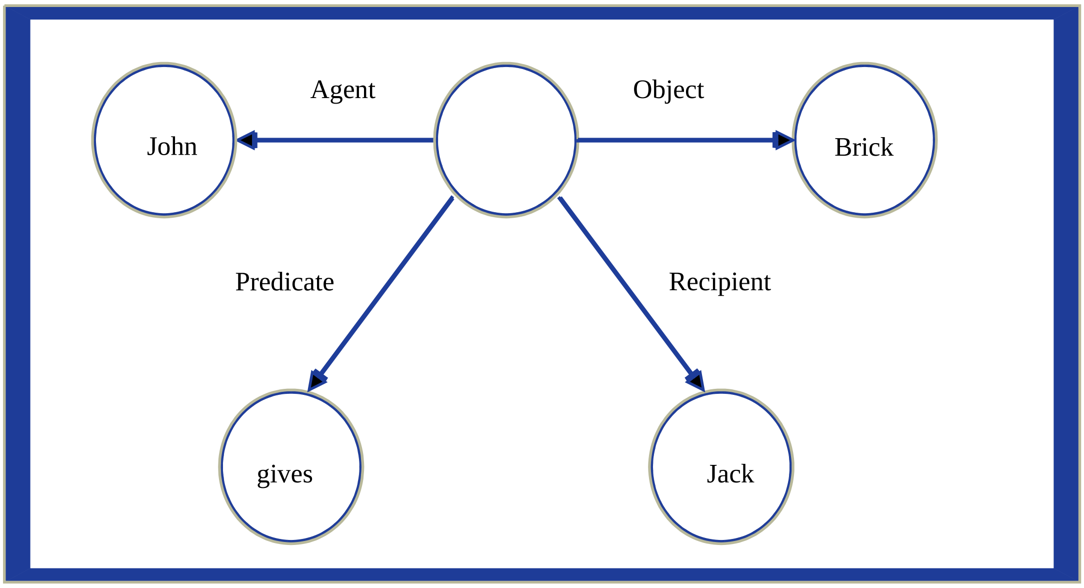

Figure 3.4 Knowledge Representation in Semantic Networks

Figure 3.4 shows a semantic network which depicts ‘John gives the brick to Jack’ and shows the structure of nodes linked together by directed arcs or links. Two main types of nodes are distinguished : object nodes(John, Jack, brick) and relation nodes(gives).Links in the network are used to connect relation nodes to other nodes and are labelled with the name of the argument they represent.

Information contained in the nodes and links of a semantic network and used for performing semantic inferences consists of known definitions of words. Because data are clearly specified , objective and associated with real world knowledge structures, no bias is introduced by specially 'tuning' definitions of words to facilitate inference. One way frequently used to represent the knowledge in the knowledge base using a semantic network structure is to form the definition into production rules of the form:

Condition >> Action

where the conditions part is matched against structures in the semantic network , and the action part may delete or add a node to the semantic network structure of the situation model. Judgement of knowledge can be represented within semantic networks in the form of rules. Rules within semantic networks are represented by a structure having the form:

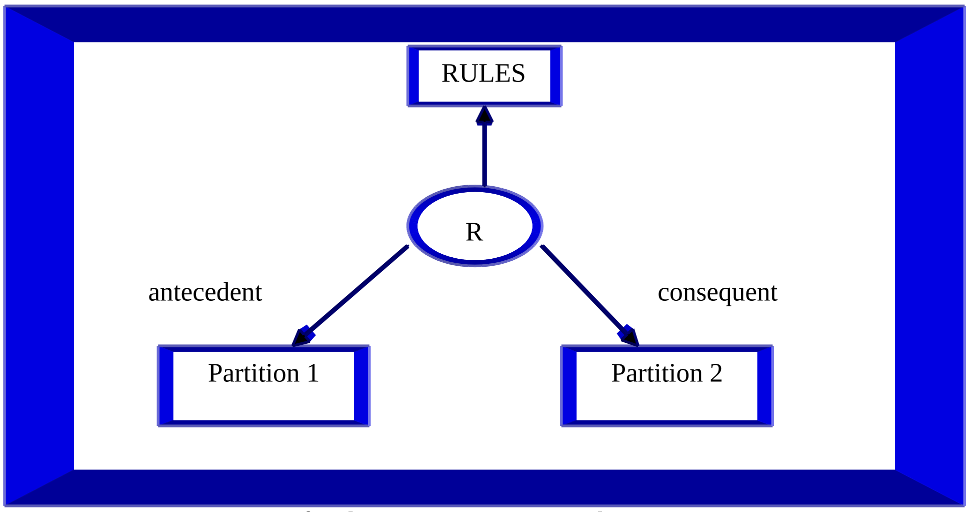

Figure 3.5 Representation of Rules in Semantic Networks.

These rules must specify the individual pieces of evidence , the hypothesis ,the implication and its strength. Separate partitions ,containing the appropriate network structures are created for the antecedent and the consequent to represent the implication.

The measure of the strength of the implication , usually shown by the specification of numbers depicting values, is attached to the rule node.

3.4.3 FRAME BASED KNOWLEDGE REPRESENTATION

A frame based representation may be simply described as a declarative representation of domain objects called frames. Frames belong to a broader class of representation techniques referred to as structured object representations that include object oriented programming. The distinguishing characteristic of such representation paradigm is the orientation around objects rather than rules or logical inferences. Frames provide a means for organising and storing declarative knowledge, such as attributes and relationships among domain objects ,and procedural knowledge such as procedures for calculating the values of attributes ,for example a beam is described by its span ,support conditions loads, etc. A frame based representation goes beyond the simple object-attribute-value construct that is provided in purely rule based representations , such as working memory elements in OSP5 or conventional programming languages such as records in PASCAL ,by providing mechanisms for associating additional information about the attributes and relationships between frames.[18] The relationship between frames allow knowledge to be shared among frames. The information can be automatically retrieved without additional programming. For example a steel beam frame may be related to the beam frame and share information about span and loads. Constructs are available in a frame-based language for organising frames that represent class taxonomies .The constructs allow a knowledge base developer to describe each class as a specialisation or subclass of other more generic classes. Hence , a hierarchical tree representing various levels of abstraction within the domain objects can be constructed.

Additional information about attributes takes the form of attributes or procedural information. Typical meta-attributes are range, such as the allowable range of spans for a type of beam ,default values such as the default value of the yield stress of steel in a steel beam, and units , such as feet or metres for length.

Procedural information associated with an attribute may be defined to calculate the value of an attribute, perform some calculations after a value is stored or associate some other program with the value of an attribute. Such procedures , known as demons, are executed automatically when specified conditions exist.

3.4.3.1 STRUCTURE OF FRAME BASED KNOWLEDGE REPRESENTATION

A frame is an abstract multi-level data type used to store information about the domain objects that a knowledge based system models. Frames are comprised of slots(or attributes), facets(meta-attributes) , views (meta-meta-attributes) and filters(values) .[19]

A frame comprises a name and a set of slots, where a slot further describes a frame. A slot comprises a name and a set of facets, where a facet further describes a slot. Examples of facets are demon, default , range ,etc. A filler is essentially a placeholder for a value. Each

BEAM

Span
value:
units: feet
restrictions : (and(>10)(<100)

Load
value:
units : kg
type : concentrated

Support
value :
default : 0 span
type :simple

Max-stress
value :
units : kg/ft2
demon: calc-max-stress

Figure 3.6 An example frame

slot can have any number of facets, each facet can have any number of views ,and each view can have any number of fillers. An example of a beam frame is shown on the previous page , where span , load ,load type, support, and max-stress are slots and value, units, restriction, default and demon are facets.

Representing Attributes:

The slots in a frame are used to store description of the object attributes. The slots have multiple values, which are stored in a facet called value. The slot name is usually the name of an attribute of the object that the frame represents , and the value facet stores the value of that attribute. While the user may create as many facets as he wishes in a frame , there are predefined facets to represent demons and to impose constraints on the values that slot might take . These facilities in a frame based language result in automatic invocation of procedures without additional programming by the knowledge base developer.

Representing Hierarchies:

Frame based languages provide constructs for describing individuals and classes of individuals in an application domain. Each individual or class is represented by a frame Frames can be organised into taxonomies using predefined links that represent relationships between frames. Some typical predefined relationships are class/subclass ,instance-of/instance, and part-of / part ; where each relationship is paired with its inverse , which is also a relationship. The user may define any number of relationships beside these. A relationship is specified as a slot name and the frame that is related is the slot value. Provided the inverse relationship has been defined , the inverse relationship is automatically created and the appropriate slot value is added to the other frame. This facility of constructing a hierarchy of domain objects and concepts helps to organise the domain knowledge in a way that facilitates reasoning and ease programming effort.

Demons:

A frame based language provides constructs for attaching procedural information , called demons. These procedures monitor changes and uses of the slots. This capability enables behavioural models of objects and expertise in an application domain to be built. There are four types of demons

- If-added demons
- If-needed demons
- If – accessed demons
- If – erased demons

Method of Inference :

In frame based systems inheritance, which is the common method of inference, enables descriptive information to be shared among multiple frames. Information flows trough certain relationships in the system known as inheritance links. In a system where the frames are organised into taxonomies of classes , subclasses and instances , information true of all members of a class needs to be stored only in the frame representing the class itself. Information not stored in an object lower down in the hierarchy of frames is made available from the higher level object via inheritance. There are two preconditions for inheritance to be possible when accessing a slot

1) The value of slot must be missing. If the slot value is present, it is interpreted as a local exception to the inherited value and inheritance is not invoked.
2) There must be a relationship defined between the frame in question and the frames that it needs to inherit from and inheritance must have been defined to exist over that relationship

Another automatic inference method uses constraints to determine whether a given item could be a value for a given slot. Finally ,I should mention that in frame based systems the knowledge stored in frames acts as a database for the system, and control of reasoning is left to the other parts of the system.

3.4.4 KNOWLEDGE REPRESENTATION WITH LOGIC

In addition to rules , frames , and semantic nets , knowledge can be represented by the symbols of logic , which is the study of the rules of exact reasoning. The application of computers to perform reasoning has resulted in logic programming and the development of logic-based languages like Prolog. Logic is also of primary importance in expert systems in which the inference engine reasons from facts to conclusions. The earliest formal logic was developed by the Greek philosopher Aristotle in the 4th century B.C .The Aristotelian logic is based on the syllogism. Syllogisms have two premises and one conclusion. The following is a classic example of a syllogism:

Premise: All men are mortal.

Premise: Socrates is a man.

Conclusion: Socrates is mortal.

In a syllogism the premises provide the evidence from which the conclusion must recently follow. Aristotelian syllogisms were the foundations of logic until 1847,when the English mathematician George Boole published the first book describing symbolic logic. One of the new concepts that Boole proposed was a modification of the Aristotelian view that the subject have existence called existential import. According to the classic Aristotelian view , a proposition such as “all mermaids swim well” could not be used as either a premise or a conclusion because mermaids don’t exist. The Boolean view, now called the modern view ,relaxes this restriction. The importance of the modern view is that empty classes can now be reasoned about.

Another contribution by Boole was the definition of a set of axioms consisting of symbols representing both objects and classes and algebraic operations to manipulate the symbols. Axioms are the fundamental definitions from which logical systems such as mathematics and logic itself are built. Using only the axioms theorems can be constructed. A theorem is defined as a statement that can be proved by showing how it is derived from axioms.

3.4.4.1 PROPOSITIONAL LOGIC

Propositional logic is a symbolic logic for manipulating propositions. It is concerned with the subset of declarative sentences that can be classified as either true or false. A sentence such as "a square has four equal sides" has a definitive truth value of true , whereas the sentence "Umit has written a short dissertation" has a truth value of false. A sentence whose truth value can be determined is called a statement or proposition. A statement is also called a closed sentence because its truth value is not open to question. If we put a preface to this dissertation saying " everything in these pages are lie" , that statement cannot be classified as either true or false. If it is true then I told the truth in the preface -which I can not do. If it is untrue , then every word written must be true so I lied, - which also can not be true. Statements of this type are known as Liar's Paradox. Statements that cannot be answered absolutely are called open sentences.

A compound statement is formed by using logical connectives on individual statements.

The common logical connectives are show below:

Connective	*Meaning*
Λ	AND: Conjunction
V	OR : Disjunction
~	NOT: Negotiation
$\rightarrow$	IF....THEN : Conditional
$\leftrightarrow$	IF AND ONLY IF : Bi-conditional

Table 3.3 Connectives and their meaning.

The conditional is analogous to the arrow of production rules in that it is expressed as an if...then form, for example :

If it is raining then carry an umbrella

can be put in the form

$$p \rightarrow q$$

where

$$p = \text{it is raining}$$

$$q = \text{carry an umbrella}$$

A tautology is a compound statement that is always true , whether its individual statements are true or false. A contradiction is a compound statement that is always false. A contingent statement is one that is neither a tautology nor a contradiction. If a conditional is also a tautology then it is called an implication and has the symbol $\Rightarrow$ in place of $\rightarrow$ .A biconditional that is also a tautology is called a logical equivalence or material equivalence and is symbolised by either $\Leftrightarrow$ or $\equiv$.

The conditional does not mean exactly the same as the IF... THEN in a procedural language or a rule based expert system .In procedural expert systems the IF...THEN means to execute the actions following the THEN if the conditions of the IF are true. In logic , the conditional is defined by its truth table. Its meaning can be translated into natural language in a number of ways. The example below describes this better:

Let's assume p represents “you are 18 or older” and q represents “you can vote” .The conditional $p \rightarrow q$ can mean:

You are 18 or older implies you can vote

If you are 18 or older then you can vote

You are 18 or older is sufficient for you to you can vote

You are 18 or older , only if you can vote

You can vote if you are 18 or older

You can vote is necessary for you are 18 or older

In some cases a change of wording is necessary to make these grammatically correct English sentences. Values for binary logical connectives are shown below:

p	**Q**	**P∧q**	**p∨q**	**p→q**	**p↔q**
T	T	T	T	T	T
T	F	F	T	F	F
F	T	F	T	T	F
F	F	F	F	T	T

Table 3.4 Binary Logical Connectives

3.4.4.2 FIRST ORDER PREDICATE LOGIC

Although propositional logic useful ,it does have limitations. The major problem is that propositional logic can deal only with complete statements. That is , it can not examine the internal structure of a statement. Propositional logic can not even prove the validity of a syllogism such as:

All humans are mortal

All women are humans

Therefore all women are mortal

In order to analyse more general cases , predicate logic was developed. Its simplest form is first order predicate logic .Predicate logic is concerned with the internal structure of sentences.

In particular it is concerned with the use of special words called quantifiers, such as “all” , “some” ,and “no”. These words are very important because they explicitly quantify other words and so make sentences more exact.

A universally quantified sentence has the same truth value for all replacements in the same domain. The universal quantifier is represented by the symbol ∀ followed by one or more arguments for the domain variable. The symbol ∀ is interpreted as “for every” , as an example “all triangles are polygons” is written as follows:

$$(\forall x)\ (x \text{ is a triangle} \rightarrow x \text{ is a polygon})$$

or

$$(\forall x)\ (\text{triangle}(x) \rightarrow \text{polygon}(x))$$

This predicate logic sentence can also be represented as a semantic net:

If x is a triangle

Then x is a polygon

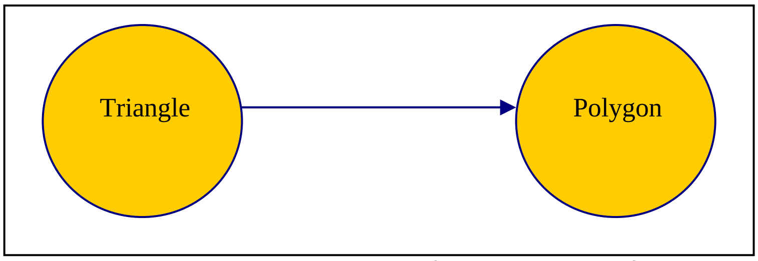

Figure 3.7 Semantical Representation of Universal Quantifier

Another type of quantifier is the existential quantifier. An existential quantifier describes a statement as being true for at least one member of the domain. This is a restricted form of the universal quantifier that says that a statement is true for all members of the domain. The existential quantifier is written as ∃ followed by one or more arguments.

The example below states that there is some x whose product with itself equals 4.

$$(\exists x)\ (x \cdot x = 4)$$

The existential quantifier may be read in a number of ways such as;

There exists

At least one

There is one

Some

Although predicate logic is very useful in many situations , there are some types of statements that cannot even be expressed in predicate logic using the universal and existential quantifiers. For example ,the following statement can not be expressed in predicate logic:

Most of the class passed

The most quantifier cannot be expressed in terms of universal and existential quantifiers. To implement most , a logic must provide some predicates for counting, as in fuzzy logic.

Another limitation of predicate logic is expressing things that are sometimes but not always true ,this problem can also be solved by fuzzy logic. This works context of knowledge representation methods is limited with these four methods further information about other knowledge representation methods can be found at various internet resources.

3.5 EXPERT SYSTEMS & CONSTRUCTION INDUSTRY

In this section we will give examples about the expert systems that are developed for & used in the construction industry. The expert systems are classified according to their knowledge representation method , so it is better to look at the examples here ,after knowledge representation section.

3.5.1 COMPOSITE LAMINATE DESIGN(Rule-based Expert System)

Here we describe the parts of an expert system for composite sublaminate design to illustrate how design knowledge can be stored in rules. The expert system is called ACOLADE , the system was developed as a part of MSc project in University of Houston.[20] Before describing the expert system it is better to look at the principles of composite laminate design. A composite is a combined material created by the syntehic assembly of two components(a selected filler and a compatible matrix binder) .One of the common kinds of composites is the fibrous composite. Collections of fibres in a particular direction are called plies. Collections of plies from a sublaminate and collections of sublaminate can form a laminate. Essential composite sublaminate design tasks can be delineated as follows:

i) Select the fibre-matrix combination (material selection)

ii) Create a hierarchy of suitable sublaminates from input on loading and atmosphere data (sublaminate generation)

iii) Evaluate the superior sublaminate groups among the ranked sublaminates an the basis of additional criteria(sublaminate elimination)

Of these three ,tasks (i & iii) are inferential and are performed using a rule based paradigm. The middle task is accomplished algorithmically.

Once the material has been selected in step (i) , a set of 165 sublaminates are evaluated based on loading and atmospheric data in a procedural fashion in step (ii) .The sublaminates differ by the number of plies in standard ply orientations of 0,45,90,135 degrees and are meant to cover all the design possibilities that may arise due to varied loading and atmospheric requirements. The evaluation of these sublaminates results in a ranking in decreasing order of suitability. The top twenty sublaminates are then loaded into working memory .Based on additional criteria , the sublaminates are further evaluated using a rule-based paradigm(iii).Sublaminates found unstable at this stage are eliminated from working memory. Finally let’s look at some rules from the rule-base of the system .We now consider the different types of rules that are used to perform the material selection and sublaminate elimination tasks.

Material Selection

Rule Name:Select_Material_2

Rule Purpose: Establish criteria for selecting Material No. x

Rule Definition

IF

attribute Longitudinal Compressive Strength has importance >=2

and

Attribute Longitudinal Modulus has importance >=2

and

attribute Transverse Compressive Strength has importance >=2

and

attribute Shear Modulus has importance >=2

and

attribute Performance at High Temps has importance >=2

and

attribute Resistance to moisture has importance <=3

and

attribute Creep Resistance has importance <=4

and

attribute Cheapness-Availability has an importance <=2

THEN

Material no=2 ,Type = BFRP ,Fibre B(4) , Matrix N5505 is most suitable

Rule Name: Update_Merit_Function

Rule Purpose: To update the merit function of all the fibre resin combinations

in working memory based on the importance of attribute “n” input by the user .

Rule Definition

IF

User has correctly entered the of attribute n

And

merit function of material i = merit function of material i + n

The rules above illustrate two strategies that are used for selecting the most suitable, fibre-resin combination. The user enters preferences for a set of attributes based on a 1-5 scale. If the conditions in the antecedent of the first rule are satisfied ,then material No 2 is selected. However it is impractical , to cover all of the combinations of user preferences with the help of such rules. The second rule is part of the merit function scheme that is used as a fall-back strategy when the Select_Material rules are not triggered. In this case , the material with the highest merit function score is selected. After a material is selected , all eight-ply sublaminate combinations are generated and are indicated by the number of plies in each direction. These 165 sublaminates are then ranked in a procedural manner on the basis of loading and atmospheric criteria. The top 20 ranked sublaminates are loaded into working memory and then the sublaminate elimination rules are used to eliminate sublaminates that are unsuitable in light of additional loading criteria. We finalise our example by explaining two rules that are used to eliminate sublaminates, which is the last step of the expert system.

