

Knowledge Based Expert System for the Selection of Retaining Walls

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Abstract— The development of a knowledge based expert system for the selection of retaining walls is discussed in this paper. The selection is made based on the selection parameters chosen for a particular site. A retaining wall selection data-base is created with all necessary details, for cut and fills type of retaining walls. The data for creating the database was obtained from case histories, published papers, books on retaining wall selection, minutes about questionnaires and interviews. This collected information forms the knowledge base of an expert system for selecting retaining wall types. An inference mechanism was arrived at based on the questionnaire which aids in the selection by searching through the database and deduce results in an organized manner. Based on the knowledge base and the inference engine user interfaces are developed which are highly interactive and user friendly with transparency of dialogue which allows the user to acquire knowledge about retaining wall types in engineering practice, while providing the user with a tool, which aids in the selection of the most appropriate wall type for a specific site . The expert system was developed using Visual Basic Software.

Index Terms— Expert System, Inference Engine, Knowledge Base, Retaining Walls

I. INTRODUCTION

Retaining Walls are of great importance in geotechnical engineering as they restrain soil to unnatural slopes. They resist the lateral pressure of soil when there is a desired change in ground elevation that exceeds the angle of repose of the soil.

In general, the cost of constructing a retaining wall is usually high compared with the cost of forming a new slope. Therefore, the need for a retaining wall should be assessed carefully during preliminary design. Selection of retaining walls for a particular site is a complex process. Only specialists can do these jobs. Lack of expertise in the selection of an appropriate retaining wall can lead to serious problems. Once the wall is erected and work commences it becomes difficult to solve such situations which involves significant cost and time. To avoid such dangerous and ineffective situations, a development of an expert system for the selection of retaining walls is quite an attractive option.

The selection of the most appropriate wall can be done efficiently once the various problems associated with the selection is identified by an expert. This paper presents the

development of a Knowledge Based Expert System (KBES) for retaining wall selection. The expert system developed can interact with the users and collect the necessary data required for selecting the most appropriate wall type for a chosen site thus replacing the human experts and serves as valuable supporting tools to supply solution-directed knowledge. As the development of KBES for all the various types of retaining structures is not feasible, hence a choice is made effectively for the development of KBES for externally stabilized cut and fill structures.

II. KNOWLEDGE BASED EXPERT SYSTEMS (KBES)

A knowledge-based expert system (KBS) is a computer program that reasons and uses a knowledge base to solve complex problems. A knowledge based system has two types of sub-systems: a knowledge base and an inference engine. The knowledge base represents facts about the world. The inference engine represents logical assertions and conditions about the world, usually represented via IF-THEN rules.

Expert System = Knowledge + Problem Solving Methods

An expert system tool or shell is a software development environment containing the basic components of expert systems shown in Fig.1. The core components are the knowledge base and reasoning engine.

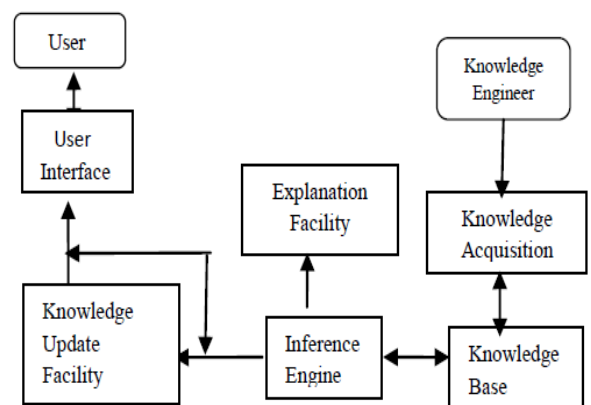


Fig. 1. Architecture of an expert system

III. KBES IN CIVIL AND GEOTECHNICAL ENGINEERING

Knowledge Base systems are intended to perform tasks which require some specialized knowledge and reasoning. A wide variety of knowledge based expert systems have been developed in civil and geotechnical engineering for various purposes.

