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FROM CASE HISTORIES TO CONCEPTUAL MODELS

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ABSTRACT

Geotechnical engineering deals with complicated and highly variable set of engineering principles. A typical geotechnical engineering project comprises site characterization, foundation / soil treatment design, execution, monitoring and quality control systems. Unlike some other civil engineering designs, highly variable soil conditions make a geotechnical designs an iterative and repetitive process which in-turn make these designs cost and time intensive.

Economy and optimization of geotechnical designs are dependent on comprehensive site characterization and evaluation of multiple alternatives. Availability of up-to-date data sets of geotechnical case histories covering entire spectrum; from techniques / technologies to results can help reduce both cost and time of future geotechnical projects. Knowledge from case histories can be used to develop geotechnical constitutive and analytical models with the help of information technology; such models can lead us to many progressive and futuristic limits of geotechnical engineering.

The authors of the paper intend to propose architectural development of “Geotechnical Information System (GTIS)”. The GTIS system covering fundamental geotechnical concepts, data of case histories such as; techniques, technologies employed, monitoring and quality control systems, results / effectiveness of techniques, will provide a framework for the following:

- increased understanding of world-wide geotechnical issues by sharing lessons learnt which will help minimize barriers of uncertainty
- enhancement of investigation and design procedures
- development of economical and efficient technologies
- identification of areas for collaborative research
- development of “Geotechnical Artificial Intelligence Systems (GTAIS)”

INTRODUCTION

Case histories are potential sources for new developments in all the spheres of practical geotechnical engineering. Geotechnical conferences and publications provide opportunities to transform the case histories into a global resource of diverse international experiences. This global resource can ultimately form the basis for re-appraisal of geotechnical principles, analysis of current practices, and enhancement of techniques.

Over the years, the amount of information rendered by case histories is so voluminous that it necessitates evolution of an efficient management system. The data offered by the case histories is of great importance and to make the best use of this data resource, it should be organized into appropriate conceptual models for learners, researchers, and practitioners alike.

The continuous growth in capabilities and reliability of computers, combined with the development of technical and managerial software packages, can address the future challenges of geotechnical data management in the construction industry. Fortunati and Pellegrino. [1998] contemplated following main advantages of applying computers in the construction process:

- facilitate the control of technical information and results produced during the construction process and their conformity with the project specification
- automate the data processing, work documentation, and certification

- compliance with the ISO 9000 quality control regulation

The availability of state of the art information systems along with formulation of appropriate models can help in compilation, management, and manipulation of data sets with the help of models to solve problems at hand. The paper deals with the basic architectural framework for the development of conceptual models, GTIS, and GTAIS for geotechnical applications.

A GEOTECHNICAL CONCEPTUAL MODEL

People receive information, process this information, and respond accordingly many times each day. This sort of processing of information is essentially a conceptual model (or mental model) of how things in our surrounding environment work. The intensity of scattered light from the atmosphere increases with decreasing wavelength. In fact the intensity of scattered light is inversely proportional to the 4th power of wavelength. [The intensity of 450 nm blue light is more than 4 times larger than that of 650 nm red light]. In Fig.1, the observer on the top sees a blue sky when looking up and the observer in lower box sees a reddish sun. More detail can be given and this can be extended into a mathematical model. However for many introductory atmospheric science classes this is a good starting point, Bob MacKay, [N.D.]. http://serc.carleton.edu/introgeo/conceptmodel/.

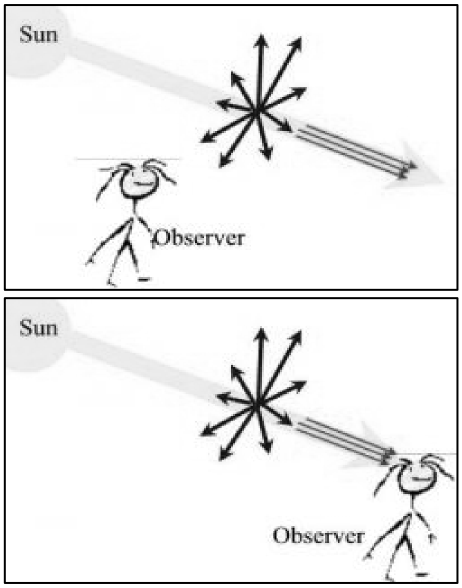


Fig. 1. A simple example of a conceptual model, http://serc.carleton.edu/introgeo/conceptmodel/