Rule Name: Shear _Load _Action

Rule Purpose : Specify the action to be taken if condition “Shear Load” is true

Rule Definition

IF

Condition “shear load” is valid

Then

Increase proportion of plies along the 45 degree directions

Rule Name : No _Shear _Action

Rule Purpose : Specify the action to be taken if condition “shear load” is false

Rule Definition :

IF

condition “shear load” is not valid

Then

ensure plies exist in all directions

Rule Shear _ Load _Action specifies that in case condition "shear load" is important , the number of oblique(45 degree) plies in the sublaminate should be relatively high in number.

Rule No_ Shear _Load _Action specifies that if there is no shear load present , there should be plies present in all the standard directions.

3.5.2 A STRUCTURAL CRITIC(Frame-based Expert System)

3.5.2.1 Definition of the expert system

A structural critic has been developed for the Integrated Building Design Environment (IBDE). IBDE is a testbed for examining several issues of integration and communication in the building construction industry IBDE address the architectural planning, structural design and construction planning of office buildings by integrating the following knowledge based systems.

ARCHPLAN: an architectural planner

CORE : a space planner for the service core

STRYPES : a structural system configurer

STANLAY : a structural layout and approximate analysis system

SPEX : a structural component designer

FOOTER : a foundation designer

CONSTRUCTION PLANEX : a construction planner, estimator and scheduler.

The primary function of the Critic , in the context of the IBDE , is structural evaluation of preliminary design generated by STRYPES , STANLAY and SPEX. The process of evaluation includes the following steps.

1.)Recognise the actual problem

2.)Formulate the idealised problem

3.)Solve the idealised problem

4.)Interpret the solution of the idealised problem judiciously to draw conclusions about the actual problem.

Step 1 and 2 comprise the modelling process, Step 3 is the analysis process and Step 4 is the interpretation process. These are the three functions that the Critic performs. The Critic is organised into three separate modules to carry out these three functions.

The Modeller:

Mathematical models are idealised mathematical representations of the physical prototype. The model allows the engineer to predict analytically the response of structural members to imposed loads. All structural theory utilises various structural models to simulate actual structures. The model has to be simple enough to be analysed , and yet not too different from the real structure. The requirements to replicate a real structure by a mathematical model include replicating system geometry , member properties ,applied loads and connection assumptions. The Modeller consists of three distinct stages.

Stage 1 reads in the data from the IBDE global datastore and develops the internal representation of the problem.

Stage 2 does the actual modelling

Stage 3 interprets the internal representation and converts it into a representation which is readable by the Analysis program.

Analysis:

Analysis is the process of determining the response of a structure to its environment , mainly imposed loads , so that the structure satisfies some functional constraints such as equilibrium ,compatibility, and stress-strain relationships. Analysis is essentially founded on the principles of structural mechanics and is a mechanical iterative process; analysis can be conducted after a suitable model has been developed for the structure. The basic considerations in the formulation of the problem for analysis are :

i.) Analyse the forces and the conditions of equilibrium

ii.) Study the deformations and the requirements of geometrical compatibility

iii.) Establish the force deformation relations from the properties of materials

The representation of a structural analysis problem within a computer program using finite element analysis includes the stiffness matrix and the load vector. All analysis programs , however accept the input at a higher level of abstraction .The input is usually a geometric model where the locations of the nodes and elements in the structure are specified in a pre-defined coordinate system. The loads as well as joint and support conditions are also represented geometrically. The analysis program usually has an internal pre-processor which converts the geometric model to a matrix representation. After solving the problem , the program usually provides the values of internal forces of the elements and displacements and rotations of the nodes.

Interpretation:

The task of this module is to perform structural evaluation and provide feedback. The feedback usually points out errors on poor decisions which are indicated by the new data available after rigorous analysis. The scope for poor decisions exists in two tasks of the design process; preliminary design and modelling.

During preliminary design ,assumptions are being made about the design loads on the structure , hence the internal forces are derived on the basis of these loads are also approximations. During interpretation and evaluation these approximate design values are checked against the most accurate values obtained by analysis. A large discrepancy in the two sets of values indicates that the structure has been either overdesigned or underdesigned, and redesign on the bases of new values may be suggested. Evaluation on a higher level of abstraction may also be done , resulting in qualitative feedback regarding material selection, layout of the structural system etc.

As modelling task also involves making assumptions , there is a scope for errors or poor decisions during this process. Poor decisions during the modelling process might be revealed by analysis results that are absurd or unusual. A sophisticated interpreter might detect these and suggest changes in the modelling. The Interpreter in the Critic incorporates checks for the following:

i.) Maximum forces and moments in members

The forces and moments used for designing the members are available in the input file to the Modeller as slot values in the member group frames. The interpreter compares these design values with the more accurate values obtained by analysis.

ii.) Poor Grouping

The values of maximum and minimum internal forces in the members of the same group are compared. In case of unacceptable discrepancy , the following information is provided.

iii.) Excessive Drift

Drift is the horizontal deflection associated with lateral wind loads. Drift affects both non-structural element and human comfort. Drift is not strictly a static phenomenon , as the dynamic behaviour can have important consequences. However since the lateral load analysis is done on the bases of equivalent static loads , the drift is computed in the Critic is a static one.

iv.) Excessive axial compression of columns

Common analysis methods assume the members to be axially incompressible. If the computed axial deflection of members is found to be high , it indicates an error in either the analysis or the modelling.

3.5.2.2 Framekit Implementation

The domain objects are either actual physical objects ,such as beams, or aggregations relevant to the design process , such as groups of beams. Each object is represented as a frame which holds all the information about that object in its slot values. The frames are arranged in the form of a hierarchical network to enable inheritance of the domain knowledge. The organisation of the structural information follows the representation of domain objects in IBDE .The Critic augments the information obtained from IBDE and completes the model so that it is ready for the analysis. To complete the model it adds the following information:

Frames:

The critic adds two types of frames to complete the description of the structure: nodal load and story. The instances of the nodal load frame represent the loads acting on the joints of the structural frame. These are created when the lateral load distribution is determined .The x, y and z coordinates represent the location of the joint of which loads act , the value slot holds the magnitude of the load .Each instance of the storey frame represents a storey in the building. These frames are also created during the determination of lateral load distribution. The previous and next slots are pointer like attributes holding the name of the frames representing the storeys below and above, respectively. The ht-above-gnd slot holds the value of the total height of the upper floor of the storey above the ground level, while the height slot holds the value of the floor-to-floor height of storey itself.

The wind-velocity and av-wind-pressure attributes are given value during the determination of the lateral load distribution which is modelled as a stepped distribution and hence varies for each storey.

Relationships:

The Critic adds several relationships to the network of frames obtained from the input. This is done to organise the representation of the structure effectively , and also to facilitate inheritance. The Critic augments the network using three relationship pairs: class/subclass , supports/supported by , previous/next .

The class/subclass relation is created by defining the class slot as a relation slot and providing subclass as its inverse , so that when the input frames are read in , the inheritance link is automatically created. The supports/supported by relationship is created between slab and beam frames during determination of gravity load distribution. The previous/next relationships are pointer like links connecting consecutive storeys in the building.

Demons:

Several demons are added to the frames at the start of the Modelling process. All the demons added are IF-NEEDED demons, used for obtaining the value for a particular attribute which is not present in the frame when the input file is read. The demons are as below:

1.)Beam cartesian, column cartesian , slab cartesian:

Each of these demons computes the value of cartesian coordinates of the frame it is invoked in.

2.)Get-height-bldg:

The demon is defined for the class building. It computes the total height of the building by summing up the floor-heights.

3.)Get-type-frame:

This demon is for the class frame(structural frame) to obtain the type of the frame.

4.)Get-grid-frame:

This demon is defined for the class frame to determine the grid describing the geometry of the frame.

5.)Get-location-frame :

This demon is defined for the class frame to determine the location of the plane frame in the building.

6.)Get-rel-stiffness frame :

This demon is defined for the class frame to compute the relative stiffness of a specific frame.

3.5.2.3 Reasoning Process

The reasoning process is divided into three distinct stages ; modelling, analysis, and interpretation. The finite element package ANSYS was used for the analysis. The modeller and the Interpreter are developed to function as interfaces between IBDE and ANSYS .These interfaces use the network of frames discussed above primarily as a database storing all known facts about the structure to be modelled. The Modeller and Interpreter are essentially procedural programs, written in Commonlisp , that add to this datastore during their execution.

The Modeller:

The modeller performs 4 basic functions – initialise the problem, load distribution , prepare file for input to ANSYS ,and identify modelling errors.

1.)Initialise the problem:

The function of initialising the problem involves defining the environment ,loading the input data, and associating demons with slots. The environment is defined through the following tasks: initialise the system variables, initialise the domain specific variables, and define domain specific relationship frames.

2.)Load Distribution

This part involves lateral and gravity load distribution. For lateral load distribution , the wind velocity and the average wind load at each storey level is computed. At the end of the task of lateral load distribution the nodal load at each joint in the frame is computed and a frame is created.

3.)Prepare ANSYS file:

This process involves using the modelling information to write a file for input to ANSYS. First , the preliminary data which is common to all structures within the scope of critic is written. Element types and material properties are examples of this type of data. Then the data specific to the frame type is written .This involves defining nodes , elements , support and loading conditions. While these steps are common to all frame types , the way in which they are defined change with the type of frame. The last in preparing the ANSYS file is writing out ANSYS post-processor commands for printing the results in a file which is used later by interpreter.

4.)Identify modelling errors:

The Modeller performs this additional task independently from the modelling process. This task involves a check for inconsistency in input the information .

The Interpreter:

The essential function of the interpreter is to evaluate the preliminary design , based on the results of the analysis and to identify errors to be sent to IBDE. The evaluation has two parts: comparison of design forces and displacement checks.

1.)Comparison of Design Forces:

After the ANSYS output file is read , the Interpreter compares the values of internal forces and moments in the components with the values used for preliminary design. The preliminary design , as carried out in IBDE , is an attempt to organise the components into groups according to similarity of function and location. One typical component in the group is designed and all other components in the group assumed to have the same section. This grouping helps achieve economy during construction , especially in the case of steel buildings. The Interpreter checks each component , comparing the analysis results with the design forces for the group .The validity of the preliminary design of the group is evaluated according to the number of over or under designed components in the group if any and the difference between the assumed forces used for preliminary design and actual forces obtained by analysis. Another check incorporated in the Interpreter is for validity of the grouping itself. If in a particular group there is a very wide discrepancy between the forces in the most stressed component and the least stressed one , then the grouping is considered inefficient and would defeat its own purpose of achieving economy.

2.)Displacement Checks:

The horizontal displacement of the top of the frame is known as drift. Drift can be high due to wind loads on tall buildings and has to be limited for the comfort of occupants. The Interpreter checks the horizontal displacement of the topmost nodes in the frame and sends a message if the value is unacceptable .In case of framed structures a common assumption is that the axial stiffness of members is very high, so that the deformation of members in the axial direction is negligible .The validity of the analysis process itself can hence be verified by checking if this is indeed the case. The Interpreter checks the vertical displacement of nodes and sends a message to IBDE if the value is too high.

3.6 CODING&TESTING THE EXPERT SYSTEM

This stage is the last stage of developing the expert system. If previous stages has been completed successfully this stage is a fairly easy one. This step can also be defined as “putting the theory into practice” step. Let’s now look at coding ,testing and verifying in detail.

3.6.1 CODING THE EXPERT SYSTEM

The knowledge base must be coded in its final form according to the syntax of the chosen shell. If the knowledge representation of the shell is comprehensible , the coding may well go hand-in-hand with the knowledge analysis and representation. Most knowledge bases can be prepared by a general editor or word processing program. Care is needed in this work because of the global nature of the elements of the knowledge base. Computer scientists are rightly scathing of large BASIC programs developed in piecemeal fashion with liberal GOTO statements joining up last minute additions to ill thought out starters. A large knowledge base can easily attain the same spaghetti-like form. The shell program(most popular one is Clips) may still be able to search through it , but humans will find that very difficult to do .All the exhortation for comprehensibility of rules will be lost if they are not grouped and ordered in some way to reflect facets of the reasoning.

Some overall form or pattern should therefore be imposed on the knowledge base. Most shells allow harmless comments to be inserted in the knowledge base. A simple form could be :

i.)preliminary questions and associated consistency rules

ii.)intermediate sub-goals with their rules

iii.)final goals and main rules.

The reverse would do just as well. Adopting one or other or some different but quite deliberate structure is a big step to maintaining comprehensibility and attaining an error free knowledge base. The consistency that comes from an overall structure to the knowledge base can be extended to the propositions themselves. Rules are more easily understood if the order of objects in propositions and the order of propositions is the same in rules which use the same elements. Thus a proposition such as :

IF cost > target_cost

Should not become , in another rule,

IF target_cost < cost

This just creates unnecessary mental gymnastics. Similarly , if lists of objects appear in the knowledge base , stick to the same order on each appearance if at all possible.

Many shells allow a descriptive label to be associated with each rule – it may only appear in the print out or it may be displayed to the user on command. If some rules have come from a technical note or a code of practice, this label can be used to refer to the source and so aid the self documentation of the knowledge base.

The syntax of how a question is actually coded for a knowledge base varies from shell to shell. It is important when phrasing such explanatory text to think carefully about the future users of the expert system. Their likely experience , knowledge of the topic and familiarity with the related jargon must be correctly judged or the explanatory text may be above their comprehension of judged to be trivial. A similar problem must be faced when planning explanatory texts to be used when answering the user’s question “why ?” .As mentioned earlier , some shells show the rules themselves when answering this question , some allow "canned text" attached to a rule to be displayed. The same strictures about thinking of potential users clearly apply when choosing such text , but there is another consideration. If a hierarchy of several layers of rules is being evaluated when the user asks "why ?" , the explanatory texts associated with each rule must make sense when displayed altogether as some shells do. Even if a shell displays only the text of the current rule , it is likely to allow repeated use of "why ?" to penetrate through the hierarchy , thus exposing each explanation. Clearly , any inconsistency or contradictions in the explanations will be non user-friendly.

Providing displays to keep the user informed about the progress of a diagnosis is one of the recommended stages in a user friendly system. Coding these displays will be generally be by demons , i.e. rules which have as a consequent not an object but an action. The action will be to display some text on the screen , and most shells have provision for such demons. Devising rules to put intermediate displays on the screen will only be worthwhile in large and therefore long-running systems, but they make a real contribution to acceptability. Clearly shells which allow several consequents to follow THEN make it simple to cause a suitable display to appear as soon as an important sub-goal has been successfully evaluated.

3.6.2 TESTING THE EXPERT SYSTEM

The robustness of well-proven shell coupled to the freedom of rule order makes it disarmingly simple to get an expert system running very quickly indeed and with a very professional appearance. The contrast with the usual extended birth of a conventional program can create a false impression of an immediately tested system. It is of course not

the case. Indeed , the searching strategy of shells produces a problem of a terrifyingly large number of possible routes through a knowledge base. A careful analysis of the rules in a middle sized expert system produces an estimate of well over 20000 possible combinations of answers all leading to a sensible result, and this sample expert system only has 170 rules.

This is an illustration of combinatorial explosion once thought to be a barrier to expert systems progress, but now solved by modern searching methods. It remains still a problem for humans testing an expert system. As with conventional programs , there are a few steps one can take to eliminate the “ basic” errors before starting a test programme. Many shells make a check on the syntax of the knowledge base before attempting to execute it and this stage is often part of a compilation process designed to produce fast execution .Clearly such shells will pick up simple errors made in key words , and some shells go a long way towards checking that the object and constants in propositions are of matching types. Shells usually produce lists of the names of objects referred to in rules. From experience it has been found to be well worthwhile spending time examining such a list before embarking upon tests. Typing errors may well cause extra unwanted objects to appear , and spotting those at an early stage can save much time. For a simple knowledge base having a list in an alphabetic order can make it easier to spot the rouge names but for a larger knowledge base where groups of related objects have been defined together in frames , alphabetic ordering can destroy an otherwise useful adjacency .Of course an entirely object oriented approach to creating the knowledge base avoids this type of error.

It is usually easy to commence testing on a small part of a knowledge base perhaps one goal or even one sub-goal . A temporary action list to evaluate only one or two objects can be used to test one part of a large knowledge base without any other surgery. If a new shell is being used this is the opportunity to become familiar with its working method. It is a very good practice to follow either the knowledge base itself or a knowledge diagram and check that the shell asks each question in the order you expect. This is not very easy with many rules being triggered but tackling it with a subset of knowledge base that relates to just one sub-goal will keep the problem in scale. One particular problem can be mentioned here again. It concerns the manner in which shells update the knowledge base as each object is evaluated, i.e. how, rather then when, the opportunistic forward-chaining is deployed. In principle this should be immediately an object gets a value , but some shells delay updating until the rule currently being considered is finished with. This can cause unnecessary questions to be asked but, more critically , can hold up demons which are ready to trigger some action , particularly that of displaying messages to the user. A firm understanding of how the shell works may help find ways round such problems.

Having tested all the parts of a knowledge base by the device of evaluating one object one object at a time , testing of the full system can commence. Clearly the best material for this is a set of case studies of past problems provided by the expert , but you should take care to use straightforward test cases with clear-cut answers. This is the stage of iterative improvement of the knowledge base and is to be expected that the test problems will help refine the knowledge as well as find errors in the knowledge representation. There is no need to complicate this process by tackling problems which could defeat the expert.

The potential users of the expert system should not be forgotten in this testing phase. Their ability to understand the text of questions , of messages , and even the results, is all part of the iterative refinement of the knowledge base. Involving the users in this work is also an excellent way of motivating their enthusiasm for its eventual introduction. Indeed a formal evaluation by users could parallel the verification stage to be discussed next , and it should never be forgotten that the utility of any program hinges on the user’s answer to the question “Is it worth the trouble ?”

3.6.3 VERIFICATION OF THE EXPERT SYSTEM

Bearing in mind the enormous number of possible routes through a knowledge base it is unrealistic to believe that a knowledge base can ever be fully tested. In addition we have to face the likelihood that the knowledge base will not contain all our expert’s knowledge on the chosen topic and the possibility that our expert is himself not infallible. Put together , that appears to yield a statement that we can not produce a totally reliable expert system. What is needed is to verify our expert system to gain confidence in it to the same extent as we have in our expert.

How can we do that ?.How would we test a new human expert ?Putting those two questions together raises the possibility of making blind comparisons of the results of trials on both the expert system and on known experts. Such comparisons eliminate the known bias people have towards or against computers. We are still left with the task of selecting a suitable set of problems and be sure we know right answers to them The suitable set of problems should reflect the distribution of problems in real life i.e. that if some causes are very common , then most problems should be set to test those causes. This is certainly the easiest way , since producing such trials only requires looking up sufficient past case studies. But is this how we would test a new human expert ? .Surely we would want to talk to him, to probe his knowledge generally and then try him out with a few standard problems and a few difficult problems. The analogous approach to verifying an expert system would then seem to be:

i.) Get all available experts to examine the knowledge base (with knowledge diagrams to aid their understanding of it)

ii.) Put to the expert system a number of real problems exploring , the less common as well as the usual cases.

iii.) Put same problems to other experts

iv.) Make a blind comparison of the results obtained from (ii) and (iii)

Verification is a task which will increase greatly with the size of an expert system knowledge base ,but for medium sized diagnosis and advice systems a combination of careful testing and verification explained above can be satisfactory.

INTERNET & ADVANCED WWW TECHNOLOGIES

4.1 INTRODUCTION

Internet technology has its origins in 1960s military solution to communication. After 1984 the US National Science Foundation applied the same technology to connect computers at major universities in US. It was called internet-shortened for “inter network” – a network that inter connects other networks. By the mid 90s , the Internet became one of the most popular communication technologies. In principle all computers connected to internet are peers ; in practice however , some are dedicated to provide a service for the other ones. The
“service provider” computers are called “servers” and should be connected to the internet 24 hrs/day. The other ones are called “clients” ,(personal computers, workstations)which are used to access the information at the servers. The use of Internet has been complex until early 1990s .In 1989,the European Institute for Particle Physics developed an Internet service that enabled the distribution of the hypertext .In 1993 , the US National Centre for Supercomputing Applications developed a friendly graphical program for reading hypertext documents and browsing the web , the use of the internet outside scientific community exploded.[22]

But the internet is not limited just with World Wide Web(W3) and there are many other tools and functions of the internet that are extremely useful. The most known are e-mail, news, and chat and cu-see-me applications.

4.2 WORLD WIDE WEB BASICS

The world wide web is a system with a universally accepted set of standards for storing , retrieving , formatting and displaying information using a client/server architecture. It was developed to allow collaborators in remote sites to share their ideas on all aspects of a common project.