Expert Systems have applications in almost all the fields of civil engineering as follows:

- a. Expert Systems in Structural Engineering: (DAPS, SACON, FACS, BDES etc)
- b. Expert Systems in Environmental Engineering: (GEOTOX, DEMOTOX, SEPIC etc)
- c. Expert Systems in Construction Engineering: (CRANES, SIGHTPLAN, BERT, SAFEQUAL etc)
- d. Expert Systems in Transportation Engineering: (LOGOIL, CHINA, STREETSMART etc)
- e. Expert Systems in Geotechnical Engineering: (CONE, RETWALL, SOILCON etc)

Geotechnical engineering calls to a large extend upon the individual experience of skilled engineers and is certainly less computerized than other engineering fields. This is mainly because the soil is a complex, multiphase, heterogeneous natural material and also because soil mechanics is a rather young science.

Systems have been developed in various streams of geotechnical engineering for site characterization, interpreting ground conditions, classification and parameter assessments of soil and rock, for foundation construction and design, for pile selection, for design and analyzing failures of earth retaining structures, in soil and rock slopes, in tunnels and underground openings, for evaluating damage due to mining subsidence, in the evaluation of liquefaction potential of soil subject to earthquake excitation and liquefaction hazard assessment, for the selection of ground improvement methods, for the selection and design of geo-textiles, as a diagnostic tool for seepage problems associated with ground water dams, for the evaluation of roads and earthworks.

A brief description on the various KBES developed for retaining walls is shown in table1:

TABLE I. GEOTECHNICAL EXPERT SYSTEMS

Year	Expert Systems on Retaining Walls		
	System Name	Description	Development Environment
1991	ESPGIS	Selection of retaining walls (Arockiasamy et al,1991)	M.I Rule master
1986	WADI	Failure diagnosis of Gravity and Cantilever retaining walls (Canine 1986)	-
1985	RETWALL	Selection of earth retaining walls (Hutchinson 1985)	BUILD
1989	RETAIN	Failure and rehabilitation of earth retaining walls (Adams et al,1989)	-

IV. RETAINING WALLS

Retaining devices assist us in two basic scenarios: a fill or a cut. Fill walls support a backfill while cut walls support the natural ground. A cut site is where we cut into and remove the soil whereas a fill site requires extra soils to fill in behind the entire wall. Good backfill materials have to be brought onto the site. Sometimes a fill has limited space, making long embankments an unfeasible option. On the other hand, cuts require retaining devices to maintain stability or reduce settlements. A literature review of the available retaining technologies and their classification is presented.

A. WALL CLASSIFICATION

A wide variety of retaining devices exists and is currently used for soil retention throughout the world. Before the 1970s, the predominant types of retaining devices for permanent structures were gravity and cantilever walls (Cheney, 1990). Gould (1990) describes the advances from the end of Second World War until 1970. Gould (1990) traced the beginning of soil nailing to France around 1972. O Ro-urke and Jones (1990) described the changes and improvements of retaining devices based on materials used in reinforced soils. Gravity walls, Mechanically Stabilized Earth Walls (MSE Walls), tieback walls, soil nailing etc are most common types. Each device has their limitations. Recommendations and guidelines are available but are dispersed through the technical literature which makes it complex to opt for the optimum selection of the wall type. Hence a brief classification of the retaining wall types becomes an essential need for wall selection.

Wall Systems are categorized:

- Based on their intended functional life as: Permanent Walls, Temporary Walls and Interim Type Walls
- Based on the basic geotechnical mechanism used to resist lateral loads : Externally Stabilized Structures and Internally Stabilized Structures
- Based on the construction method used for the installation of the wall: Cut Type Retaining Walls and Fill Type Retaining Walls.

A study on classification of retaining walls will provide quality information of existing wall types, from which the designer can choose the best wall for a specific site.