A conceptual model is a theoretical construct that represents something, with a set of variables and a set of logical and quantitative relationship between them. Such models enable reasoning within an idealized logical framework about these processes and are an important component of scientific theories. Idealized here means that the model may make explicit assumptions that are known to be false (or incomplete) in some detail. Such assumptions may be justified on the grounds that they simplify the model while at the same time, allowing the production of acceptably accurate solutions, www.wikipedia.com. A geotechnical conceptual model would encompass principles, variables, and solutions concerning the geotechnical engineering.

RELEVANCE OF A GEOTECHNICAL CONCEPTUAL MODEL TO GEOTECHNICAL ENGINEERING

A typical geotechnical conceptual model would revolve around either of the two broad geotechnical areas; the geotechnical environment and geotechnical management. Geotechnical environment encompasses all the existing conditions related to a geotechnical project such as, geological, hydrological, seismological, drainage, etc. Geotechnical management is the optimal manipulation of existing conditions to address safety and stability requirements of a particular project.

The relevance of geotechnical conceptual models to geotechnical engineering is twofold; to facilitate geotechnical students in understanding of the geotechnical problems, and to serve as the basis for development of GTIS and GTAIS for the construction industry in better management of diverse aspects of a geotechnical project. Development of GTIS and GTAIS can then serve as a framework for optimization of technology and economization of time and cost of worldwide geotechnical projects. In geotechnical context, application of conceptual models is as diverse as the conceivable geotechnical issues. In soil improvement perspective, some of the applications of conceptual models can be following:

- site characterization
- cost-benefit models of various possible alternate solutions
- design of optimum solution
- quality control model
- post completion monitoring model
- development of GTIS
- development of GTAIS

PROPOSED CLASSIFICATION OF GEOTECHNICAL CONCEPTUAL MODELS

Geotechnical models can be divided into three main categories; learning conceptual models for the students, research conceptual model for research and development related individuals / institutes / organizations, and the construction conceptual models for the construction industry. These will take the form of a pyramid, as shown in Fig. 2. Each of the preceding models will provide guidelines to the formulation of subsequent model in the specific hierarchy.

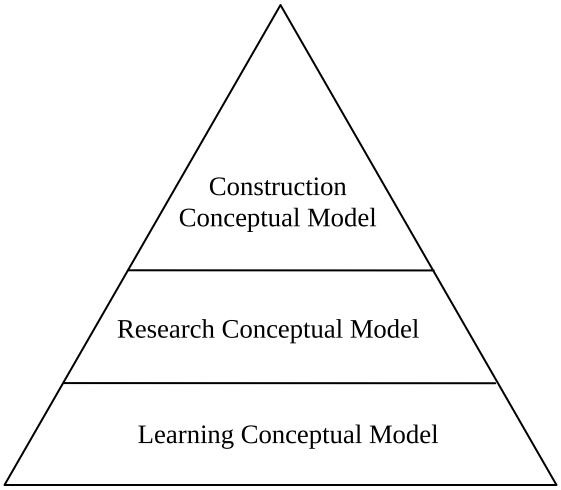


Fig. 2. Hierarchy of geotechnical conceptual models

GEOTECHNICAL LEARNING CONCEPTUAL MODELS

This model can be prepared by the students manually or through the automated systems of the respective institutes. In general all models have an information input, an information processor, and an out put of expected results, www.wikipedia.com.

Parameters of A Learning Conceptual Model

The parameters are illustrated in Fig. 3, specimen is shown in Fig. 4.