Whereas the other methods of accessing information on the net are primarily character based , the Web combines text , graphics, and multimedia .The Web uses graphical user interfaces for easy viewing. It is based on a hypertext language called Hypertext Markup Language(HTML) that formats documents and incorporates dynamic links to other documents and pictures stored in the same or remote computers.[23] HTML can also be defined as a simple data format providing a simple markup language used for Web hypertext. Often HTML files are static documents ; via gateways , HTML can be used to represent dynamic data such as information from databases. This type of HTML is called DHTML which stands for Dynamic Hypertext Markup Language. HTML is a simplified version of Standard Generalised Markup Language(SGML) , a formal defining document system. The HTML markup is simple , yet powerful enough to represent most common documents.HTML based documents are transferred via HTTP the Hypertext Transfer Protocol. HTTP is the main method that Web protocols use to transfer data between a server and a client. It uses a request/response model. An HTTP client ,or user agent(often a web browser) ,connects to an HTTP server by using a URL(Uniform Resource Locator) and requests a resource , such as a HTML document. Traditionally HTTP clients/servers talk over TCP/IP (Transmission Control Protocol/Internet Protocol) using port 80 , other ports can be used if specified in the URL. HTML uses tags to describe a document. Tags are used to create headings, paragraphs ,lists ,frames and hyperlinks. Most HTML tags come in pairs ,each pair consisting of a starting tag and an ending tag. Starting tag is shown by <Tag> and ending tag is shown by </Tag>.Here are some examples of commonly used HTML tags:

<B></B>	Bold
<TITLE></TITLE>	Document Title
<HEAD></HEAD>	Heading
<A HREF= “ http://www.dissertation.com”> My Dissertation</A>	Hyperlink

<IMG SRC= “ http://www.building.com/Building.jpg”>	Image Source
 	Page Break
<FONT FACE= “Arial Black”>Engineer</FONT>	Font Type
<EMBED SRC= “Sound . wav” >	Insert Object

Another common application to be mentioned here is the CGI. The common gateway interface(CGI) is a platform independent interface used to run software in conjunction with an HTTP server. It allows for “gateway” connectivity between non-HTTP servers and other forms of data. One of the most popular forms is a database gateway , which is used for Web representations of data stored in a database. The HTTP server executes the CGI process ,which is often a stand alone application. A CGI application is initiated by an HTTP client , specifying a URL that points to the CGI application. The HTTP server executes this CGI application and returns the output to the HTTP client. CGI defines the interface between HTTP servers and CGI applications , including command line ,environment variables, input and output. Script based software is frequently used , often in the Perl language ,so that CGI applications are commonly referred as CGI script. A multimedia web database server , WODA[24] can be a good example for CGI applications used in the construction industry. This is a very brief definition of World Wide Web ,there are various issues that are not stated here can also be reached by using the links at the resources section.

4.3 ADVANCED WORLD WIDE WEB TECHNOLOGIES

The previous section defined a basic Web architecture using URLs to name resources ,HTTP to transfer resources ,HTML to display resources ,and the CGI to provide basic HTTP server extensibility. These technologies still remain the core of the Web ,but new protocols have evolved quickly and from many resources. This section describes new emerging web technologies and advanced methods that are used to send and receive information between the server and the client. There are developments extending the capabilities of the web server ,and various innovations have extended the capabilities of web clients.

4.3.1 EXTENDING THE WEB SERVER

Web server has evolved from a basic HTTP server with CGI extensibility. Scripting has became an option for server side HTML creation .ASP is also a new technology that provides the server - side equivalent to using a scripting language and objects on the client. It is better to look at these technologies in detail.

4.3.1.1 COMMON GATEWAY INTERFACE

The common gateway interface CGI[25] is a standard for interfacing external applications with information servers, such as HTTP or Web servers. A plain HTML document that the Web daemon retrieves is static, which means it exists in a constant state like a text file that doesn't change. A CGI program ,on the other hand, is executed in real time ,so that it can output dynamic information. For example if we want to put our Unix database to the World Wide Web ,to allow people from all over the world to query it, one way of doing this is creating a CGI program that the Web daemon will execute to transmit information to the database engine and receive results back again and display them to be the client. This is an example of a gateway ,and this where CGI got its origins. Since a CGI program is executable ,it is basically the equivalent of letting the world run a program on your system(or server) which isn't the safest thing to do. Therefore , there are some security precautions that need to be implemented when it comes to using CGI programs. Probably ,the one that will affect the typical web user the most is the fact that CGI programs need to reside in a special directory, so that the Web server knows to execute the program rather than just display it to the browser. This directory is usually under the direct control of the webmaster, prohibiting the average user from creating CGI programs.

A CGI program can be written in any language that allows it to be executed on the system, such as :

- C,C++
- Fortran
- Perl
- TCL
- Any Unix Shell
- Visual Basic

It just depends on what you have on your system. If you use a programming language like C or Fortran you know that you should compile the program before it will run. If you use one of the scripting languages instead, such as Perl ,the script(small embedded program) itself only needs to reside in the "*/cgi-bin*" directory, since there is no associated source code. Many people prefer to write CGI scripts instead of programs, since they are easier to debug, modify and maintain than a typical compiled program.

4.3.1.2 ACTIVE SERVER PAGES

An Active Server Page (ASP) is an HTML page that includes one or more scripts that are processed on a Microsoft Web Server before the page is sent to the user. An ASP is similar to CGI (Common Gateway Interface) application in that all involve programs that run on the server, usually tailoring a page for the user. The script in the Web page at the server uses input received as the result of the user's request for the page to access data from a database and then builds or customises the page on the fly before sending it to the requestor.[26]

ASP is a feature of the Microsoft Internet Information Server (IIS) ,but, since the server side script is just building a regular HTML page ,it can be delivered to almost any browser. You can create an ASP file by including a script written in VBScript and Jscript in an HTML file and then renaming it with the ".asp" file suffix. Microsoft recommends the use of the server side ASP rather than a client side script, because the server side script will result in an easily displayable HTML page. Client-side scripts may not work as intended on older browsers.

Main Built in ASP objects are :

- Response Object
- Server Object
- Request Object
- Session Object
- Application Object

The most important one is the Response Object ,it is used for sending text, data and cookies to the browser and control each stage of transmitting the page. The Response Object is useful , feature rich and subtle. The most fundamental capabilities of the Response Object are;

- response.write
- response.redirect
- response.end

The script below writes some information about time to the browser using Response Object.[27]

```
<html><head>
<title>response.asp</title>&
<body color="#FFFFFF">
<%
when=now()
tommorow=dateadd("d",1,when)
twoweekslater=dateadd("w",2,when)
monthlater=dateadd("m",1,when)
sixminuteslater=dateadd("n",6,when)
sixhourslater=dateadd("h",6,when)

response.write "Now <b>" & when & "</b><br>"
response.write "1 month from Now <b>" & monthlater & "</b><br>"
response.write "2 weeks from Now <b>" & twoweekslater & "</b><br>"
%>
six minutes from now <b> <%=sixminuteslater%> </b><br>
six hours from now <b> <%=sixhourslater%> </b><br>
</body></html>
```

ASP comes with various low-level ActiveX controls, such as OBDC database controls that allow easy access to database-driven content. By providing low-level objects as ActiveX controls , ASP allows developers to write only high level code in the form of scripts that manipulate these objects. When the Web server uses the ActiveX script engine interface,

a variety of script languages can be used. Thus, scripts in Jscript, VBScript , Perl , Tcl and other languages can be employed.[28]

The advantages of ASP can be summarised as follows:

- ASP allows dynamic HTML content to be generated using any programming or scripting language- VBScript , Jscript , REXX , Perl , Tcl ,Java, Visual Basic ,C++ , and even COBOL.
- ASP simplifies the task of generating a dynamic HTML page and allows the page to be generated with no coding at all.(Only Scripting)
- ASP allows the data access logic that is required for generating a Web page to be separated from the logic required for presenting the content of the page.
- These makes development , debugging , and maintenance simpler.
- ASP allows changes to be made without immediate completion. The completion is done automatically when the file is accessed by a browser.(client)
- ASP has built-in components that recognise the capabilities of a browser and act accordingly. The browser is simply expected to display the dynamic HTML generated by execution within the ASP environment at the server.

4.3.2 EXTENDING THE WEB CLIENT

A web browser was simply a tool that displayed text and that could follow hyperlinks to retrieve that text. Various innovations have extended the capabilities of Web browsers. Today a Web browser is often viewed as a universal client because it performs the functions that were previously handled by dedicated clients. There are various new technologies for improving clients(browsers) capabilities , like XML , Client Pull and Server Push ,and HTTP cookies.

4.3.2.1 EXTENSIBLE MARKUP LANGUAGE

Extensible Markup Language (XML) is a markup language for documents containing structured information. Structured information contains both content and some indication of what role that content plays (for example, content in a section heading has a different meaning from the content in a footnote, which means something different than content in a figure caption or content in a database table).We know that a markup language is a mechanism to identify structures in a document. The XML specification defines a standard way to add markup to the documents.

Extensible Markup Language is a new language designed to make information self describing. This change in how computers communicate has the potential to extend the Internet beyond information delivery to many other kinds of human activity. Indeed , since XML was completed in early 1998 by the World Wide Web Consortium(W3C) ,the standard has spread like wildfire through science and into industries ranging from manufacturing to medicine.

The hopes are about XML will solve some of the Web's biggest problems. These are wildly known: the Internet is a speed-of-light network that often moves at a crawl; and although nearly every kind of information is available online, it can be very difficult to find one piece you need.

Both problems arise in large part from the nature of Web's main language. Although HTML is the most successful electronic publishing language ever invented , it is superficial : in essence it describes how a Web browser should arrange text ,images and push-buttons on a page .

HTML's concern with appearances makes it relatively easy to learn , but it also has its costs. One is the difficulty in creating a Web site that functions as more than just a fancy fax machine that sends documents to anyone who asks. People and companies want Web sites that take orders from customers, transmit medical records ,even run factories and scientific Instruments from half a world away.HTML was never designed for such tasks.

As an example a doctor may be able to pull up his patient's drug reaction history on the Web browser, he can not then e-mail it to a specialist and expect her to be able to paste the records directly into her hospitals database. Her computer would not know what to make of the information, which to its eyes would be no more intelligible than <H1>Reaction <H1>.

It is mentioned at the previous section that these angle-bracketed labels above are called tags.HTML has no tag for a drug reaction , which highlights another of its limitations, it is inflexible. Adding a new tag involves a bureaucratic process that can take so long that few attempt it. And yet every application, not just the interchange of medical records, needs its own tags.

The solution in theory , is very simple: it is to use tags that say what the information is, not what it looks like. For example, label the parts of an order for a shirt not as boldface, paragraph row and column –what HTML offers—but as price, size quantity and colour. A program can then recognise this document as a customer order and do whatever it needs to do.

In order explain XML in detail , we have to mention SGML.SGML (Standard Generalised Markup Language) is the language for describing languages(it can be called a meta-language) has been useful in many large publishing applications. Indeed HTML was defined using SGML. The only problem with SGML is that is too general and more complex than Web browsers can cope with.

XML is created by removing frills from SGML to arrive at a more streamlined meta-language. XML consists of rules that anyone can follow to create a markup language from scratch. The rules ensure that a single compact program, often called a parser , can process all these new languages. The unifying power of XML arises from a few well-chosen rules. One is that tags almost always come in pairs. Like parentheses , they surround the text which they apply, and like quotation marks , tag pairs can be nested inside one another to multiple levels. The nesting rule automatically forces a certain simplicity on every XML document which takes on the structure known as a tree. As with a genealogical tree, each graphic and bit of text in the document represents a parent or a child ,relationships are unambiguous.[29]

As XML spreads , the Web should become noticeably more responsive. At present computing devices connected to the Web, whether they are powerful desktop computers or tiny pocket planners ,cannot do much more than get a form, fill it out and then swap it back and forth with a Web server until a job is completed. But the structural and semantic information that can be added with XML allows these devices to do a great deal of processing on the spot. That not only will take a big load off Web servers but also should reduce network traffic dramatically. As more of the information on the net is labelled with industry-specific XML tags, it will become easier to find exactly what you need. Hyperlinks Will do more when powered by XML. The standard for XML links(Xlink) will allow us to choose from a list of multiple destinations. Other kinds of hyperlinks will insert text or images right where we click, instead of forcing us to leave the page.

For the users, the XML powered Web will be faster, friendlier and a better place to do business , Web site designers ,on the other hand, will find it more demanding. Web designers will need to work on not just in the production of words and graphics but also in the construction of multi-layered , interdependent systems of DTDs (Document Type Definition) data trees, hyperlink structures , metadata and stylesheets.[30]

4.3.2.2 CLIENT PULL & SERVER PUSH TECHNOLOGIES

The general idea is that browsers have always been driven by user input. For gathering data or information we click on a link or an icon or an image .As a next step people wanted to give a server ability push new data down to the browser. It hasn't been possible for a long time.

Server push and client pull are the new technologies that enables this kind of communication.

The short description for both is below:

Server Push: The server sends down a chunk of data ; the browser display the data but leaves the connection open ; whenever the server wants it sends more data and the browser displays it , leaving the connection open ; at some later time the server sends down yet more data and the browser displays it .

Client Pull: The server sends down a chunk of data, including a directive(in the HTTP response or the document header) that says "*reload this data in 5 seconds*" or "*load this other URL in 10 seconds*". After the specified amount of time has elapsed ,the client does what it was told.

In Server Push , a HTTP connection is held open for an indefinite period of time (until the server knows it is done sending data to the client and sends a terminator, or until the client interrupts the connection).In client pull , HTTP connections are never held open; rather the client is told when to open a new connection, and what data to fetch when it does so.

In server push , the magic is accomplished by using a variant of the MIME message format "multipart/mixed", which lets a single message(or HTTP response) contain many data items. In client pull, the magic is accomplished by an HTTP response header that tells the client what to do after some specified time delay.[31]

There are many other ways to extend the capabilities of the web client including MIME helper applications, HTTP Cookies, Netscape plug-ins ,Web Channels, Macromedia

Shockwave, Cascading Style Sheets, and the new are new standards to develop a safer and friendlier Web including PICS(Platform for Internet Content Selection), P3P(Platform for Privacy Preferences Project).

4.3.3 SCRIPTING & SCRIPTING LANGUAGES

One of the most powerful innovations for Web protocols has been the ability to add a script(a small program) ,written in a scripting language, to an HTML document. Client Scripting and Server Scripting serve different purposes. Server Scripting can be used to create HTML pages on the fly on the Web server that are then sent to the browser. Client Scripting , is used to make pages more interactive after they have been sent to the browser. The table below shows the differences between the tags that are used in client and server scripting.

Task	Client Script Tag	Server Script Tag
Start Script and Identify the Language	<SCRIPT LANGUAGE= “MyScript”>	<%@ LANGUAGE= “MyScript”%>
Start Script	<SCRIPT LANGUAGE= “MyScript”>	<%
Hide Script from browsers without script capability	<!- - Place Script Here -->	Not applicable to server script
End Script	</SCRIPT>	%>
Print Server Script or variables in Client Script	Document.write	<% variable name here %>

Table 4.1 Client Scripting vs. Server Scripting

There are various scripting languages like JavaScript, VBScript ,ECMA Script and ActiveX Script, the commonly used ones are JavaScript and VBScript.[32]

4.3.3.1 JAVA SCRIPT

Jscript is a relatively simple object-oriented scripting language , designed to create and manipulate script objects. It was created by Netscape and was originally called Live Script , JavaScript is not Java , although aspects of the Java script language were designed to look and feel like Java. The source code of Jscript is inserted into an HTML document using

<SCRIPT LANGUAGE = "JavaScript"> tag. When rendering the HTML document, the browser passes the code to the Java Script interpreter. Java Script has the ability to access the properties and methods of objects. It comes with a set of core objects: Array ,Boolean, Date , Function , Math ,Number , RegExp, and String. Browsers expose an additional object model in order to expose the safe functionality of the browser to JavaScript enabled Web pages. The Document and Form objects deal with the HTML document. The Window and Browser objects deal with the browser's window, frames, history, MIME types and related functionality. For interactive programming ,JavaScript provides event objects and event handlers. There are events named like onMouseOver, onKeyPress and so on.[28]

4.3.3.2 VISUAL BASIC SCRIPT

VBScript is essentially a subset of the Microsoft Visual Basic language. It is implemented as a fast , portable , lightweight , interpreter for use in Web browsers. Similar to Jscript , VBScript code is inserted into an HTML document by using

<SCRIPT LANGUAGE= "VBScript"> tag.

When rendering the HTML document the browser passes the code to VBScript interpreter .As an alternative to Java Script , VBScript is useful in that it allows the large Windows developer community to employ their Visual Basic development skills in the creation of interactive Web content. The example below shows a simple VBScript ,the script enables us to display a message when the user clicks a button in a Web page.[33]

```
<HTML>
<HEAD>
<TITLE>Test Page</TITLE>
<BODY>
<FORM NAME= "Form1">
<INPUT TYPE = "Button"  NAME= "Button1" VALUE "Click">
<SCRIPT FOR = "Button1" EVENT= "onClick"  LANGUAGE= "VBScript">
            MsgBox ("Button Pressed")
</SCRIPT>
</FORM>
</BODY>
</HTML>
```

4.3.4 ACTIVE-X TECHNOLOGY

Microsoft ActiveX is a set of technologies from Microsoft that enables interactive content for the World Wide Web. With ActiveX Web sites come alive with multimedia effects, interactive objects and sophisticated applications.[34]

ActiveX provides a framework for dynamically extending capabilities of Web clients as well as Web servers. In fact more recent versions of Internet Explorer (Microsoft's Web Browser) are relying more and more on a set of ActiveX controls . No specific programming language is required to create an ActiveX control .As the technology stands , ActiveX controls can be implemented using Visual C++ ,Visual Basic ,or Java.

ActiveX is based on a technology from Microsoft called the Component Object Model(COM) COM itself has gone through series of revisions. It began as OLE (Object Linking and Embedding) ,and OLE2 introduced COM. The term ActiveX has become favoured as a replacement for OLE , although there are some technological differences between the two .

Prior to ActiveX ,OLE controls (OCXs) were used to accomplish a specific objective, such as displaying HTML .ActiveX controls are similar to OLE controls but with some important differences:

- ActiveX controls are more lightweight. An ActiveX control doesn't need to implement all the interfaces that an OCX must. An ActiveX control has less communications overhead than an OCX.
- ActiveX allows for the use of asynchronous monikers(a moniker is an OLE object that understands how to initialise another OLE object) in an effort to provide higher efficiency.
- ActiveX controls allow for the use of security and code signing.

ActiveX consists of several underlying technologies. Let's now look at these technologies in detail.

ActiveX Controls:

ActiveX controls constitute the basic building blocks of ActiveX. When someone refers to ActiveX he or she is usually referring to ActiveX controls. An ActiveX control is a software module that can not stand by itself. It must run within the framework of an ActiveX container , such as a Web browser ,a word processor, or a spreadsheet. The functionality of the ActiveX control can be almost anything that the creator of the ActiveX control wants. It can be a database access ,file access, time(value) retrieval and so on.

ActiveX Scripting :

ActiveX scripting allows code to exist in the HTML file itself instead of being pre-compiled and then embedded into the HTML code. The code is interpreted and executed. In some cases the code must first be downloaded.

ActiveX scripting includes support for JavaScript as well as VBScript. It also includes support for the ActiveScript API which provides a smooth migration for existing OCX container applications so that can be converted easily to ActiveX scripting containers.

4.3.5 JAVA PLATFORM & LANGUAGE

It is very difficult to explain Java technology so briefly(or abstracted), because it is a big area of research and there are a lot of ongoing developments about the Java technology , but in this section I will try to mention some important points about the language and the platform .

Originally called "Oak" Java was developed at Sun Microsystems in 1991.It is a programming language that resembles C++ in form , but it is purely object oriented and architecture neutral.[35]

The Java programming language and environment is designed to solve a number of problems in modern programming practice. Java started as a pert of a larger project to develop advanced software for consumer electronics. These devices are small reliable, portable , distributed, real-time embedded systems. When the Java team started the project they intended to use C++ ,but a they have come across a number of problems.

Initially these were just compiler technology problems , but as the time passed more problems emerged that were best solved by changing the language. In the light of the work done by Java team ,the language is now defined as - a simple , object-oriented ,network-savvy , interpreted ,robust ,secure ,architecture neutral , portable ,high-performance ,multithreaded , dynamic language.[36]

The Java platform is a fundamentally new way of computing based on the power of networks and the idea that the same software should run on many different kinds of computers. With Java technology we will be able to use the same application from any kind of machine- a PC , a Mac ,or a NC(Network Computer). Java technology is wildly regarded as revolutionary , because it was designed to let computers and devices communicate more easily than ever before. The Java Platform is incorporated into all major Web browsers and soon the Java platform will be built into next-generation telephones ,TV set-top boxes ,smart cards and many other business and consumer devices.

The most visible examples of Java software today are on the internet and on enterprise networks. They are interactive programs called Java Applets. Applets work inside Web browsers on computers, the applets enables us to do almost everything including putting data into a database, querying it or doing an engineering calculation just using our browser, even to build an expert system working directly on the web.