A detailed classification is shown in Figure.2

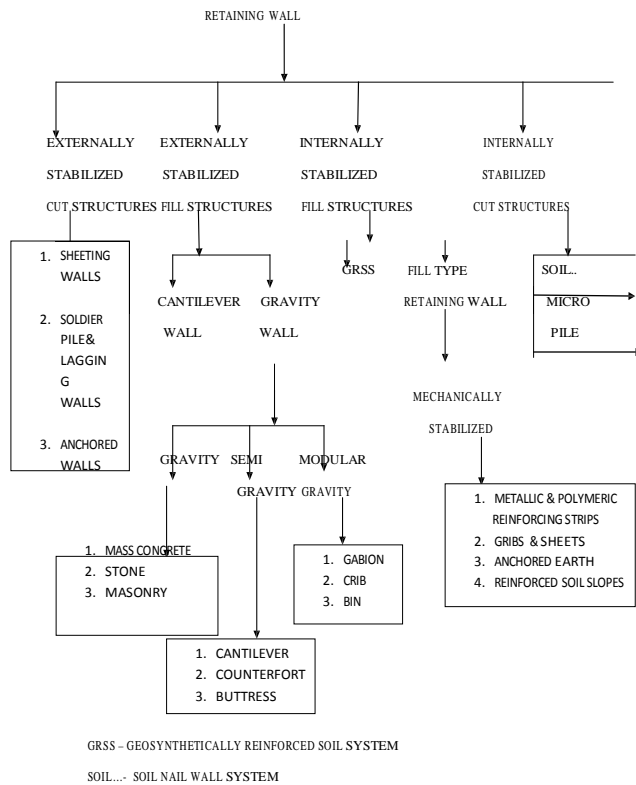


Fig.2. Classification of Retaining Walls

The above tree diagram showing the various types of retaining walls proves the necessity of a KBES to be developed for the wall selection, but the development of KBES for all the various types of retaining structures is not feasible, hence a choice is made effectively for the development of KBES for the externally stabilized cut and fill structures. Table.II. summarizes the wall types for which KBES is developed.

TABLE II. RETAINING WALLS FOR WHICH KBES HAS BEEN DEVELOPED

EXTERNALLY STABILIZED STRUCTURES		
SL NO	CUT TYPE RETAINING WALLS	FILL TYPE RETAINING WALLS
1	SHEET PILE WALLS	CONCRETE GRAVITY WALLS
2	SOLDIER PILE/LAGGING WALL	CONCRETE CANTILEVER WALLS
3	SLURRY/DIAPHRAGM WALL	CONCRETE COUNTERFORT WALLS
4	TANGENT PILE WALL	CONCRETE CRIB WALLS
5	SECANT PILE WALL	METAL BIN WALLS
6	SOIL MIXED WALL	GABION WALLS
7	ANCHORED WALL	-

B. WALL SELECTION PARAMETERS

Once the need of a retaining wall is established, a series of factors have to be considered to determine the optimum retaining wall for the specific needs. The following factors are considered for developing KBES for wall selection.

- Height of the Retaining Wall.
- Size Requirements/ Base Width.
- Type of Soil.
- Slope.
- Type of Fill Material (Backfill Soil).
- Depth of Cut.
- Ground Water Depth.

The look and aesthetics of the retaining wall is a selection factor for permanent retaining walls, where it is necessary to accomplish a pleasing appearance for the wall. Environmental issues like noise and vibrations can also be taken into account for considering selection of wall depending upon site conditions. A database of retaining wall case histories, with analysis of the factors leading to their selection, can prove useful.

A selection chart for fill type and cut type retaining walls was formulated considering the above mentioned parameters which made the selection process much simple. The selection chart for cut type and fill type walls are shown in Tables.III & IV respectively.

TABLE III. CUT WALL SELECTION DATASHEET

SL NO	WALL TYPE	WALL HEIGHT (in m)	BASE WIDTH	TYPE OF SOIL	GROUND WATER DEPTH (in m)
1	SHEET PILE WALLS	Up to 5	N/A	Gravel	6
2	SOLDIER PILE WALL	Up to 5	N/A	Sand	6.9
3	SLURRY WALL	6-24	0.4-1	Clayey Soil	12.2
4	TANGENT PILE WALL	3-9/6-24	0.5-1	Soft Clay	12
5	SECANT PILE WALL	3-9/6-24	0.5-1	Cohesive Soils	18
6	SOIL MIXED WALLS	6-24	1	Silt Sand	7-10
7	ANCHORED WALL	5-20	0.6	Granular Soil	8