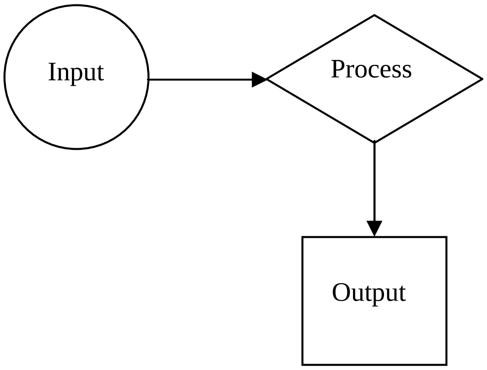
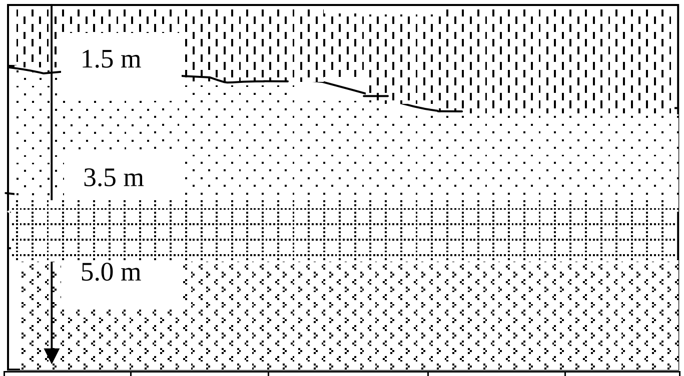


Fig.3. Parameters of a learning conceptual model

Input. Geotechnical parameters that are fed to the model to be processed are called input parameters. Input parameters of a conceptual model for site characterization may include Grain Size Distribution, Atterberg Limits, Moisture Content, Density, N-value, geological and hydrological conditions, etc.

Processing. Processing involves analysis of the input parameters against the criteria defined requisite geotechnical principles to produce results, i.e., output.

Output. Output is the result of analysis of input parameters against prescribed criteria. In case of site characterization, the result will be geotechnical model of the given site; a specimen is shown in Fig. 4. The geotechnical model will highlight the type and nature of strata along with their horizontal and vertical variability. The model can then be used for assessment of suitability of the given area or measures to improve the site for the desired project.



Soil Symbol	Soil Type	Fines (%)	Moisture (%)	Unit Weight (kN/m^3)
▦	Silty Sand	8	15	19.50
Shear Strength	Internal Friction	Permeability	Bearing Capacity	SPT N-value

Fig.4. A hypothetical learning geotechnical conceptual model showing soil profiles and few index properties

Advantages of Learning Conceptual Models

- provides logical and systemized approach towards understanding of geotechnical fundamentals
- enables efficient application of geotechnical principles
- assist in identification of existing geotechnical conditions at a particular site
- highlights the flow of various activities in a logical sequence
- makes the engineers more knowledgeable
- provides better employment opportunities to the graduating engineers who are efficient in development and application of geotechnical models

GEOTECHNICAL RESEARCH AND CONSTRUCTION CONCEPTUAL MODELS

Parameters of a Research and Construction Conceptual Model

Such models in addition to the parameters of learning model will have additional parameters as shown in Fig. 5.

Feedback. It concerns with the processed data. It may include a processed graphic or performance depending on the nature of the model.

Control. It allows the end user to constantly monitor the quality of processed results. The feedback data allows concerned engineers to effect changes where necessary.

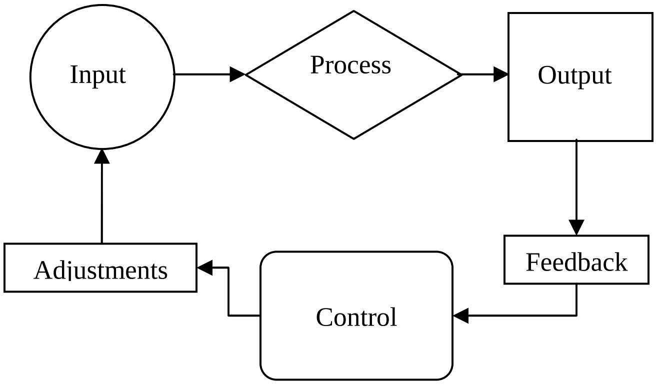


Fig. 5. Parameters of a project conceptual model

Research conceptual models falls within the learning and construction models and amount of detail should depend on the purpose and resources of the researcher. This conceptual model being the founding pillar of the impending geotechnical project, should contain as many layers as possible to characterize the desired site in fullest details. The best option to do so is addition of various layers sequentially. Simple illustration of site characterization and quality control conceptual construction model is shown in Fig. 6 and Fig. 7, respectively. The proposed site characterization conceptual model should preferably have following profiles:

- topographical
- geophysical such as electrical resistivity, etc
- stratigraphical
- geotechnical soil profiles
- table of geotechnical properties

Advantages of Geotechnical Construction Conceptual Models

- provides logical and systemized approach towards understanding of geotechnical fundamentals
- enables efficient application of geotechnical principles
- ensures coordinated effort of the organization and institute
- assist in identification of existing geotechnical conditions at a particular site
- facilitate in optimization of management of geotechnical issues
- highlights the flow of various activities in a logical sequence
- can be used as a project management tool for the managerial staff of an organization
- can serve as a tool to monitor certain critical or desired activities for the site engineers and supervisors
- assist in decision making process
- helps in resource and technology optimization
- will provide competitive advantage to the organizations and institutes
- can enhance productivity and thus the economy and efficiency of geotechnical projects

DEVELOPMENT OF GEOTECHNICAL INFORMATION SYSTEM (GTIS)

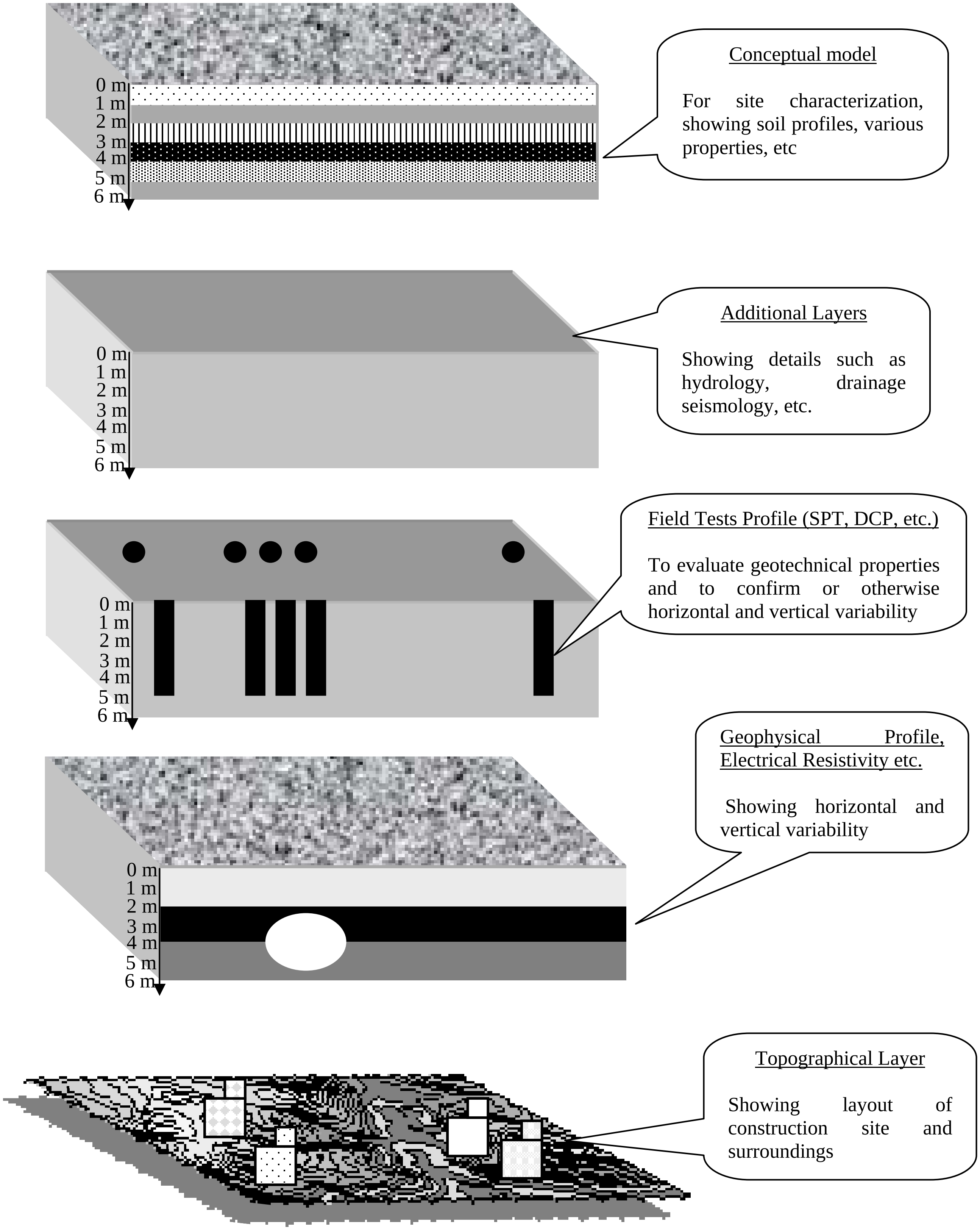
An information system is a system that accepts data resources as input and processes them as information products as output. It uses the resources of people (end users and information specialist), hardware (machines and media), and software (programs and procedures) to perform input, processing, output, storage, and control activities that convert data resources into information products, O'Brian James. [1996].