There are also other kinds of Java software. Java programs can run directly on our computer (without requiring a browser) , or on servers, on large mainframe computers.

The Java software running on servers in large companies monitors transactions and ties together data from existing computer systems. Some companies are using Java software o their internal Web sites to streamline communication and the flow of information between departments, suppliers and customers.[37]

MASONRY ARCH BRIDGES AND ANALYSIS METHODS

5.1 INTRODUCTION

Bridges have always fascinated people, be it a primitive bridge over a torrent or a deep gorge or one of the magnificent modern bridges whose immense spans almost defy the imagination . A variety of qualities are called for to build a modern bridge ; a considerable amount of knowledge , the courage to take daring decisions and the ability to lead a large team of fellow workers to the successful completion of the project. Bridge building is one of those difficult constructional endeavours that both attract and challenge the energetic and self-confident engineer. The importance of bridge building gives rise to a correspondingly intense joy and satisfaction when successfully completed.

The arch is the strongest embodiment of a bridge , its shape expresses obviously its ability to carry loads across a river ,valley or gorge . Therefore ,arch bridges are considered beautiful by their evidently suitable shape. This is valid for small and large bridges alike.

5.2 MASONRY ARCH BRIDGES (CHARACTERISTICS)

The beauty of natural stone masonry is best expressed in small bridges , if the arch and the face walls form a unit. The small culvert can be shaped as a semi-circle or as a segmental circle. Long wing walls for a 1:2 slope of embankment are in this case important for the aesthetic balance. The arch should not be too thin at its crown and ,therefore , closed parapets are recommended. For larger widths e.g. for the underpass of a highway ,the Roman semi-circle looks stiff; instead a parabolic shape should be chosen which follows the thrust line caused by dead load. Wing walls parallel to the upper road with a massive parapet are here also to be preferred, if there is no ample depth above the crown, allowing a fascia strip and open railings. The shallow segmental arch over one opening can be boldly shaped, if good soil conditions can provide for a large thrust to allow a small rise of the arch. If the vertical alignment of the road is curved , then this curvature can be accentuated by a slightly projecting fascia plate well above the crown of the arch. There are many possibilities for arranging a series of arches. To obtain the impression of stability it is essential that the piers between the arches are sufficiently thick and not too high in relation to the width and depth of the spans. This is especially valid for flat arches which should also not be too thin at the crown , because this would cause an impression of insufficient stability and create a lack of balance in relation to the face wall. On secondary roads ,the curvature of the road in elevation between the ramps can perhaps be so pronounced that a stepwise increase of spans is the best solution, this is what makes old bridges so charming. For these spans the depth of the crown should be kept almost constant. To change from small span arches to one main span arch requires low and wide piers or protruding pillars up to the top, so that the large thrust of the long span arch is turned downwards by ballast and the appearance inspires confidence. The span/rise ratio can be chosen rather low masonry arches , if the foundation conditions are good. For spans above 35-40 m and span/rise ratios larger than 1:7 , closed face walls look heavy. This appearance of massiveness can be relieved by breaking up the face area with openings between transverse walls, leading to barrel arches.[38]

5.3 ANALYSIS OF MASONRY ARCH BRIDGES

5.3.1 MEXE METHOD

Mexe method is based on an empirical method developed by Military Engineering Experimental Establishment ,to help military engineers assessing the masonry arch’s capacity. At that time the assessment method is used for understanding the capacity of the arch to carry military vehicles. During the second world war the increase of weight of military vehicles forced engineers to develop simple correlation methods for assessing the strength of the bridges quickly.

The method was empirical and was based on the work of Professor Pippard in 30's and 40's and re-structured by full scale destructive tests carried out by Davey. Pippard's analysis was based on a two hinge parabolic arch with a central point load. In his analysis failure axle load was taken twice this load as there are two wheels to the axle. The full scale tests carried out by Chettoe and Henderson in the 50s and the resulting knowledge of arch behaviour was consolidated in Solog Study at 1963. As a result of all these research and revisions BA 16/94 was issued as the modern modified MEXE method.

The MEXE method uses a nomogram , based on the span of the arch and the combined thickness of the barrel and fill at the crown, to give an axle loading for a perfect arch. The arch is assumed to be two pinned and perfectly elastic with a compressive strength of 13 tons per square foot. The arch is assumed to be parabolic , with a cross section that increases from the crown to the springings and with a level of road surface.

The factors are for modifying the provisional axle load to take into account variations from the idealised arch. The span/rise factor allows for the basic proportions of the arch and is based on the ratio of the quarter span to the half span height. The profile factor is for determining the difference between the shape of the arch and the parabola. The material factor is a combined factor which takes into account the estimated strength of the arch material and strength of the fill over the barrel. The joint factor takes into account the width and depth of the joints and the estimated strength of the mortar. The condition factor takes into account the condition of the arch, the condition factor can be determined by looking at cracks and deformations of the arch.

The provisional axle load is modified by the MEXE factors to obtain Modified Axle Load and this is further modified by axle factors for single, double and triple bogies to obtain the allowable construction and use loading. The axle factors depend on whether axle lift-off can take place over the arch , such as on a hump-backed bridge.[39]

The MEXE method is used by many assessment engineers as it is simple and quick to apply, and the engineering judgement plays an important role while applying this method for assessment.

5.3.2 THE MECHANISM METHOD

The basic mechanism analysis done by Pipard in 1939 is illustrated in .

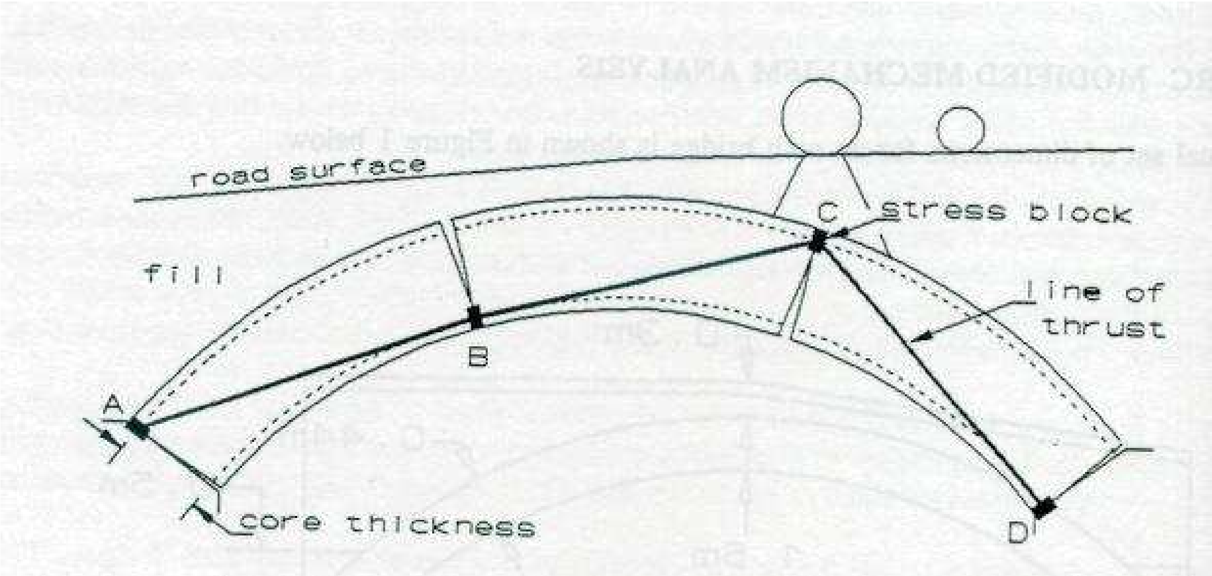

Figure 5.1 Principles of Mechanism Method

The hinge locations at A,B,C, and D are assumed on a longitudinal section of the unit width. Moments are taken at C and B to obtain two equations in terms of the unknown reactions at A. The vertical reaction at A can then be eliminated from the equations and the horizontal reaction calculated. Moments then taken about D for the whole arch and the unknown load W can be calculated. This is repeated for different hinge locations to obtain the minimum value of W.

The disadvantage of Pippard’s method is that it allows hinges to form at the outside edges of the arch barrel thereby assuming infinite compressive stress, also if the wrong critical load positions or the wrong hinge locations are selected then the capacity of the arch is over estimated. The mechanism method involves lengthy iterative calculations and is gaining in popularity as more and more computer programs are developed. The Assessment Standard

BD 21/84 requires analysis in terms of ultimate limit state of collapse for masonry arch bridges. There are two criteria for failure :

1.) The formation of four hinges in the arch barrel to convert the structure into a mechanism.

2.) Excessive compressive stress in the barrel.

These failure criteria have been illustrated by full scale tests carried out by the Transport and Road Research Laboratory on a number of redundant masonry arches in United Kingdom. The task of the assessment engineer is complex. The strength of the arch depends on the geometry and yet this is difficult to measure and define. Drawings are rarely available for these structures and so critical factors critical factors such as the thickness of the barrel is difficult to determine. Masonry arches tended to be built by rules of thumb and so the load carrying capacity can vary even between similar structures.

5.3.3 THE FINITE ELEMENT METHOD

The finite element study is carried out by Robert Falconer in 1990 , and by myself in 1999 as a part of my research. Values of material densities are taken in according to Assessment standard 2100 kg/m3 for both masonry and fill. The values of elastic modulus assumed for the masonry and the fill were 10000 N/mm2 and 40 N/mm2 . The poison ratio is taken as 0.2 for masonry and 0.4 for fill. As a result of the study ,that involves comparison of finite element method and mechanism analysis it is found out that maximum allowable stress value is 0.25 N/mm2 where the crack occurs.

5.4 THE APPLICATION OF MEXE METHOD

In order to make the next chapter more clear it is better to look at the application of mexe method in detail. We should look at the factors and dimensions ,that are used in the mexe method , one by one.

The span length (L) :

Span length is the distance between springings.

Barrel Thickness (d) :

Barrel Thickness is the distance between intrados and extrados which is measured radially under the carriageway.

Depth of Fill (h) :

This value is the depth of the fill from top of the surfacing to the crown of the arch

Rc Value (Rc) :

The rise of arch barrel at the crown.

Rq Value (Rq) :

The rise of arch barrel at quarter points.

Material Factor(Fm) :

This factor helps us to take into account the impact of material properties/strength to overall arch strength .The material factor is obtained by the formula below

$Fm = ((Fb*d) + (Ff*h))/(d+h)$

Barrel Factor (Fb) :

Barrel factor is the factor that takes into account the respective strength of the different kinds of masonry and quality of workmanship.

Fill Factor (Ff) :

Fill factor takes into account the strength of different kinds of fill.

Joint Factor (Fj) :

The strength and stability of the arch barrel depend to a large extent on the size and condition of joints. The joint factor takes into account the impact of joint condition to determine the overall strength. The joint factor is obtained from multiplying width, depth and mortar factors.

$Fj = Fw * Fd * Fmo$

Width Factor (Fw) :

Width factor is the factor that takes into account the width of joints between the voussoirs.

Depth factor (Fd) :

This factor takes into account the loss of mortar from the joints due to weathering.

Mortar Factor (Fm) :

This factor takes into account the quality of mortar to determine the arch strength.

Span/Rise Factor (Fsr) :

Flat arches are not so strong under a given loading as those of steeper profile, and the provisional assessment must therefore be adjusted. A span/rise ratio of 4 and less is assumed to give optimum strength and has a factor of 1.When the span/rise ratio is greater than 4 ,reference should be made to the graph in Fig 3/3 at BA 16/93.

Profile Factor(Fp) :

There is evidence that elliptical arches are not so strong as segmental and parabolic arches of similar span/rise ratio and barrel thickness. The ideal profile has been taken to be parabolic and for this shape the rise at the quarter points Rp=0.75 Rc ,where Rc is the rise at the crown.

The profile factor Fp for ratios of Rq/Rc less than 0.75 should be taken to be unity , and for ratios greater than 0.75 should be calculated from the following expression.

$Fp=2.3*((Rc-Rq)/Rc)^{0.6}$

Condition Factor (Fc)

- Cracks and deformations
- Defects

Provisional Assessment:

Provisional Axle Load is calculated by the formula below, if PAL is more than 70 according to the formula ,the PAL is assumed as 70.

$PAL= (740(d+h)^2)/L^{1.3}$

Application of MEXE Method:

After finding out the appropriate values for modifying factors the Modified Axle Load is calculated according to the equation below:

MAL = Fsr*Fm*Fj*Fc*PAL

The unrounded value of this modified axle load should be multiplied by the appropriate axle factors form Figure 3.5 at BA 16/93 to give allowable axle loads for single and multiple axles.

INTELLIGENT MEXE

6.1 INTRODUCTION

This chapter is the most important and vital part of this work. The previous chapters provide background information to help the reader have a better understanding about this work. The aim of this is research was finding a method to make expert systems more accessible for construction industry. The methodology used for our research is (1) creating a sample prototype expert system which can also be reached and used over the internet and then (2) finding the possibilities of applying such a system in the real world . When I started my research I have already known that is not an easy task ,even to develop a prototype expert system that is working over the internet. It took us more than 7 months (for me and Mr. Robert Falconer) just to develop something that is working. There have been lots of literature review , interviews and testing stages during this time. All these efforts ended up with first version of IMEXE which seems as a simple Visual Basic application to the end user.

I will explain IMEXE in detail in this chapter. After developing IMEXE (the working model) I also have a chance to get the user's comments about the expert system. This research, here is not just limited to a prototype expert system .The important point is to find an answer to the questions like "How can we make expert systems more accessible for the construction industry ?" , "Will internet be the appropriate way for sharing the expert knowledge ?" , "How could we use expert systems with large knowledge bases , over the internet ?" , "How could internet effect the development of the knowledge base ?" , "How can a knowledge base be updated by using the internet ?" and so on. There are also many questions in researchers' minds like the ones above , we can be able to find answers to some of them here in this work and some of them could be a start point for a further research. In the following sections we will look at what we've found out in this research. First we will talk about the knowledge based systems and internet , then we will look at IMEXE in detail(both to its knowledge base and user interface),later on we will talk about two important facts(Java vs. VBA & Shells vs. Conventional Languages) that are discussed during the development process of IMEXE, the chapter will be finalised by the user's comments about IMEXE.

6.2 KNOWLEDGE BASED SYSTEMS AND THE INTERNET

Internet has became a major tool for communication and for reaching the knowledge.

Now we can combine the terms knowledge , information and communication together by using internet perspective. As tasks on the internet become more information and knowledge-laden , the requirement for knowledge based systems and decision support systems continues apace. The Internet is growing very fast which makes , the search for, identification and retrieval of , information very difficult. We can argue that even the Internet should be managed by an intelligent system. The artificial intelligence can be found and used over the internet now ,but in the future artificial intelligence will be vital for managing all the information (including a small personal web site and a large company intranet using lots of database applications) over the internet. The use of knowledge bases(serving for AI applications) over the internet can be in two different forms. The first form will be industry-wide knowledge bases(which can also be called macro knowledge bases) and second form will be application specific knowledge bases(which can also be called micro knowledge bases).Micro knowledge bases are similar to the domain specific knowledge bases that we use in the construction industry now. They are developed to find a solution to a specific type of a problem. On the Internet the users can interact with these simple shells by Java clients(most web browsers now can act as a Java client) or ActiveX clients or even by using ordinary office packages(IMEXE is an example of systems that have a micro knowledge base) , these micro knowledge bases can be downloaded from server and can be used at the client end. These applications are small applications(regardless of the environment used to develop them) and the download time is very short. When the knowledge domain becomes bigger , the knowledge base will become larger and download time will be very long. Also the larger databases will be required to store the information in large knowledge bases, then the management of larger databases over the internet will be problematic. To find a solution to all these problems researchers and scientists started to look at how we can develop industry wide knowledge bases and how we can manage them. Industry wide knowledge bases designed to act as a single entry point to a set of distributed databases. The industry wide (or macro) knowledge bases contain multi databases ,multi media environment ,search engines and micro knowledge bases all based through hypertext and can be reached by web clients.

Blackboard systems can also be considered as macro knowledge bases . Typically each micro knowledge base will address a sub-problem , and will communicate with each other via a central blackboard. Blackboard systems allow more modular knowledge based systems (and even hierarchical organisation) , and increased flexibility. Such a scenario raises questions of coordination , at this point World Wide Web can be seen as an integrating technology , permitting access to specialised knowledge based systems across the globe. A user should be able to view and execute remote information systems ,download results onto the remote host and update working memory. This process would be re-iterated to fill-in all the required details. Unsatisfied goals , queries might be passed onto the remote sites for further refinement. Thus any one sub-system should have knowledge of the kinds of knowledge held elsewhere which might be of use to it. This could be implemented through information/knowledge classification , ontologies and general knowledge maps , detailing types , quantities and alternative sources of knowledge even mirror sites. Thus requests for knowledge which it is unable to answer may be passed onto other sites. So for instance a micro knowledge base in this system should be able to :

- Use rules to deduce new information
- Ask questions of users
- Search working memory for current conditions
- And access remote resources like other KBS ,or even a human expert.

The industry wide knowledge bases and maybe global knowledge bases will be used commonly and effectively in 10-15 years time or sooner. Now the industry wide knowledge bases approach is seen as the only right approach for developing and making use of the large knowledge bases. The research should continue to find an answer for how we can develop user interfaces and which techniques of knowledge representation will be used to represent the knowledge in industry wide knowledge base. Further research is also needed for developing knowledge acquisition and knowledge filtering mechanisms in such systems.

6.3 INTELLIGENT MEXE

Intelligent Mexe is a prototype expert system working over the internet. Mexe is a method used for Masonry Arch Bridge Assessment (which is also described in previous chapter) IMEXE(Intelligent MEXE) (1) automates the calculations done by engineers and (2) enable all the engineers to reach the expert knowledge about this specific knowledge domain. IMEXE is a multi-functional program covering analysis and design issues and supplying expert knowledge to the end user at the same time. IMEXE is a rule based expert system. Forward chaining mechanism is used for the knowledge representation. IMEXE is developed using VBA (Visual Basic for Applications) programming language which is a subset of Microsoft Visual Basic® .There are two important facts to be discussed about using VBA to develop an expert system (because even novice users can easily understand it is a different method to use a Visual Conventional Programming Language to develop an expert system.).On the next section we will look at issues about VBA in detail. IMEXE has a nice , easy to learn/ easy to use user interface and has an easy to understand knowledge base behind it. The user interface can be explained in 4 parts which is shown on the Table 6.1 below.

Parts	AI Functions
1-Getting the user information.	**Get the data needed for ES**
2-Getting the information about bridge dimensions.	**Get the data needed for ES Support the users decision**
3-Getting the information about the condition of the bridge(determining the factors).	**Get the data needed for ES Decide by using the knowledge base**
4-Displaying analysis results.	**ES functionality is not needed**

Table 6.1 Parts & AI functions of IMEXE

First part consists of only one interactive window that can be seen below.