TABLE IV. FILL WALL SELECTION DATASHEET

SL NO	WALL TYPE	WALL HT (in m)	BASE WIDTH (of wall ht)	TYPE OF SOIL	WATER TABLE DEPTH (in m)
1	CONCRETE GRAVITY WALLS	1-3	0.5-0.7	Sand	10
2	CONCRETE CANTILEVER WALLS	2-9	0.4-0.7	Gravel	12
3	CONCRETE COUNTERFORT WALLS	9-18	0.4-0.7	Thin Gravel	11
4	CONCRETE CRIB WALLS	2-11	0.5-0.7	Earth Backfill	20
5	METALBIN WALLS	2-11	0.5-0.7	Crusher Run Stone	11
6	GABION WALLS	2-8	0.5-0.7	Roughly Cut Stones	6

C. FLOWCHARTS FOR WALL SELECTION

Flowcharts have been developed both for fill type retaining walls and cut type retaining walls, taking into account the selection parameters. The flowcharts form the basis for analyzing wall necessity for a chosen site. Fig.3 shows the flowchart developed for analyzing retaining wall necessity for a chosen site, Fig.4 and Fig.5 shows the flowcharts formulated for Fill wall and Cut wall selection.

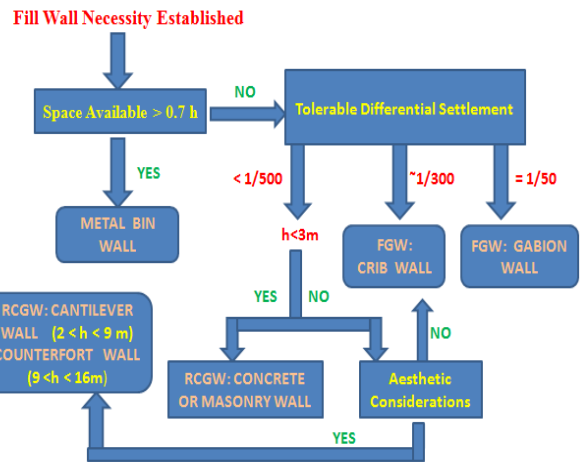


Fig.4. Flowchart for Fill Wall selection

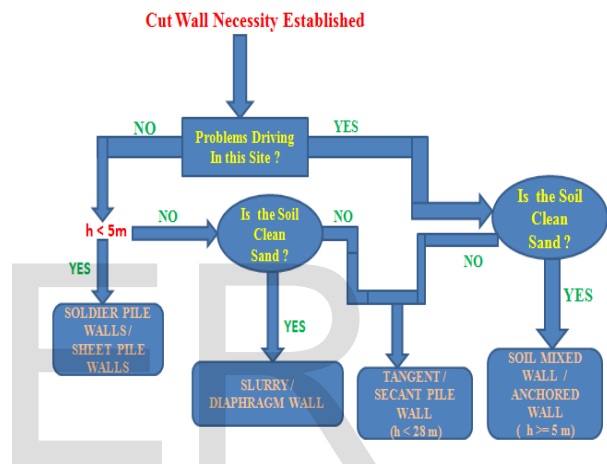


Fig.5. Flowchart for Cut Wall selection

D. ANALYZES FOR RETAINING WALL NECESSITY

The first step in the development of a Knowledge Based Expert System is to analyze the necessity of a retaining wall for a chosen site. Fig.5. briefly outlines the necessity of retaining walls for a specific site. The expert system user has to interact with the system to analyze the wall necessity, for which a series of questions have to be answered by the level 1 user. The questionnaire is developed considering the selection parameters. Questions formulated for analyzing wall necessity are as follows:

- What is the type of soil prevailing at the site?
- What is the depth of ground water present at the site?
- Does the site chosen have any surcharges present?
- Was the site previously excavated?
- What is the elevation of ground?
- Is the site chosen environmentally sensitive?
- Is there any other retaining wall present at the chosen site?