Geotechnical Data Management Challenges

Geotechnical management deals with all the possible solutions to the geotechnical issue in hand. Cost-benefit analysis of all the possible solutions vis-à-vis availability of expertise, technology, time, and cost, etc., demands an interactive and efficient system that allows manipulations of input data to observe their effects on various aspects of a particular solution. The evolution of optimal and economic geotechnical solutions can thus be arrived at through dedicated geotechnical data management programs.

The geotechnical data management challenges can be grouped into four major areas. The degree of accuracy employed in the methodology to evaluate and reliability of data management programs in the four geotechnical areas will affect their usefulness in evolving a geotechnical cycle for a particular project. The four major areas are:

- Geotechnical Environment
- Project requirements
- Geotechnical principles
- Geotechnical management



Conceptual model

For site characterization, showing soil profiles, various properties, etc

Additional Layers

Showing details such as hydrology, drainage seismology, etc.

Field Tests Profile (SPT, DCP, etc.)

To evaluate geotechnical properties and to confirm or otherwise horizontal and vertical variability

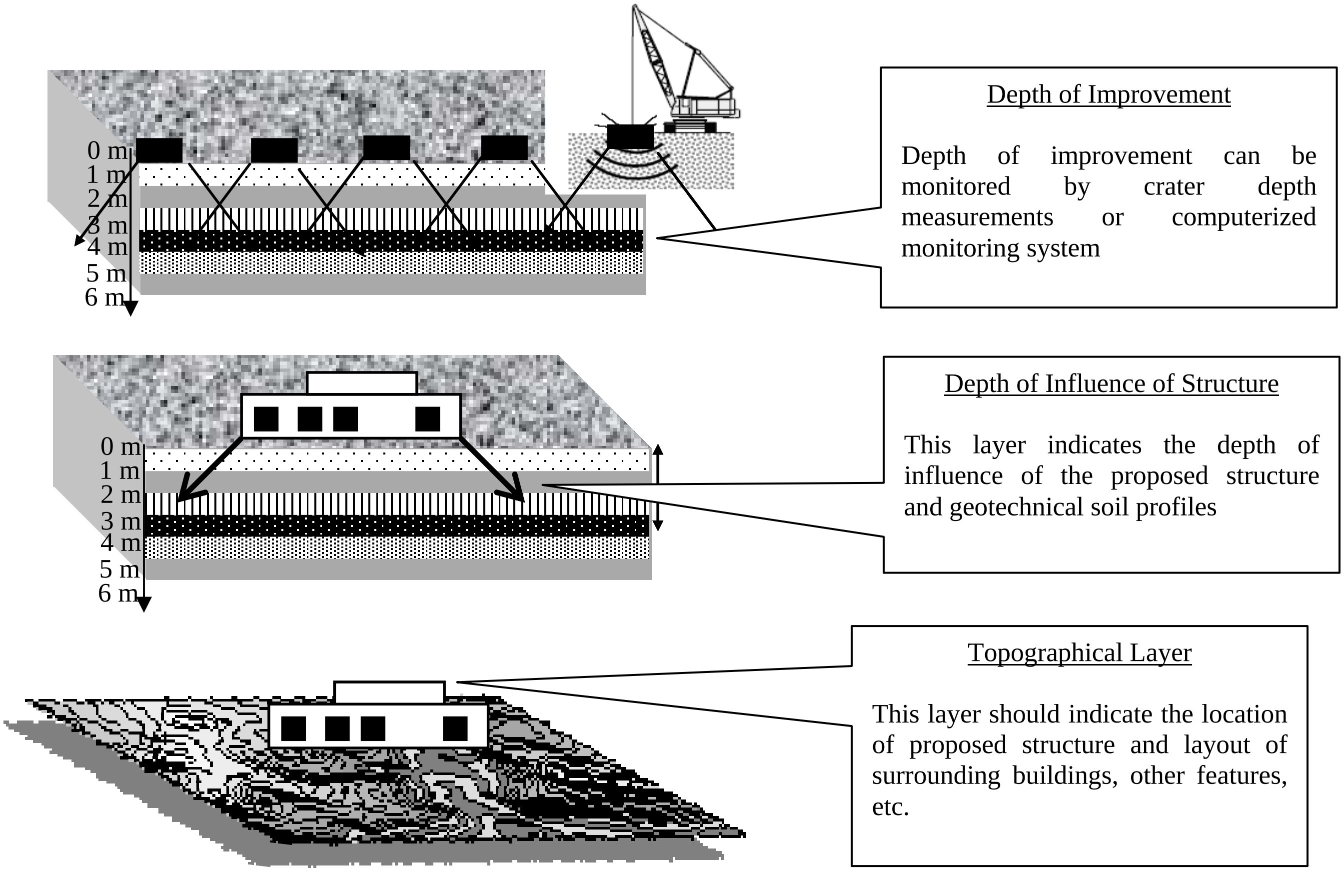
Geophysical Profile, Electrical Resistivity etc.

Showing horizontal and vertical variability

Topographical Layer

Showing layout of construction site and surroundings

Fig.6. Geotechnical construction conceptual model for site characterization



Depth of Improvement

Depth of improvement can be monitored by crater depth measurements or computerized monitoring system

Depth of Influence of Structure

This layer indicates the depth of influence of the proposed structure and geotechnical soil profiles

Topographical Layer

This layer should indicate the location of proposed structure and layout of surrounding buildings, other features, etc.