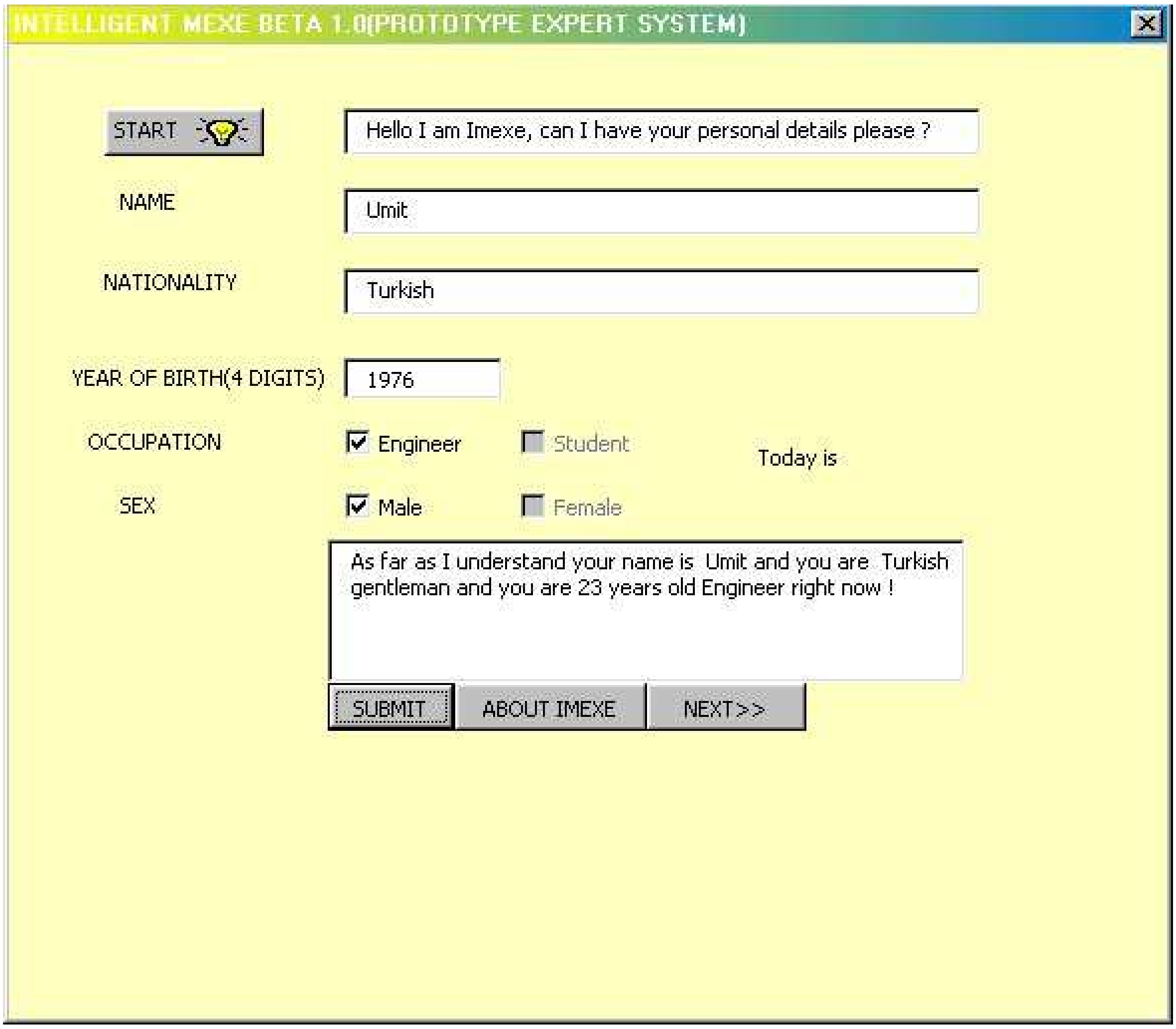

Figure 6.1 IMEXE User Info Window

Here the knowledge base gets the information about the user ,which will be used later. The expert system stores some specific values in its temporary memory ,the knowledge base here is also stores some person-specific information in its knowledge base , e.g. if you input a developer's name to the temporary memory ,IMEXE shows different kind of greeting messages. This part is a simple introduction to artificial intelligence, for the novice user. The user information stored in the temporary memory is used on all other windows e.g. the IMEXE always call you by your name. This also shows that in the future a filtering mechanism(or a security mechanism) can be implemented here to avoid unwanted users use the expert system. This idea can be seen contradicting with the aim of this research “making expert systems more accessible”, they will be more accessible by the power of internet , but also we should think that expert systems over the internet can bring commercial benefits to the organisations that develop them by selling them over the internet or rent them by pay-per-use bases. The second part of the system consists of 5 interactive windows. These 5 interactive windows are about span length , barrel thickness ,depth of fill, centre rise, rise at quarter points. The user can ask questions to the system and the system helps the user to input the appropriate value. The system here also gives the information about how we can measure that value in practice and explains the user why that certain value is important for analysis and allowable limits for design and many more issues like that. The shape and contents of these 5 windows in second part are very similar to each other so looking at one of the knowledge bases and user interfaces will be enough. Here we will look the interactive window about span length in detail.

Next pages show the algorithm of the rule base that is about span length. I want to mention here again that this code is just for one interactive window(containing 12 rules) . The actual rule base contains more than 100 rules.

Rule Base for Span Length Interactive Window:

RULE 1
Define & Write Question/Command = “What is L value ?”
Define & Write Question/Command = “Why do you want to learn L value ?”
Define & Write Question/Command = “What are the limits for L value ?”
Define & Write Question/Command = “Return”
End RULE 1

RULE 2
IF Question = “What is L value ?”
THEN GOTO RULE 3 ELSE
IF Question = “Why do you want to learn L value ?”
THEN GOTO RULE 4ELSE
IF Question = “What are the limits for L value ?”
THEN GOTO RULE 5 ELSE
IF Command = “Return”
THEN GOTO RULE *
End RULE 2

RULE 3
WRITE DECISION = “For square arch its the distance between springings , for skew arch it is horizontal perpendicular distance between springings”
Define & Write Question/Command = “What is the skew arch ?”
Define & Write Question/Command = “What is the square arch ?”
Define & Write Question/Command = “Return”
GOTO RULE 6
End RULE 3

RULE 4
WRITE DECISION= “Because the capacity of the arch inversely depends on the span”
Define & Write Question/Command = “Return”
GOTO RULE 6
End RULE 4

RULE 5
WRITE DECISION= “L value should be between 4 and 12 metres”
Define & Write Question/Command = “Why should the span be between 4 and 12 metres ?”
Define & Write Question/Command = “Return”
GOTO RULE 6
End RULE 5

RULE 6
IF Question = “What is the skew arch ?”
THEN GOTO RULE 7 ELSE
IF Question = “What is the square arch ?”
THEN GOTO RULE 8 ELSE
IF Question = “Why should the span be between 4 and 12 metres ?”
THEN GOTO RULE 9 ELSE
IF Command = “Return”
THEN GOTO RULE *
End RULE 6

RULE 7
WRITE DECISION= “The longitudinal centre line of the arch is not perpendicular to the line of the springings”
Define & Write Question/Command = “What is longitudinal centre line ?”
Define & Write Question/Command = “What is the springing ?”
Define & Write Question/Command = “Return”
GOTO RULE 10
End RULE 7

RULE 8
WRITE DECISION= “The longitudinal centre line of the arch is perpendicular to the line of the springings”
Define & Write Question/Command = “What is longitudinal centre line ?”
Define & Write Question/Command = “What is the springing ?”
Define & Write Question/Command = “Return”
GOTO RULE 10
End RULE 8

RULE 9
WRITE DECISION= “If L<4 metres the equations have not been proved , if L>12 metres the equations become conservative”
Define & Write Question/Command = “Return”
GOTO RULE 10
End RULE 9

RULE 10
If Question = “What is the longitudinal centre line ?”
OR
If Question = “What is the springing ?”
THEN GOTO RULE 11 ELSE
If Command = “Return”
THEN GOTO RULE *
End RULE 10

RULE 11
WRITE DECISION= “Refer to the drawing 1”
End Rule 11

RULE *
Define & Write Question/Command = “What is L value ?”
Define & Write Question/Command = “Why do you want to learn L value ?”
Define & Write Question/Command = “What are the limits for L value ?”
Define & Write Question/Command = “Return”
GOTO RULE 2
End RULE *

After completing the rule base the code above is re-written with Visual Basic for Applications programming language. There is also additional code in the program needed for developing the application in Visual Basic environment. A VBA code for the same interactive window (for the span length) can be seen below:

VBA Code for Span Length Interactive Window:

```
Private Sub Command1_Click()
Text1.Text = Form1.Textn + " I want you to give me information about L value"
Call level1
End Sub

Sub level1()
ComboBox1.AddItem "What is L value ?"
ComboBox1.AddItem "Why do you want to learn L value ?"
ComboBox1.AddItem "How can I measure L ?"
ComboBox1.AddItem "What are the limits for L value ?"
End Sub
```

```
Private Sub Command2_Click()
Formd.Show
Forml.Hide
End Sub

Private Sub CommandButton1_Click()
If ComboBox1.Text = "What is L value ?" Then Call level2a
If ComboBox1.Text = "Why do you want to learn L value ?" Then Call level2b
If ComboBox1.Text = "How can I measure L ?" Then Call level2c
If ComboBox1.Text = "What are the limits for L value ?" Then Call level2d
If ComboBox1.Text = "Return" Then Call retur
Rem level2 SUBS
If ComboBox1.Text = "What is the skew arch ?" Then Call level2a1
If ComboBox1.Text = "What is the square arch ?" Then Call level2a2
If ComboBox1.Text = "Why should the span be between  4 and 12 metres ?" Then Call level2d1
Rem level3 SUBS
If ComboBox1.Text = "What is longitudinal center line ?" Then Call level2a1a
If ComboBox1.Text = "What is the springing ?" Then Call level2a1a
End Sub


Private Sub CommandButton2_Click()
Call retur
End Sub

Sub level2a()
Texta.Text = "For square arch it is the distance between springings,for skew arch it is horizantal perpendicular distance between springings"
ComboBox1.Clear
ComboBox1.AddItem "What is the skew arch ?"
ComboBox1.AddItem "What is the square arch ?"
ComboBox1.AddItem "Return"
End Sub

Sub level2b()
Texta.Text = "The capacity of the arch inversely depends on the span. "
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub


Sub level2c()
Texta.Text = "With a measuring tape or a thedolite"
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub



Sub level2d()
Texta.Text = "L value should be between 4-12 metres"
ComboBox1.Clear
ComboBox1.AddItem "Why should the span be between  4 and 12 metres ?"
End Sub
```

```
Sub level2a1()
Texta.Text = "The longitudinal center line of the arch is not perpendicular  to the line of springings"
ComboBox1.Clear
ComboBox1.AddItem "What is longitudinal center line ?"
ComboBox1.AddItem "What is the springing ?"
End Sub




Sub level2a2()
Texta.Text = "The longitudinal center line of the arch is perpendicular to the line of springings"
ComboBox1.Clear
ComboBox1.AddItem "What is longitudinal center line ?"
ComboBox1.AddItem "What is the springings ?"
End Sub


Sub level2d1()
Texta.Text = "If L<4 metres the equations have not been proved, if L>12 metres equations become
conservative"
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub

Sub retur()
ComboBox1.Clear
ComboBox1.AddItem "What is L value ?"
ComboBox1.AddItem "Why do you want to learn L value ?"
ComboBox1.AddItem "How can I measure L ?"
ComboBox1.AddItem "What are the limits for L value ?"
If ComboBox1.Text = "What is L value ?" Then Call level2a
If ComboBox1.Text = "Why do you want to learn L value ?" Then Call level2b
If ComboBox1.Text = "How can I measure L ?" Then Call level2c
If ComboBox1.Text = "What are the limits for L value ?" Then Call level2d
End Sub

Sub level2a1a()
Texta.Text = "Please refer to drawing L1"
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub
```

It is not necessary to explain the VBA code here , VBA is a very similar language to the Visual Basic ,the user with a novice knowledge of Visual Basic can easily understand the code above. After the coding process the graphical appearance of the interactive window can be seen below. At first step user will start from first set of questions. Here the user can ask 4 questions to the program. These questions are the frequently asked questions about the subject. These are determined by interviews with experts and non-experts.

After the user asks the program the question the program gives the answer to user(which can be seen in Figure 6.3). At the same time a new set of further questions(about the given answer) appear in the question field (ComboBox in VB.)

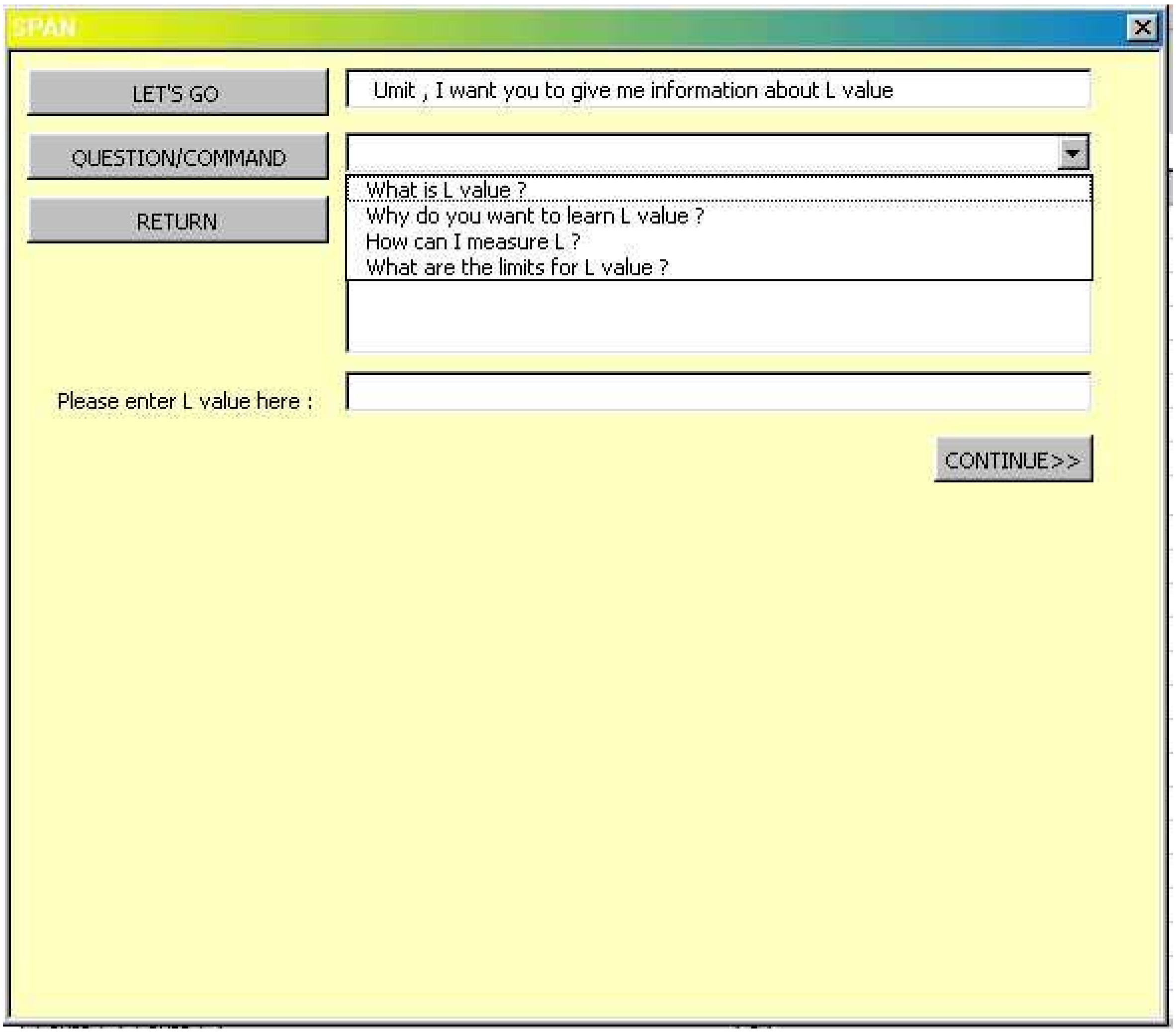

Figure 6.2 IMEXE Span Length Window(1)

This is the most important fact about the program which can be called as dynamic ComboBox property. The contents of the ComboBox(Question Box) changes dynamically according to the decision made by the expert system. This function makes IMEXE different from other conventional programs, in other words this function gives IMEXE its semi-intelligence.

Figure 6.3 shows the answer to the question : “What is L value ?” , after the appropriate answer is given by the expert system ,the contents of the ComboBox changes as seen on Figure 6.4.

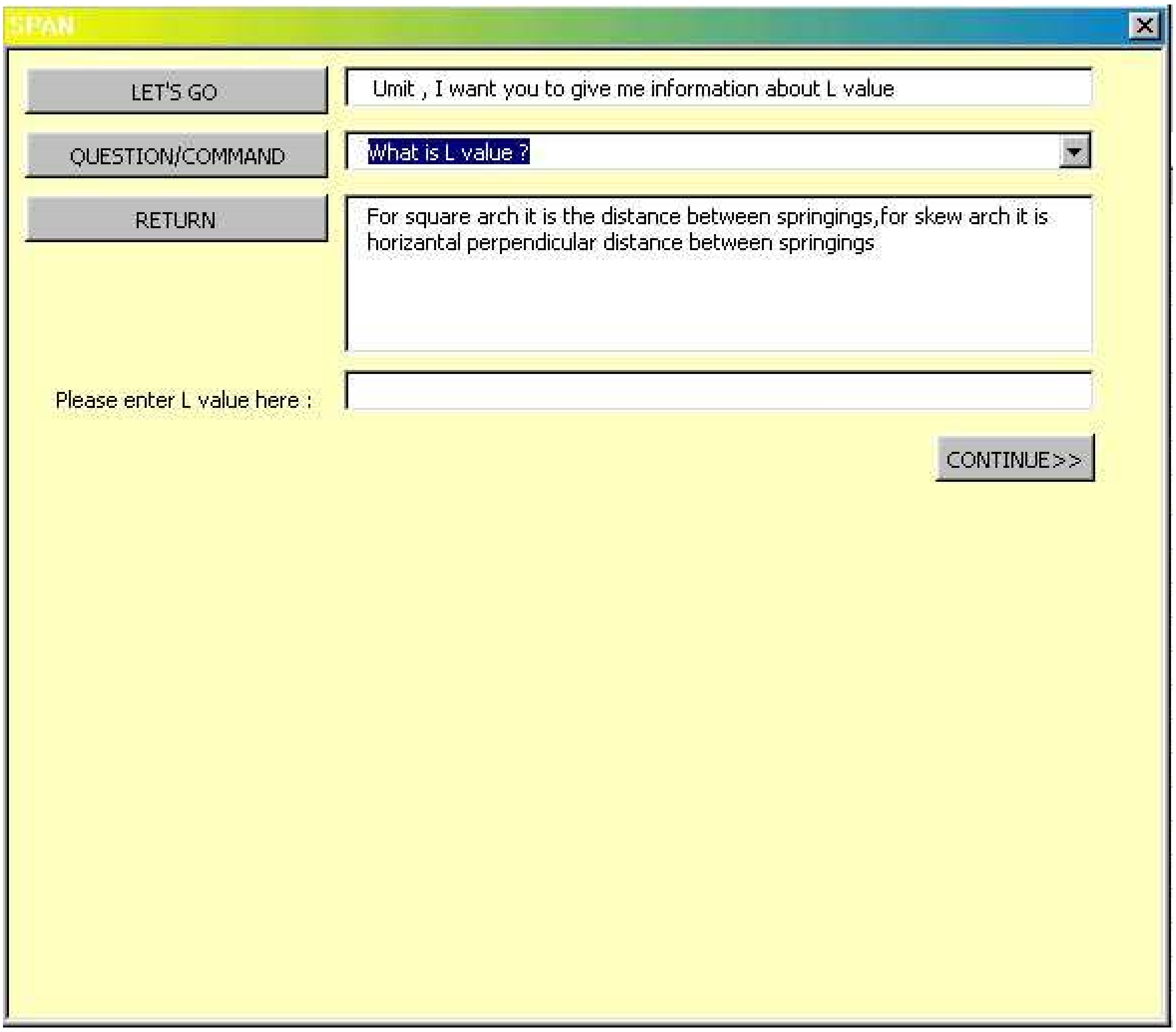

Figure 6.3 IMEXE Span Length Window(2)

The same dynamic process continues(Figure 6.5) until the user reach the end point of the rule base about that specific domain. When the user reaches the end only "Return" command can be seen in the dynamic ComboBox. At that time if user had any more questions in his/her mind he/she can return to the beginning phase , or if he/she is satisfied with the answers given by the program the user can enter the appropriate value(in this case it is L) to the input field. The values which are entered to the input field are stored in the temporary memory and used later on for analysis(as mentioned earlier IMEXE is also capable of doing mathematical operations as well as logical ones.). The other 4 interactive windows in Part 2 are similar to this one so we will now continue to explain IMEXE with Part 3.