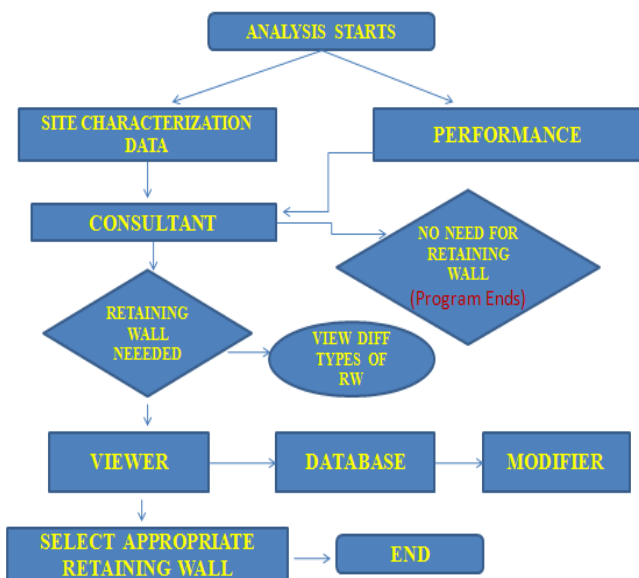


Fig.3. Flowchart for analyzing retaining wall necessity

- Is there any natural water body present nearby the chosen site?
 Once the answers to the above set of questions have been made by the expert, the next step is to decide what type of retaining wall is to be selected for the chosen site. It is not essential that the expert has to answer all the above set of questions for analyzing wall necessity. Once the need for a retaining wall is arrived at by the expert, then the user is directed to a next set of questions to identify the type of retaining wall needed for the chosen site.
- Will the wall be retaining a cut face or a fill material?
- If it is a fill material, will it be a controlled fill?
- If it is a cut face, what type of ground is it?

Thus an expert system allows the general level users usually termed as level 1 users to acquire knowledge about retaining wall types and its necessity by allowing the user to interact with the system by querying in an expert level. The knowledge is derived from the knowledge base of the system and the inference mechanism evaluates the selection parameters accordingly to derive a conclusion.

V. ORGANIZATION OF EXPERT SYSTEM

The expert system has to be organized in a proper manner to function efficiently. The designer must have the freedom to choose the best wall for a given project. for which appropriate information must be readily available to make the best decision.

A. CREATION OF DATABASE

The database forms the major backbone for the proper consultation and processing of an expert system. It is connected with the front engine of the KBES using algorithms in Visual Basic. Provisions are made in the model for easy update and modification of the database by the user. The database can also be saved or printed. Two datasheets, one for the selection of cut type retaining walls and other for the selection of fill type retaining walls are generated as shown in Tables III and IV respectively.

B. CODING FOR WALL SELECTION

Coding has been done for all the 13 wall types for which the KBES has been developed. Initially coding is done generally by taking into account all the parameters for analyzing a specific site generally, then analyzes will be done for each of the specific wall type based on the selection constraints from which the most appropriate wall will be selected by an expert based on the questionnaire.

C. USER INTERFACES

User interfaces have been developed using Visual Basic software. The interfaces are highly interactive with the simplicity in design and ability of reasoning. Figures.6 to 12 show the various modules for retaining wall selection.