Fig.7. Geotechnical construction conceptual model for quality control and monitoring for dynamic compaction project

Geotechnical Environment. Geotechnical environment is the most basic, most intricate, and common aspect to all geotechnical projects. The level of accuracy and completeness of this aspect determine the reliability of designs and ultimately the safety and stability of the structures. Geotechnical site characterization involve planning, reconnaissance, field tests, lab tests, evaluation of soil index and geotechnical properties, and interpreting of ground conditions into a geotechnical conceptual model.

The large quantum of tasks involved in site characterization coupled with uncertainties in ground conditions from place to place, human errors in field tests, extraction of samples, and the quality of samples, variations in field and lab conditions, all contribute towards complexity of the first and foremost step in the chain of geotechnical projects. Site characterization thus requires comprehensive and futuristic management for maximum accuracy.

Geotechnical Principles. Geotechnical principles when applied to the findings of site characterization, determine the expected ground behavior under impending structural load conditions. Geotechnical principles thus lay down the guidelines to various possible solutions to manage existing ground conditions vis-à-vis safety and stability requirements of the proposed structures.

Geotechnical Management. In geotechnical engineering, even the best designs are attributed to the uncertainties due to ever changing ground conditions such as variation in moisture content, seismology, etc. Efficient application of fundamental geotechnical principles to geotechnical issues thus requires due attention to the past experience in respective fields. The multifarious global and local geotechnical experiences in diversified areas need a knowledge based system to manage the constraints of uncertainty of ground conditions and safety of the structures.