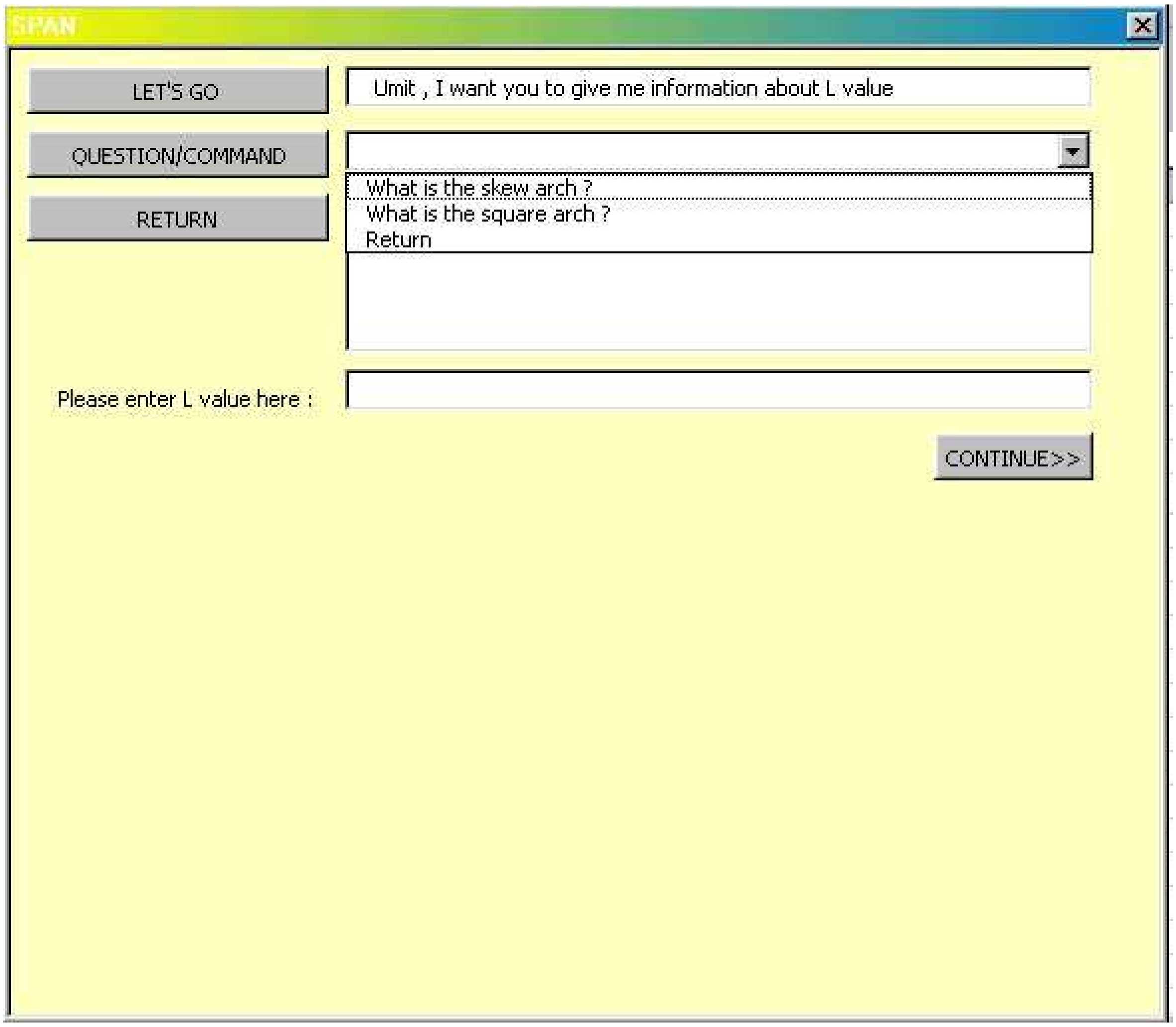

Figure 6.4 IMEXE Span Length Window(3)

There are two main differences between Part 2 and Part 3 of IMEXE. Part 3 is about the "factors" that are used in MEXE assessment. The first difference between them is in Part 2 the role of IMEXE can be seen as a decision support system , but in Part 3 IMEXE makes the decisions by itself. The second difference is about the rule base. The rule base of Part 3 is not complex as the rule base of Part 2. The IF.....THEN ,AND, OR , GOTO statements are used less in Part 3.The Figure 6-6 below shows the differences between both rule bases. The third part consists of 6 interactive windows , these all 6 windows are about factors in MEXE assessment. Now we will look at one of them , the interactive window about barrel factor, in detail.

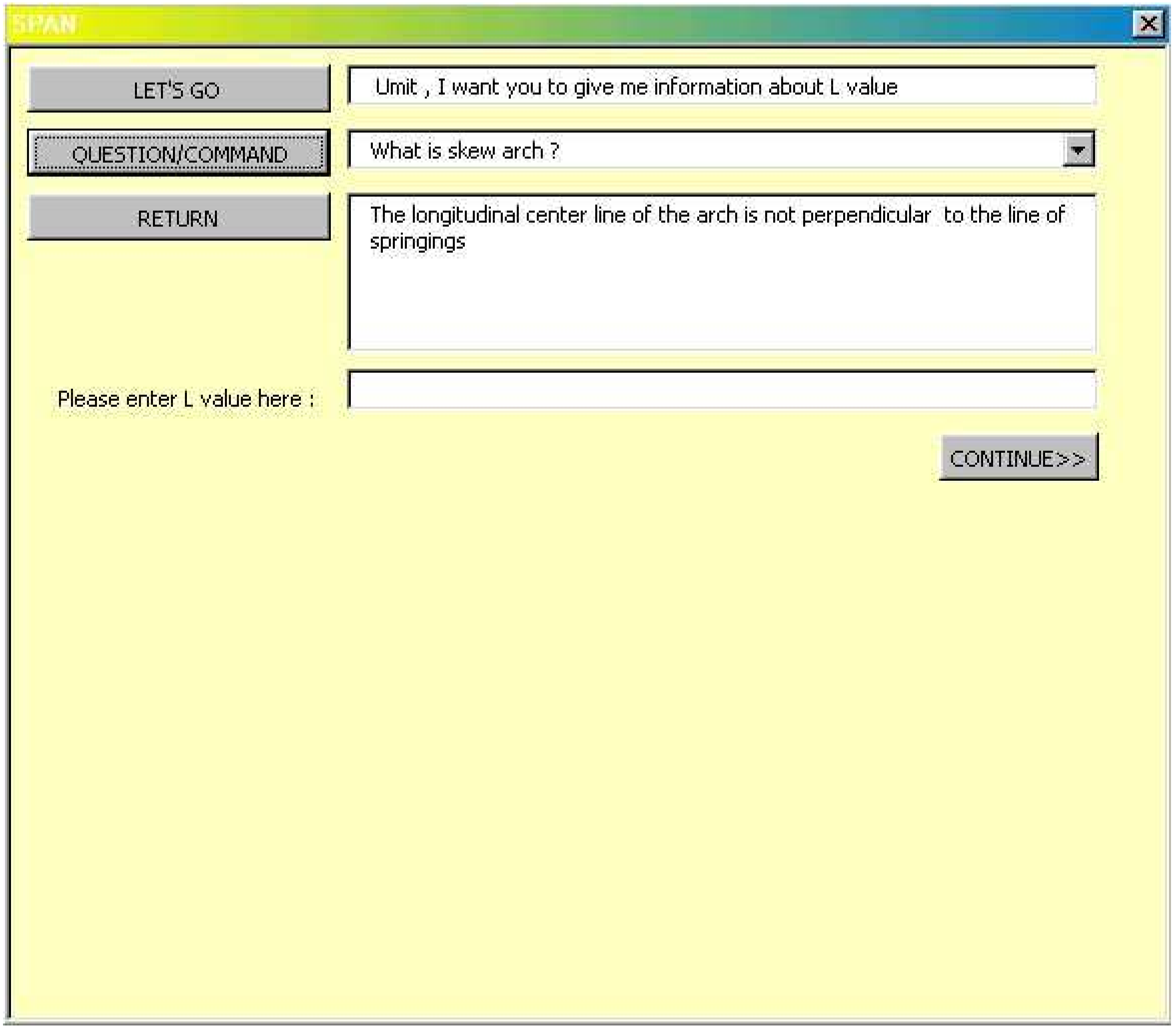

Figure 6.5 IMEXE Span Length Window(4)

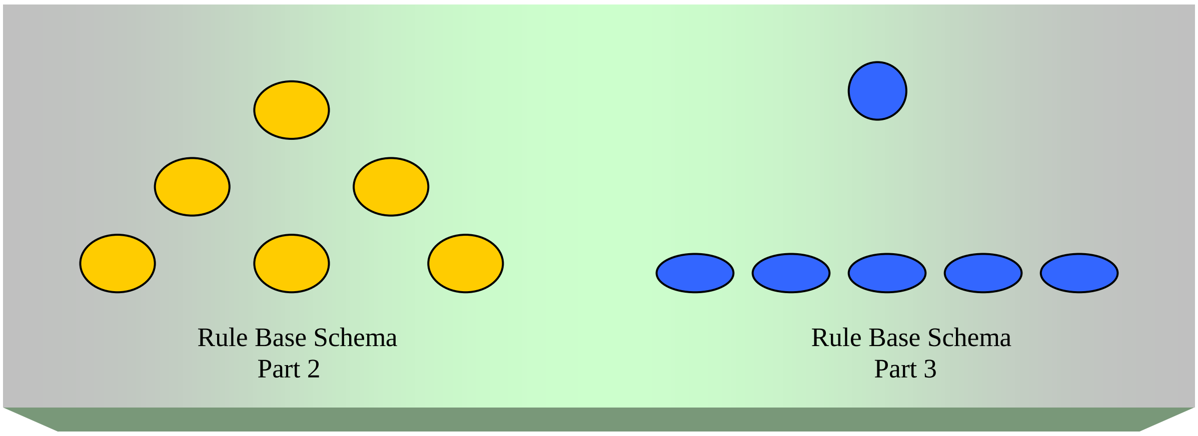

Figure 6.6 Rule Base Schema of IMEXE

The rule base about the barrel factor window is as below :

Rule Base for Barrel Factor Interactive Window:

RULE 1
Define & Write Question = "What is the barrel factor ?"
Define & Write Question = "What is the effect of the material shape to determine the barrel factor ?"
Define & Write Question = "Why do we use high material factor for arches built with Granite & Whinstone ?"
Define & Write Question = "Why do we use high material factor for the arches built with large masonry ?"
Define & Write Question = "Why do we use a lower barrel factor for arches built with a limestone ?"
Define & Write Question ="Can you describe the masonry in poor condition ?"
Define & Write Question = "What is the effect of the reactive chemicals to masonry arches ?"
GOTO RULE 2
End RULE 1

RULE 2
IF Question = "What is the barrel factor ?"
THEN
WRITE DECISION = " It is the factor that takes into account the respective strength of the different types of masonry used in barrel construction and it also takes into account the quality of workmanship."
ELSE
IF Question = "What is the effect of the material shape to determine the barrel factor ?"
THEN
WRITE DECISION = "The transfer of stress depends on the shape of the material ,and if there is a good transfer of stress between the voussoirs than the arch barrel will be stronger."
ELSE
IF Question = "Why do we use high material factor for arches built with Granite & Whinstone ?"
THEN
WRITE DECISION = "Granite and Limestone have high compressive strength, barrels built with these materials are strong barrels"
IF Question = "Why do we use high material factor for the arches built with large masonry ?"
THEN
WRITE DECISION = "Large shaped masonry has good load transfer properties and as I said in question 2 and if there is a good transfer of stress between the voussoirs then the arch barrel will be stronger."
ELSE
IF Question = "Why do we use a lower barrel factor for arches built with a limestone ?"
THEN
WRITE DECISION = "Limestone is a weaker material then Granite and Whinstone."
ELSE
IF Question ="Can you describe the masonry in poor condition ?"
THEN
WRITE DECISION = "We can describe the masonry in poor condition as masonry that has suffered from frost failure or masonry that has softened due to water absorption."
ELSE
IF Question = "What is the effect of the reactive chemicals to masonry arches ?"
THEN
WRITE DECISION = "Arches are generally very tolerant of leaching chemicals. Problems may arise with limestone barrels if the leaching water is acidic."
End RULE 2

RULE 3
DIMENSION BARREL FACTOR
Define OPTIONS FOR BARREL FACTOR
Define Question = “What is the barrel material ?”
Define OPTION 1 = “Granite and Whinstone whether random or coursed and all built-in-course masonry except limestone, all large shaped voussoirs.”
Define OPTION 2 = “Concrete or engineering bricks and similar sized masonry (not limestone!!!)”
Define OPTION 3 = “Limestone, whether random or coursed ,good random masonry and building bricks, all in good condition”
Define OPTION 4 = “Masonry of any kind in poor condition (many voussoirs flaking or badly spalling, shearing etc.)”
GOTO RULE 4
End RULE 3

RULE 4
IF OPTION 1=TRUE THEN BARREL FACTOR = 1.5
IF OPTION 2=TRUE THEN BARREL FACTOR = 1.2
IF OPTION 3=TRUE THEN BARREL FACTOR = 1.0
IF OPTION 4=TRUE THEN BARREL FACTOR = 0.7
End RULE 4

Now let’s look at the VBA code for this interactive window.

VBA Code for Barrel Factor Interactive Window:

```
Private Sub Command1_Click()
Text1 = Form1.Textn + " I want to learn the barrel factor from you..."
Call level1
End Sub

Private Sub Command2_Click()
Formff.Show
Formfb.Hide
End Sub

Private Sub CommandButton1_Click()
Call level2
End Sub

Private Sub CommandButton2_Click()
If opt15 = True Then Textfb = 1.5
If opt12 = True Then Textfb = 1.2
If opt10 = True Then Textfb = 1
If opt07 = True Then Textfb = 0.7
End Sub


Sub level1()
ComboBox1.AddItem "What is the barrel factor ?"
ComboBox1.AddItem "What is the effect of the material shape to determine the barrel factor ?"
ComboBox1.AddItem "Why do we use high material factor for arches built with Granite&Whinstone"
ComboBox1.AddItem "Why do we use high material factor for the arches built with large masonry"
```

```
ComboBox1.AddItem "Why do we use a lower barrel factor for arches built with a limestone ?"
ComboBox1.AddItem "Can you describe the masonry in poor condition ?"
ComboBox1.AddItem "What is the effect of the reactive chemicals to masonry arches ?"
End Sub


Sub level2()
If ComboBox1 = "What is the barrel factor ?" Then Texta = "It is the factor that takes into account the respective strength of the different types of masonary used in barrel construction and it also takes into account the quality of workmanship."

 If ComboBox1 = "What is the effect of the material shape to determine the barrel factor ?" Then Texta = "The transfer of stress depends on the shape of the material ,and if there is a good transfer of stress between the voussoirs than the arch barrel will be stronger."

If ComboBox1 = "Why do we use high material factor for arches built with Granite&Whinstone" Then Texta = "Granite and Limestone have high compressive strength, barrels built with these materials are strong barrels"

If ComboBox1 = "Why do we use high material factor for the arches built with large masonry" Then Texta = "Large shaped masonry has good load transfer properties and as I said in question 2 and if there is a good transfer of stress between the voussoirs then the arch barrel will be stronger."

If ComboBox1 = "Why do we use a lower barrel factor for arches built with a limestone ?" Then Texta = "Limestone is a weaker material then Granite and Whinstone."

If ComboBox1 = "Can you describe the masonry in poor condition ?" Then Texta = "We can desribe the masonry in poor condition as masonry that has suffered from frost failure or masonry that has softened due to water absorbtion."

If ComboBox1 = "What is the effect of the reactive chemicals to masonry arches ?" Then Texta = "Arches are genarally very tolerant of leaching chemicals. Problems may arise with limestone barrels if the leaching water is acidic."

End Sub
```

The graphical form of the window can be seen at Figure 6-7 .It can be easily noticed that the number questions are more at first step of Part 3 than the first step of Part 2 .The reason for that is the Part 3 interactive windows consist of only one step. Because the important aspect of the Part 3 is to show how decision is made by the expert system , so complex knowledge representation is not necessary at this part. In contrast ,the second part is developed to show how complex reasoning can be represented in expert systems. The interactive windows in Part 3 also contain Option Boxes. These Option Boxes are used to get user input about the specific properties of the bridge. These properties are used by the expert system as parameters that effect the decision.

After getting all the information from the user IMEXE makes its decision and outputs the value for that specific factor, this output(& all outputs like this one)

is than considered as an input for analysis.

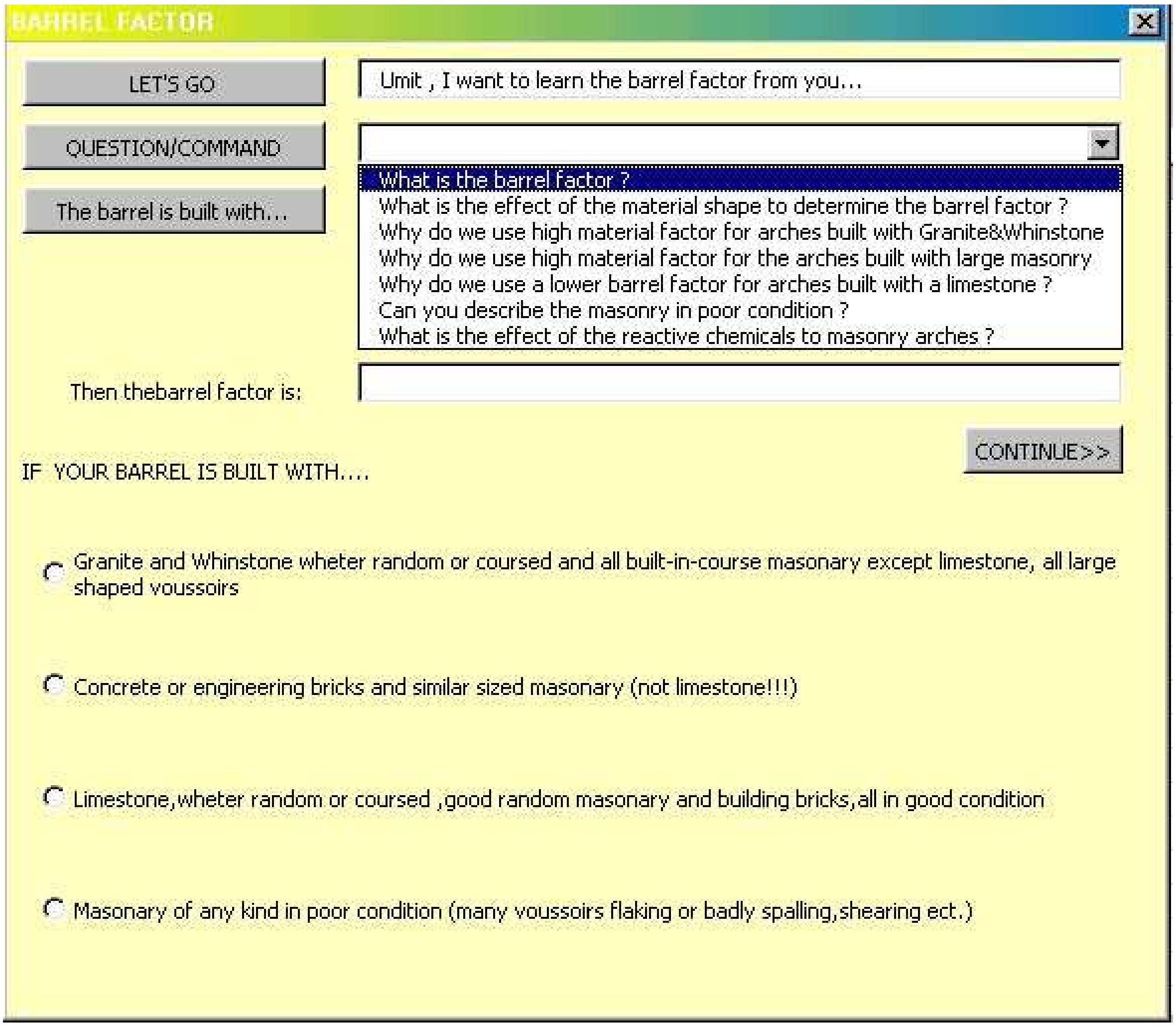

Figure 6.7 IMEXE Barrel Factor Window(1)

If we look at Figure 6.8 we can see here that first option(Granite & Whinstone) is chosen as a barrel material and the knowledge base decides the Material Factor as 1.5 .At the same time the expert system gives the information to the use about the specified domain. As mentioned earlier in this chapter there are 6 windows that is very similar to this one , and their functionality are very similar to this one as well. Now it is better to continue with last

part of IMEXE which is about the analysis.