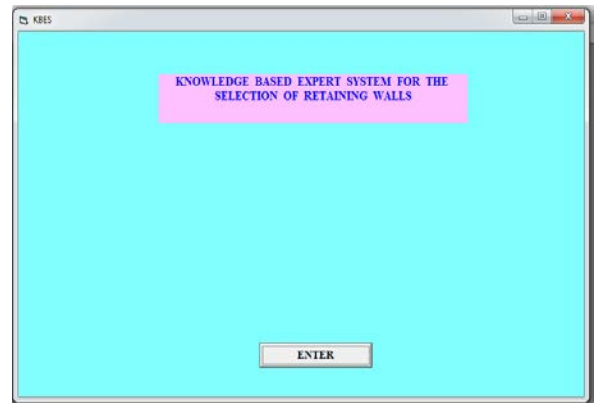


Fig.6. Welcome Screen

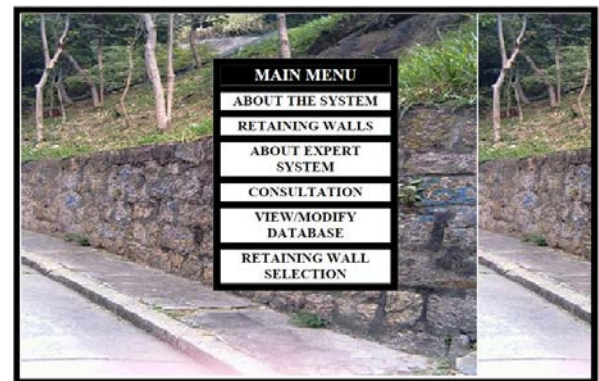


Fig.7.Main Module

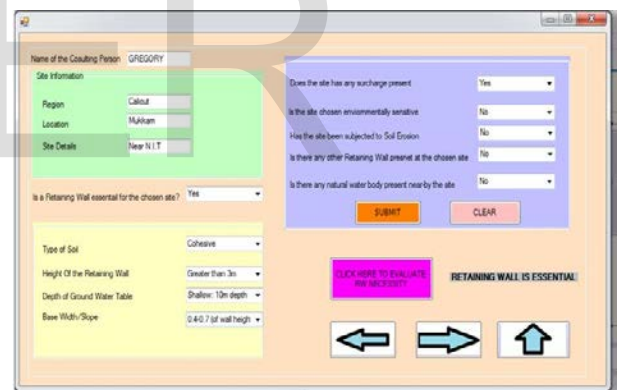


Fig.8.Consultation Module for Level 1 user



Fig.9.Consultation Module for Fill and Cut type walls

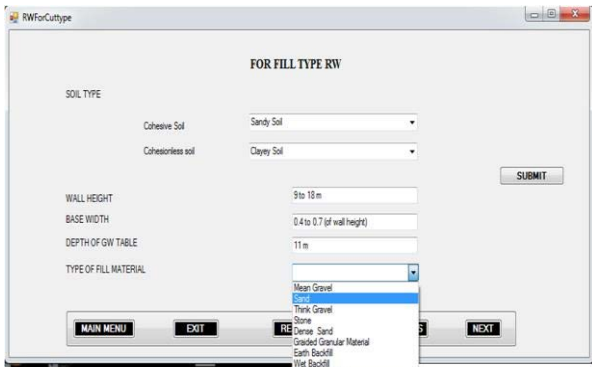


Fig.10. Selection Wizard for Fill type wall

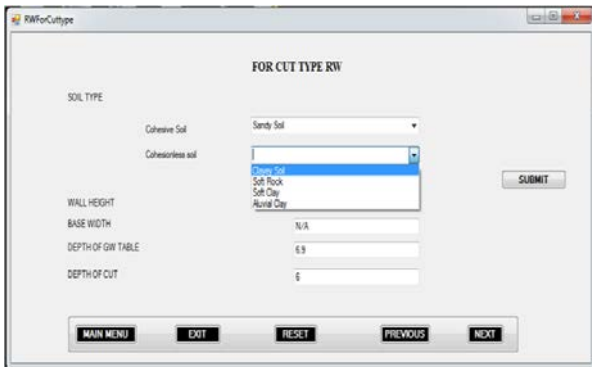


Fig.11. Selection Wizard for Cut type wall

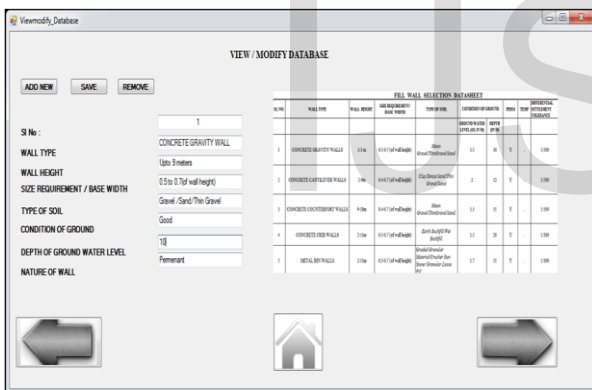


Fig.12. Module to View or Modify database

VI. CONCLUSIONS

The development of a Knowledge Based Expert System for the selection of retaining wall is difficult as there are no general procedures for wall selection. Moreover, the availability of varied number of retaining wall types makes the selection process more complex. Thus the KBES developed allows the user to select the most appropriate retaining wall which would suit a particular site and application thereby minimizing the time and work effort in wall selection

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