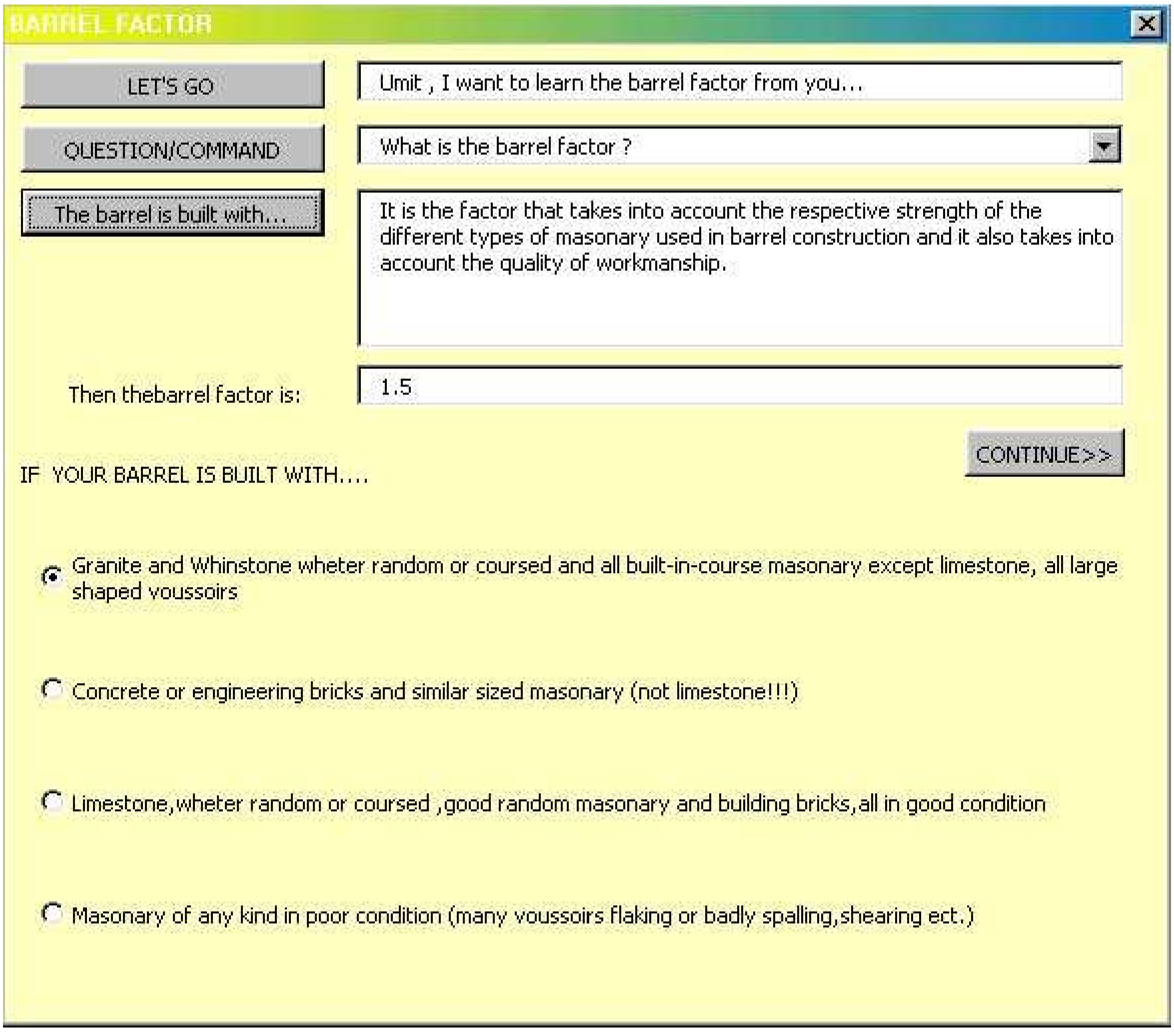

Figure 6.8 IMEXE Barrel Factor Window(2)

The Part 4 of IMEXE is about making the structural analysis of the masonry arch bridge.

The formulas for structural analysis are obtained from British Standards about Assessment of Masonry Arch Bridge.[40] IMEXE here makes these calculations using the same algorithms as conventional programs. In other words there is no expert system function at Part 4. After structural analysis IMEXE displays the results in two windows. One of them can be seen below. It is not possible to explain everything about IMEXE here in this chapter.

The information above is to enlighten some dark sides of IMEXE , as all programmer say the best way to learn about a program is to use it. Also you can get more information about IMEXE from IMEXE web site at http://come.to/mexe.

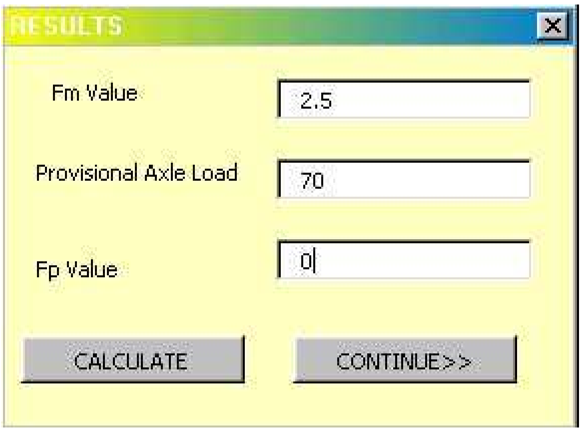

Figure 6.9 IMEXE Results Window

6.4 DISCUSSION VB/VBA/ACTIVEX vs. JAVA

One of the main issues to be enlightened about IMEXE is ,why we used Visual Basic instead of Java. Most of the developers like and use Java technology in their applications on the Web As mentioned earlier in Chapter 4 , there are many ways to add a program to a web page the most popular methods are (1)using a scripting language(Jscript, VBScript, Perl, ASP) or (2) using Java Language & developing a Java Applet or (3) using Macromedia applications(Authorware, Flash, Shockwave) or (4) using ActiveX technology and (5)using Microsoft Office applications with VBA. All these 5 methods(even Macromedia Authorware) can be used to develop a prototype expert system(like IMEXE).We do not need to mention here again the advantages of Java , everybody knows that Java is the most powerful and common used development method. In United States a group o researchers have developed a Java Based Expert System Shell (JESS) working directly over the internet. JESS uses a special algorithm called Rete to match the rules to the facts. Rete makes JESS much faster than a simple set of cascading if.....then statements in a loop. JESS was originally conceived as a clone of CLIPS , but nowadays has many features that differentiate it from its parent.[41]

The research about developing expert systems in Java is continuing very rapidly and I also agree that Java will never lose its importance as tool to develop expert systems on the Web

So what is the problem about Java?. The problem is not very difficult to imagine. Java is a C like language and very easy to learn for computer experts. But on the other hand it is very difficult to learn Java for novice users(e.g. Engineers with a general knowledge of computing.) let's consider somebody who knows Java it will take him/her more than a year to develop an expert system like IMEXE. So a civil engineer with a knowledge of computing should spend 2/3 years to develop an expert system with Java. Even if he/she learns how to use JESS(or a shell like that one) , it will be very time consuming to develop such an application. In other words in context of my research it seem as very impractical way to develop a system in Java. Our aim was also to show alternative easy methods for internet programming. At that point we had two choices to go for : (1) VBA and (2) ActiveX .If we had chosen ActiveX the user should download the appropriate ActiveX control and should make the registry settings for the ActiveX control by himself or by a helper application like ActiveX Manager. It is important to know that even you have the ActiveX control on your machine , if you can not make the appropriate registry settings you will see a blank web page instead of the expert system. VBA is a very easy and commonly used tool. If the user has Microsoft Office package the VBA shell comes inside the Microsoft Office package. Microsoft Office is a commonly used application so the programs developed by VBA can reach lots of users world-wide. VBA is an easy to use and flexible programming tool that suits the user needs. The developers don't have to spend much time even to develop complex applications and all the VBA applications can be viewed with a simple web client. The factors above explain main points about our choice of VBA. In the future researchers can use other methods for developing applications like IMEXE. My personal view is that developers should work on Macromedia Software and future research should be about developing Multimedia Expert Systems.

6.5 DISCUSSION SHELLS vs. CONVENTIONAL LANGUAGES

In Expert Systems knowledge is usually represented by rules , logic, semantic nets ,frames or neural nets. When knowledge domain becomes bigger , the number of rules(or frames ,or logic propositions) increase. Coding a rule base with lots of rules causes problems for conventional programs. Conventional programming languages are designed for programming conventional algorithms. When the number of logical statements is too much , conventional programming languages interpret/compile the program in a very long time , and also give lots of error messages. The Expert System Shells are developed to find a solution to this problem.

Visual PROLOG is the most effective way to develop AI applications. Also CLIPS is a well known expert system shell. Three types of programming paradigms are supported by CLIPS:

rule-based, object-oriented and procedural. CLIPS supports only forward chaining rules. CLIPS , an acronym for C Language Integrated Production System , was designed using the C programming language at NASA/Johnson Space Centre with the specific purpose of providing high portability , low cost and easy integration with external systems. Shells(CLIPS & many more) are effectively used at developing expert systems with large knowledge domains and with large rule bases. The appropriate method for developing an expert system is to develop it with a shell program(ES programming language).In our research IMEXE is not developed with a shell , because (1) only shell we came across(that is working on the internet) was JESS and as mentioned earlier it is not practical to develop it with a Java based program and (2) as you know IMEXE consists of just more than 100 rules and every conventional program on the market is capable of interpreting/compiling such a program. The future research can be about developing more easy-to-use and user friendly expert system shells which can work over the internet.

6.6 USER COMMENTS ABOUT ES ON THE INTERNET & IMEXE

Here in this section we will summarise the user comments about the use of expert systems on the internet and Imexe as a practical example. These comments are results of interviews with academic staff ,experts, non-experts and students in University of Greenwich (UK) , University of Salford (UK) , Istanbul Technical University (TR) and Gazi University(TR) and Ege University (TR) . The user comments are can be found below:

Q: Which profession in construction industry use expert systems more efficiently ?

- Engineers generally use analysis packages and specific software ,ES applications are sometimes used with analysis packages but it is not very common in practice.
- Architects rarely use intelligent systems with CAD applications(e.g. ICAD) , but as architects want to use their own ideas and concepts in design they do not like to use intelligent applications.
- Decision support systems are also used in construction management. The use of AI in construction management is at the same level as the use of AI in engineering applications.

Q: What is the importance of expert system shells in developing expert systems ?

- If we have a knowledge base with more than 1000 rules in it ,the system should be developed by using a shell to optimise the system performance.
- Large scale expert systems are developed using expert system shells. The main point is to consider the scale of the system and choose a tool(a conventional program or a shell) to develop the expert system. This action will optimise the system performance.

Q: Until today most of the expert systems developed could not be used in practice, why?

- Construction industry does not like to spend money on artificial intelligence ,and does not have any effort to put the theory in practice.
- Researchers don't apply pressure to the industry , they end their research after they get the results.

- Expert systems developed until now are for a single specific knowledge domain , multi purpose expert systems should be developed for practical applications.

Q: Is it necessary to use visual programming tools to develop an expert system ?

- Absolutely it is. IMEXE is a very good example to explain this to the construction industry. Most users are tired of old graphical user interfaces and that effect the popularity of expert systems.
- We also need powerful PCs to use applications that are developed by visual programming tools(like IMEXE.)

Q: How can we use internet for knowledge acquisition ?

- Internet can be used very effectively for getting the expert knowledge. The expert knowledge can be stored on web databases.
- But it is not possible to automate the process of building a knowledge base after getting the expert knowledge from the web.
- A filtering mechanism should be developed to eliminate the unnecessary knowledge
- And knowledge base should be developed manually.

Q: What kind of filtering mechanism should be applied ?

- Filtering can be done by a specific conventional program.
- It can also be done by using Neural Networks.

Q: What other areas of AI can benefit from internet ?

- Neural Network can be trained using internet.
- Internet can help to gather the expert knowledge
- Internet enables us to build large industry wide knowledge bases.

Q: What are the future web technologies that will make knowledge representation easier ?

- XML can be seen as the biggest challenge.
- Developments in Java will provide a simpler knowledge representation.

Q: VBA is used to develop IMEXE, in other words IMEXE is an application that is hidden in a Microsoft Office Spreadsheet , what do you think about this approach ?

- The approach is very new and very sensible.
- As an example in finance world all experts agree to use hidden AI applications.
- People do not like to use classical AI applications because classical AI applications make them think they are losing the control over the work.
- Hidden AI approach is also accepted and used by Microsoft , Word Assistant is a very good example of using hidden AI in Office applications.
- VBA is a new technology and the industry is optimistic about VBA.

Q: What are the weaknesses of IMEXE ?

- IMEXE does not have a good user documentation
- IMEXE has still got bugs in Beta version.

Q: How can multi-media technology be used together with expert systems on the web?

- In the future Virtual Reality applications will require some kind of intelligence ,so VR can be a good start point for binding those two together in one application.

Before finalising this chapter about IMEXE I want to thank everybody who support me and share their opinions about my research including Dr. Keith Jones, Mr. Robert Falconer, Dr. Ian Watson, Prof. .Ziga Turk ,all my colleagues in The University of Greenwich and all my colleagues in Turkey .

CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

Expert systems are not commonly used in practice in construction industry. This research is aimed at finding a way to make expert systems more accessible for construction industry. After the research we can conclude that internet can be the appropriate gateway for industry to reach expert knowledge. The previous sentence was a very brief conclusion , it is true, in fact we should look at the factors behind this conclusion in more detail.

First let's start with IMEXE .IMEXE is programmed in Visual Basic for Applications Language. IMEXE's graphical user interface was found good by most of the users. As everybody supports visual programming approach now and they agree that IMEXE will be a good example that will motivate those who wants to develop expert systems using visual programming languages.

During the development process of IMEXE the researcher also developed a World Wide Web site (http://www.angelfire.com/ut/mexe) which provides a background knowledge to the user about masonry arch bridge design. The web site is found useful by the users and has more than 50 hits until now. Also the web site is also important for good presentation of research We can conclude that, a WWW site about the research will have a great supportive when the research is internet related.

Another issue to be mentioned here is , IMEXE is developed by using a conventional programming language, in fact as a result of the research the we can conclude that it is better to develop the expert system with an expert system shell. In 1999 it is very difficult to develop a network expert system by using shells because the shells seem not user friendly. In the future the developments in Visual C and Visual Java and Visual Prolog will enable developers to create network expert systems easily .

The last point about IMEXE is that, everybody should consider IMEXE as an application developed for a Construction I.T research project. When we are developing IMEXE , the experts were civil engineers , the supervisors were civil engineers, knowledge engineer & the developer was a civil engineer. The researcher knows that IMEXE is not a perfect application and there can still be a lot of add on’s to it. In the future IMEXE will have the capability to interact with its web site and users will be able to see the results in HTML format. During the research the most important discussion was about whether IMEXE could learn from other experts and modify its knowledge base. The researcher worked a lot to find a method to make it possible for IMEXE to have this functionality. The researcher developed a learning shell for IMEXE(which can be found at IMEXE web site.) and showed how this could be possible. Even if it has bugs in it , IMEXE is the first expert system in the world construction industry that can be used directly from internet. I think the statement above would clearly explain the importance of IMEXE .

If we look at other findings of this research , it is better to start with network expert systems. The idea of industry wide knowledge bases was first mentioned in the paper by Dutton, Amor , Bloomfield [42].The industry wide knowledge bases can be foundation for industry wide expert systems. The industry wide expert systems will use internet infrastructure to get and share and update knowledge. For that reason we can call them network expert systems. Network expert systems will have their knowledge base spread in various sites(on various web databases) , and a central knowledge manager will control the flow of knowledge. There should be powerful DBMSs to control the flow of data and information. Neural networks can also be used for filtering unwanted information in network expert systems.

When we look at the research from AI perspective, AI applications should be developed also as web applications . It will help AI to gain its popularity again. Other important point about AI applications is they should be developed as hidden AI applications. The user should notice AI activity as less as possible.

XML will be very popular in the near future. XML will create big changes on the web. It may change all our methods of knowledge representation(on the web) that we use now. In other words internet will become sensitive to knowledge. Representation and retrieval of knowledge will be easier. Today as the web is not knowledge oriented(it is text oriented), the expert systems of today could not interact with the information on web pages. Future intelligent systems on the internet or network expert systems should make use of XML and should interact with knowledge oriented web pages.

To summarise all , we can conclude that construction industry is still lagging behind the I.T era , it has still difficulties in communication and sharing the expert knowledge. Internet could be a solution to communication problems . AI together with the internet will help engineers to solve their analysis , design and management problems.

7.2 RECOMMENDATIONS FOR FUTURE RESEARCH

As mentioned in the previous section , industry wide knowledge bases and network expert systems can be a subject for future research. The issues like learning paradigms of network expert systems , problems of knowledge management in network expert systems are worth to investigate.

Java based expert systems will also be a good area for research. Because expert systems can benefit from Java technology , and also the developments in Java technology can make it vital for network expert systems.

Another research area can be management of expert systems on the web. When the expert systems become commonly used on the internet , there will be problems about management.

Management of network expert systems is more important and more difficult than developing them .

Also ,the effect of internet infra-structure and structure to represent and share knowledge can be an interesting area of research for all disciplines of construction industry.

So that’s all.....I want to thank here again to Mr. Robert Falconer for all the hours he spent with me in the meeting room in front of the blackboard , and in the computer lab, if IMEXE is a success it is not only my success it is his success as well . I also want to thank Dr. Keith Jones , he was one of the best lecturers I have ever known, one day I hope I can speak in the lectures as fast as him , I want to thank him for all his lectures about Construction I.T and for all his efforts in the IMEXE project.

BIBLIOGRAPHY

1. Blaxter,L. Huges,C. Tight,M.
   ‘How to research’,
   Buckingham,Philadelphia, Open University Press,1996

2. Elliot,J
   ‘Action Research for Educational Change’ ,
   Buckingham,Philadelphia, Open University Press, 1991

3. Kemmis ,S. Mc.Taggart, R
   ‘The action research planner’,
   Victoria, Deakin University ,1988

4. Brebbia,C. & Ferrante,A.
   ‘Computational methods for the solution of Engineering Problems’
   Pentech Press,London,1986

5. World Wide Web Site
   http://www.qbasic.com

6. World Wide Web Site
   http://www.strath.ac.uk/CC/Courses/Fortran.html

7. Harrison,H,B.
   ‘Structural Analysis and Design, some microcomputer applications.’
   Pergamon Press , 1980

8. Rockey,K.C. Evans,H.R.
   ‘The finite element method, a basic introduction for engineers’
   Collins Technical Books ,1985.

9. World Wide Web Site
   www.csiberkeley.com

10. Winston, P.H.
    ‘Artificial Intelligence’
    Addison-Wesley ,1981

11. Stefik,M.J.
    ’The Organisation of Expert Systems’
    A Tutorial ,1982

12. Wager,D.M.
‘Expert Systems and the Construction Industry’
CICA Press ,October 1984

13. Allwood,R.J.
‘Techniques and Applications of Expert Systems in Construction Industry’
Ellis Horwood Ltd.

14. Waterman,D.A Hayes-Roth,F.
‘Pattern-Directed Inference Systems’
Acedemic Press ,1978

15. Maher,M.L. ,Allen,R.H.,
‘Expert Systems in Civil Engineering :Technology & Application
ASCE Press, 1987

16. Brachman,R.J.
‘Readings in Knowledge Representation’
Morgan-Kaufman,CA,1985

17. Simon,H.A. , Newell,A.
‘Computer Augmentation of Human Reasoning’
Spartan Books, Washington 1965

18. Maher ,M.L. , Vora,P.
‘Expert Systems in Civil Engineering :Technology & Application’
ASCE Press, 1987

19. Carbonel J.G and Joseph R
‘FREMEKIT+: A knowledge Representation System’
Technical Report, Carnegie Melon University ,1985.

20. Acolade,A.B
‘A Hybrid Knowledge-Base System for Composite Laminate Design’
University of Houston.

21. Fenves,S.J. , Flemming ,U.
‘An integrated Software Environment for Building Design and Construction’
Proceedings of the Fifth Conference for Building Design and Construction , ASCE Press

22. Turk.,Z.
‘Publishing Construction Information on the Web’
Structural Engineering International ,Autumn 1997

23. Laudon,K.C. , Laudon,J.P.
‘Management Information Systems’
Prentice Hall,1998

24. World Wide Web Site
http://itc.fgg.uni-lj.si/woda

25. World Wide Web Site
http://www.cgiforme.com

26. World Wide Web Site
http://www.whatis.com/asp.htm

27. World Wide Web Site
http://www.activeserverpages.com/learn/res.asp

28. Naik,D.
‘Internet Standards and Protocols’
Microsoft Press,1999

29. World Wide Web Site
http://www.xml.com/pub/98/10/guide1.html

30. Bosak,J. ,Bray,T.
‘Extensible Markup Language’
Scientific American, May 1999

31. World Wide Web Site
http://home.netscape.com/assist/net_sites/pushpull.html

32. World Wide Web Site
http://msdn.microsoft.com/library/teachart/msdn_viscript.htm

33. World Wide Web Site
http://msdn.microsoft.com/scripting/VBScript

34. World Wide Web Site
http://msdn.microsoft.com/library/backgrnd/html/msdn_awhatis.htm

35. World Wide Web Site
http://www.mirrorscape.com/what_is_java.html

36. World Wide Web Site
http://java.sun.com/docs/overwievs/java/java-overwiev-1.html

37. World Wide Web Site
http://www.sun.com/java/platform.jhtml

38. Leonhardt, F.
'Bridges'
The Architectural Press , 1982

39. Falconer,R.
Assessment of Masonry Arch Bridges
University of Greenwich,1998

40. BA 16/93
The Assessment of Highway Bridges & Structures.
The Department of Transport ,UK.,1993

41. World Wide Web Site
http://herzberg.ca.sandia.gov/jess

42. Dutton,D.M. ,Amor,R. ,Bloomfield,D.P.
Knowledge-based Systems and the Internet :A Future Perspective
1996

-PROGRAM CODE-

FORM 1

```
Dim varage As String
Dim varocc As String
Dim varsex As String
Dim vartextn As String

Private Sub Commandabt_Click()
Formabt.Show
End Sub

Private Sub Commandh_Click()
Labelh.Visible = True
End Sub

Private Sub CommandButton1_Click()
If opteng = True Then
varocc = "Engineer"
Else
varocc = "student"
End If
If optmale = True Then
varsex = " gentleman"
Else
varsex = " lady"
End If
If Val(Formabt.textyear) > 1999 Then
If Textage < 1930 Then Texte = "Don't try to cheat me you can't be so old" Else
If Val(Textage) > 1990 Then Texte = "Don't try to cheat me you can't be so young" Else
varage = Val(Formabt.textyear) - Val(Textage)
Else
varage = 1999 - Val(Textage)
End If
If Textn = "Keith G. Jones" Then
vartextn = "Keith G. Jones and Umit Isikdag specially wants to thank you for your help "
Else
If Textn = "Robert E. Falconer" Then
vartextn = " Robert E. Falconer and Umit Isikdag specially wants to thank you for your help "
Else
vartextn = Textn
End If
Texte = "As far as I understand your name is  " + vartextn + " and you are  " + Textnat + varsex + " and
you are " + varage + " years old " + varocc + " right now !"
textyasgizli = varage
End Sub

Private Sub opteng_Click()
optStu.Enabled = False
End Sub

Private Sub optFemale_Click()
optmale.Enabled = False
End Sub
```

```
Private Sub optmale_Click()
optFemale.Enabled = False
End Sub

Private Sub optStu_Click()
opteng.Enabled = False
End Sub

Private Sub Command1_Click()
Text1 = "Hello I am Imexe, can I have your personal details please ?"
End Sub

Private Sub Command2_Click()
Forml.Show
Form1.Hide
End Sub

Private Sub Command3_Click()
Textea1 = "hello   " + Textn + "   welcome to the imexe"
End Sub

Function umit()
Textea1.Text = "i like you very much"
End Function
```

FORM d

```
Private Sub Command1_Click()
Text1 = Form1.Textn + " now I want to ask you  about the barrel thickness ?"
Call level1
End Sub

Private Sub Command2_Click()
Formh.Show
Formd.Hide
End Sub

Sub level1()
ComboBox1.AddItem "What is  the thickness of the barrel ?"
ComboBox1.AddItem "Why do you want to learn about the barrel thickness ?"
ComboBox1.AddItem "How can we measure the barrel thickness ?"
End Sub

Private Sub CommandButton1_Click()
'level2 sub
If ComboBox1.Text = "What is  the thickness of the barrel ?" Then Call level2a
If ComboBox1.Text = "Why do you want to learn about the barrel thickness ?" Then Call level2b
If ComboBox1.Text = "How can we measure the barrel thickness ?" Then Call level2c
If ComboBox1.Text = "Return" Then Call retur
'level3 sub
If ComboBox1.Text = "Do you have any warning ?" Then Call level3c
If ComboBox1.Text = "Return" Then Call retur
End Sub


Private Sub CommandButton2_Click()
Call retur
End Sub
```

```
Sub level2a()
Texta.Text = "It is the distance between extrados and intrados which is measured radially under the carriageway"
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub

Sub level2b()
Texta.Text = "The capacity of the arch directly depends on the barrel thickness"
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub

Sub level2c()
Texta.Text = "We excavate through the carriageway to the extrados preferably at the crown,or we core through the barrel in a radial direction and measure the thickness directly or we can use the ultrasound technique."
ComboBox1.Clear
ComboBox1.AddItem "Do you have any warning ?"
ComboBox1.AddItem "Return"
End Sub

Sub retur()
ComboBox1.Clear
Call level1
If ComboBox1.Text = "What is thickness of the barrel ?" Then Call level2a
If ComboBox1.Text = "Why do you want to learn barrel thickness ?" Then Call level2b
If ComboBox1.Text = "How can we measure barrel thickness ?" Then Call level2c
If ComboBox1.Text = "Return" Then Call retur
End Sub


Sub level3c()
Texta.Text = "Do not measure the thickness of the barrel at the elevation as this is often very different to the actual barrel thickness ,and barrels can have  internal spandrel  walls which can increase the effective barrel thickness."
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub
```

FORM Fb

```
Private Sub Command1_Click()
Text1 = Form1.Textn + " I want to learn the barrel factor from you..."
Call level1
End Sub

Private Sub Command2_Click()
Formff.Show
Formfb.Hide
End Sub

Private Sub CommandButton1_Click()
Call level2
End Sub
```

```
Private Sub CommandButton2_Click()
If opt15 = True Then Textfb = 1.5
If opt12 = True Then Textfb = 1.2
If opt10 = True Then Textfb = 1
If opt07 = True Then Textfb = 0.7
End Sub


Sub level1()
ComboBox1.AddItem "What is the barrel factor ?"
ComboBox1.AddItem "What is the effect of the material shape to determine the barrel factor ?"
ComboBox1.AddItem "Why do we use high material factor for arches built with Granite&Whinstone"
ComboBox1.AddItem "Why do we use high material factor for the arches built with large masonry"
ComboBox1.AddItem "Why do we use a lower barrel factor for arches built with a limestone ?"
ComboBox1.AddItem "Can you describe the masonry in poor condition ?"
ComboBox1.AddItem "What is the effect of the reactive chemicals to masonry arches ?"
End Sub

Sub level2()
If ComboBox1 = "What is the barrel factor ?" Then Texta = "It is the factor that takes into account the respective strength of the different types of masonary used in barrel construction and it also takes into account the quality of workmanship."
 If ComboBox1 = "What is the effect of the material shape to determine the barrel factor ?" Then Texta = "The transfer of stress depends on the shape of the material ,and if there is a good transfer of stress between the voussoirs than the arch barrel will be stronger."
If ComboBox1 = "Why do we use high material factor for arches built with Granite&Whinstone" Then Texta = "Granite and Limestone have high compressive strength, barrels built with these materials are strong barrels"
If ComboBox1 = "Why do we use high material factor for the arches built with large masonry" Then Texta = "Large shaped masonry has good load transfer properties and as I said in question 2 and if there is a good transfer of stress between the voussoirs then the arch barrel will be stronger."
If ComboBox1 = "Why do we use a lower barrel factor for arches built with a limestone ?" Then Texta = "Limestone is a weaker material then Granite and Whinstone."
If ComboBox1 = "Can you describe the masonry in poor condition ?" Then Texta = "We can desribe the masonry in poor condition as masonry that has suffered from frost failure or masonry that has softened due to water absorbtion."
If ComboBox1 = "What is the effect of the reactive chemicals to masonry arches ?" Then Texta = "Arches are genarally very tolerant of leaching chemicals. Problems may arise with limestone barrels if the leaching water is acidic."
End Sub
```

FORM Fd

```
Private Sub Command1_Click()
Text1 = Form1.Textn + " if you are not bored ,I want to talk about the depth factor now..."
Call level1
End Sub

Private Sub Command2_Click()
Formfc.Show
Formfd.Hide
End Sub


Private Sub CommandButton1_Click()
Call level2
End Sub
```

```
Private Sub CommandButton2_Click()
If opt15 = True Then Textfd = 0.9
If opt12 = True Then Textfd = 0.8
If opt10 = True Then Textfd = "It is realy up to you erase this text and put the value you want"
End Sub

Sub level1()
ComboBox1.AddItem "What is the depth factor ?"
ComboBox1.AddItem "What is the effect of the joint depth to determine the overall strength ?"
ComboBox1.AddItem "What can be the minimum value for depth factor ?"
End Sub

Sub level2()
If ComboBox1 = "What is the depth factor ?" Then Texta = "It is the factor to take into account the loss of mortar from the joints due to weathering"
If ComboBox1 = "What is the effect of the joint depth to determine the overall strength ?" Then Texta = "Mortar loss will cause a reduction of thickness of the barrel , the effective barrel thickness should be measured to the face of the mortar,if there is no loss of mortar we can assume the full effective barrel thickness in the assessment ."
If ComboBox1 = "What can be the minimum value for depth factor ?" Then Texta = "It is determined by engineering judgement ,I can advise you 0.3-0.4 as a minimum value"
End Sub
```

FORM Ff

```
Private Sub Command1_Click()
Text1 = Form1.Textn + " please give me some more information ,I want to talk you about the fill factor"
Call level1
End Sub

Private Sub Command2_Click()
Formfw.Show
Formff.Hide
End Sub

Private Sub CommandButton1_Click()
Call level2
End Sub

Private Sub CommandButton2_Click()
If opt15 = True Then Textff = 1
If opt12 = True Then Textff = 0.9
If opt10 = True Then Textff = 0.7
If opt07 = True Then Textff = 0.5
End Sub

Sub level1()
ComboBox1.AddItem "What is fill factor ?"
ComboBox1.AddItem "What is the effect of the filling material to overall strength ?"
ComboBox1.AddItem "What is the effect of  water in the filling material to overall strength ?"
End Sub
```

```
Sub level2()
 If ComboBox1.Text = "What is fill factor ?" Then Texta = "It is the factor that takes into account the respective strength of the different types of fill"
If ComboBox1.Text = "What is the effect of the filling material to overall strength ?" Then Texta = "The stronger the material the greater the load spreading properties and the greater the contribution to the stability of the arch barrel."
If ComboBox1.Text = "What is the effect of  water in the filling material to overall strength ?" Then Texta = "Water can leach out fines  from granular fills and so reduce the density and therefore the strength of the fill. If there is inadequate drainage  then the water can increase the pressure on the barrel"
End Sub
```

FORM Fmo

```
Private Sub Command1_Click()
Text1 = Form1.Textn + " I want to ask you about the mortar factor at this dialog..."
Call level1
End Sub

Private Sub Command2_Click()
Formfd.Show
Formfmo.Hide
End Sub

Private Sub CommandButton1_Click()
Call level2
End Sub

Private Sub CommandButton2_Click()
If opt15 = True Then Textfmo = 1
If opt12 = True Then Textfmo = 0.9
End Sub

Sub level1()
ComboBox1.AddItem "Why do we use the mortar factor ?"
ComboBox1.AddItem "Can you explain the difference between lime mortar and cement mortar ?"
ComboBox1.AddItem "Why do we use mortar factor to determine the joint factor ?"
End Sub

Sub level2()
If ComboBox1 = "Why do we use the mortar factor ?" Then Texta = "Mortar binds the voussoirs together and transfers the thrust between voussoirs,this factor  also takes into account the impact of the mortar quality to determine arch strength."
If ComboBox1 = "Can you explain the difference between lime mortar and cement mortar ?" Then Texta = "Lime mortar tended to be used in earlier arches and deteriorates with age, however it is more tolerant of movement than cement mortar."
If ComboBox1 = "Why do we use mortar factor to determine the joint factor ?" Then Texta = "MEXE method is based on a perfect arch with no joints. Joints weaken the arch (e.g weaker mortar means weaker joint  and therefore weaker arch)."
End Sub
```

FORM Fw

```
Private Sub Command1_Click()
Text1 = Form1.Textn + " I want to ask you about the width factor "
Call level1
End Sub


Private Sub Command2_Click()
Formfmo.Show
Formfw.Hide
End Sub

Private Sub CommandButton1_Click()
Call level2
End Sub

Private Sub CommandButton2_Click()
If opt15 = True Then Textfw = 1
If opt12 = True Then Textfw = 0.9
If opt10 = True Then Textfw = 0.8
End Sub

Sub level1()
ComboBox1.AddItem " What is width factor ?"
ComboBox1.AddItem "Why do we need to know width factor ?"
ComboBox1.AddItem "How do we measure the joint width ?"
ComboBox1.AddItem "When the joint width is low  why  will the strength of the arch increase ?"
ComboBox1.AddItem "What does a well pointed joint mean ?"
End Sub

Sub level2()
If ComboBox1.Text = " What is width factor ?" Then Texta = "It is the factor that takes into account the
width of the joints  between the voussoirs."
If ComboBox1.Text = "Why do we need to know width factor ?" Then Texta = "Wider joint is the weaker
joint ,and weaker joint means the weaker arch .The width factor takes this  into account in determining
the arch strength."
If ComboBox1.Text = "How do we measure the joint width ?" Then Texta = "We measure the average
joint width at the soffit of the arch."
If ComboBox1.Text = "When the joint width is low  why  will the strength of the arch increase ?" Then
Texta = "Mortar is weaker than the material of the voussoirs.When the joint becomes thinner the barrel
becomes stronger. "
If ComboBox1.Text = "What does a well pointed joint mean ?" Then Texta = "Joints with mortar that
extends to the surface of the voussoirs with no voids."
End Sub
```

FORM h

```
Sub level1()
ComboBox1.Clear
ComboBox1.AddItem "What is h ?"
ComboBox1.AddItem " Why do you want to learn h value"
End Sub
Private Sub ComboBox1_Change()
End Sub
```

```
Private Sub Command1_Click()
Text1 = Form1.Textn + " now can you please give me information about h value"
Call level1
End Sub

Private Sub Command2_Click()
Formrc.Show
Formh.Hide
End Sub

Private Sub CommandButton1_Click()
Rem level1 subs
If ComboBox1.Text = "What is h ?" Then Call level2a
If ComboBox1.Text = " Why do you want to learn h value" Then Call level2b
Rem level2 subs
If ComboBox1.Text = "What is the surfacing ?" Then Call level2a1
If ComboBox1.Text = "What is the crown ?" Then Call level2a2
If ComboBox1.Text = "I want to know ,can you tell me why ?" Then Call level2b1
If ComboBox1.Text = "Return" Then Call retur
Rem level3 subs
If ComboBox1.Text = "What is extrados ?" Then Call level2a2a
End Sub


Sub level2a()
Texta = "h is the depth from the top of the surfacing to the crown of the arch"
ComboBox1.Clear
ComboBox1.AddItem "What is the surfacing ?"
ComboBox1.AddItem "What is the crown ?"
ComboBox1.AddItem "Return"
End Sub

Sub level2b()
Texta = "Because the capacity of the arch is directly dependent on the value of h"
ComboBox1.Clear
ComboBox1.AddItem "I want to know ,can you tell me why ?"
ComboBox1.AddItem "Return"
End Sub

Sub level2a1()
Texta = "It is the layer of asphalt or tarmacadom which is used as the running surface for the vehicles"
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub

Sub level2a2()
Texta = "It is the highest point of extrados of the arch barrel usally located at mid span"
ComboBox1.Clear
ComboBox1.AddItem "What is extrados ?"
ComboBox1.AddItem "Return"
End Sub

Sub level2b1()
Texta = "Because h is used in the equation to find  the allowable axle load  that a perfect arch of the given
dimensions can carry. h is also used in the equation to find the material factor Fm."
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub
```

```
Sub retur()
ComboBox1.Clear
ComboBox1.AddItem "What is h ?"
ComboBox1.AddItem " Why do you want to learn h value"
End Sub



Sub level2a2a()
Texta = "Extrados is the upper surface of the arch barrel"
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub
```

FORM l

```
Private Sub Command1_Click()
Text1.Text = Form1.Textn + " I want you to give me information about L value"
Call level1
End Sub

Sub level1()
ComboBox1.AddItem "What is L value ?"
ComboBox1.AddItem "Why do you want to learn L value ?"
ComboBox1.AddItem "How can I measure L ?"
ComboBox1.AddItem "What are the limits for L value ?"
End Sub

Private Sub Command2_Click()
Formd.Show
Forml.Hide
End Sub

Private Sub CommandButton1_Click()
If ComboBox1.Text = "What is L value ?" Then Call level2a
If ComboBox1.Text = "Why do you want to learn L value ?" Then Call level2b
If ComboBox1.Text = "How can I measure L ?" Then Call level2c
If ComboBox1.Text = "What are the limits for L value ?" Then Call level2d
If ComboBox1.Text = "Return" Then Call retur
Rem level2 SUBS
If ComboBox1.Text = "What is the skew arch ?" Then Call level2a1
If ComboBox1.Text = "What is the square arch ?" Then Call level2a2
If ComboBox1.Text = "Why should the span be between  4 and 12 metres ?" Then Call level2d1
Rem level3 SUBS
If ComboBox1.Text = "What is longitudinal center line ?" Then Call level2a1a
If ComboBox1.Text = "What is the springing ?" Then Call level2a1a
End Sub

Private Sub CommandButton2_Click()
Call retur
End Sub
```

```
Sub level2a()
Texta.Text = "For square arch it is the distance between springings,for skew arch it is horizantal perpendicular distance between springings"
ComboBox1.Clear
ComboBox1.AddItem "What is the skew arch ?"
ComboBox1.AddItem "What is the square arch ?"
ComboBox1.AddItem "Return"
End Sub


Sub level2b()
Texta.Text = "The capacity of the arch inversely depends on the span. "
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub

Sub level2c()
Texta.Text = "With a measuring tape or a thedolite"
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub

Sub level2d()
Texta.Text = "L value should be between 4-12 metres"
ComboBox1.Clear
ComboBox1.AddItem "Why should the span be between  4 and 12 metres ?"
End Sub

Sub level2a1()
Texta.Text = "The longitudinal center line of the arch is not perpendicular  to the line of springings"
ComboBox1.Clear
ComboBox1.AddItem "What is longitudinal center line ?"
ComboBox1.AddItem "What is the springing ?"
End Sub

Sub level2a2()
Texta.Text = "The longitudinal center line of the arch is perpendicular to the line of springings"
ComboBox1.Clear
ComboBox1.AddItem "What is longitudinal center line ?"
ComboBox1.AddItem "What is the springings ?"
End Sub

Sub level2d1()
Texta.Text = "If L<4 metres the equations have not been proved, if L>12 metres equations become conservative"
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub

Sub retur()
ComboBox1.Clear
ComboBox1.AddItem "What is L value ?"
ComboBox1.AddItem "Why do you want to learn L value ?"
ComboBox1.AddItem "How can I measure L ?"
ComboBox1.AddItem "What are the limits for L value ?"
If ComboBox1.Text = "What is L value ?" Then Call level2a
If ComboBox1.Text = "Why do you want to learn L value ?" Then Call level2b
If ComboBox1.Text = "How can I measure L ?" Then Call level2c
If ComboBox1.Text = "What are the limits for L value ?" Then Call level2d
End Sub
```

```
Sub level2a1a()
Texta.Text = "Please refer to drawing L1"
ComboBox1.Clear
ComboBox1.AddItem "Return"
End Sub
```

FORM Rc

```
Private Sub Command1_Click()
Text1 = Form1.Textn + " I want to learn Rc value from you "
End Sub

Private Sub Command2_Click()
Formrq.Show
Formrc.Hide
End Sub

Private Sub CommandButton1_Click()
MsgBox ("I am sorry!!!" + Form1.Textn + " I don't think you need expert knowledge about this value,and I realy didn't understand why you clicked this button..........Regards, IMEXE ,PS: Don't be angry at me I like " + Form1.Textnat + " people a lot .")
End Sub
```

FORM Rq

```
Private Sub Command1_Click()
Text1 = Form1.Textn + " I want to ask you the Rq value"
End Sub

Private Sub Command2_Click()
Formfb.Show
Formrq.Hide
End Sub

Private Sub CommandButton1_Click()
'MsgBox ("Dear " + Form1.Textn + " You are" + Form1.textyasgizli + " and  you are behaving like a child ,but as you can see nothing very interesting will happen .....Regards,IMEXE")
End Sub
```

Result Form 1

```
Private Sub Command1_Click()
Dim a1, a2, b1, b2, a, b, c, d, E, f, g, h, I, PAL As String
a1 = Val(Formfb.Textfb)
a2 = Val(Formd.Textd)
b1 = Val(Formff.Textff)
b2 = Val(Formh.Texth)
'Err Hand
If a1 <= 0 Then a1 = 1
If a2 <= 0 Then a2 = 1
If b1 <= 0 Then b1 = 1
If b2 <= 0 Then b2 = 1
a = (a1 * a2)
b = (b1 * b2)
c = Val(Formd.Textd)
d = Val(Formh.Texth)
```

```
E = (10 * c + 10 * d) / 10
f = a + b
'Err Hand
If c <= 0 Then c = 1
If d <= 0 Then d = 1
If E <= 0 Then E = 1
Textfm = f / E
g = Val(Forml.Textl)


'Err Hand
If g <= 0 Then g = 1
PAL = (740 * (E) ^ 2) / (g ^ 1.3)
h = Val(Formrc.Textrc)
I = Val(Formrq.Textrq)
'Err Hand
If h <= 0 Then h = 1
If I <= 0 Then I = 1
'Text1.Text = PAL
If PAL > 70 Then Textpal.Text = 70 Else Textpal.Text = PAL
Textfp.Text = 2.3 * ((h - I) / h ^ 0.6)
End Sub

Private Sub Command2_Click()
Formres2.Show
Formres1.Hide
End Sub
```

Result Form 2

```
Private Sub Command1_Click()
Textfj.Text = Formfw.Textfw * Formfd.Textfd * Formfmo.Textfmo
Textfsr.Text = (Forml.Textl / Formrc.Textrc / 4) ^ -0.701
Textmal.Text = Textfsr * Textfj * Formres1.Textfm * Formres1.Textfp * Formres1.Textpal *
Formfc.Textfc
End Sub

Private Sub Command2_Click()
Form1.Show
Formres2.Hide
End Sub
```