ADVANTAGES OF A GTIS

- will assist in design optimization
- will assure quality control
- will facilitate timely modifications
- assist in project management
- support decision making in all facets of the project

- will contribute towards economy of the project in terms of time and cost
- assist in analysis of large data sets of various case histories rapidly and timely
- facilitate sharing of experiences and expertise with interested institutes and organizations both locally and globally

Components of a GTIS

A geotechnical information system will be a system that accepts geotechnical data and transforms this data into geotechnical information which would help in optimization of geotechnical solutions. A basic framework of a geotechnical information system is shown in Fig. 8. In geotechnical context, the information system resources are discussed as under:

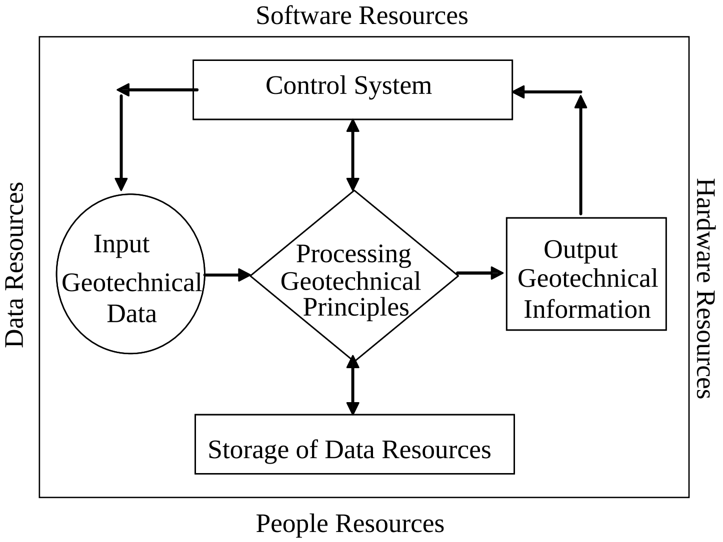


Fig.8. Components of a geotechnical information system

Human Resources. Human resources are required for use and development of the geotechnical information systems. These resources include geotechnical engineers and the computer programmers.

- Geotechnical Engineers; they are the end users of the geotechnical information systems and will include geotechnical engineers, sub-engineers, and laboratory staff, students, etc.
- Computer programmers; they are the people who will develop and may operate the geotechnical information system. They will include programmers, system analyst, computer operators and clerical staff.

Hardware Resources. Hardware resources will include all physical devices and materials used in the information processing. It is a system of central processing units such as mainframe and desktop computers, peripheral devices, and networking arrangements, etc, . The choice will depend on the size and needs of the user organization / institute.

Software Resources. Software resources refer to computer programs and procedures, brief details are:

- System software, it is the operating system program, which controls and supports the operation of a computer system.
- Application software, it consists of programs that direct processing for a particular use of computers by end users.
- Procedures, these are operating instructions for the people who will use an information system.

Data Resources. Data is the raw information concerning a particular project resource may include previous case histories in and outside the organization and institutes, experiences of engineers and contractors, etc.

GTIS Development Cycle

The GTIS development cycle should follow a systemized mission oriented approach. The engineer responsible should clearly identify impending and future requirements to be served by the GTIS. The proposed GTIS should have flexibility to adjust to the changing requirements. All opportunities and techniques should be explored to devise an efficient GTIS. Based on the identified needs, multiple alternatives are analyzed. A preliminary GTIS is then formulated which is then tested against the desired parameters. The preliminary GTIS is modified if deemed necessary. The GTIS is finalized through extensive testing. The final GTIS is still open to revisions and modification as and when required, as shown in Fig.9. Some parameters of a GTIS for soil improvement are shown in Fig. 10.

GEOTECHNICAL ARTIFICIAL INTELLIGENCE SYSTEM (GTAIS)

Attributes of a GTAIS

Artificial Intelligence is a science and technique based on disciplines such as computer science, mathematics, engineering, etc. The goal of artificial intelligence is to develop computers that can think as well as see, hear, walk, talk, and feel. A major thrust of artificial intelligence is the development of computer functions normally associated with human intelligence such as reasoning, learning, and problem solving. Attributes of intelligent behavior that artificial intelligence can duplicate with the capabilities of computer-based systems are, O’ Brian A. James. [1996]:

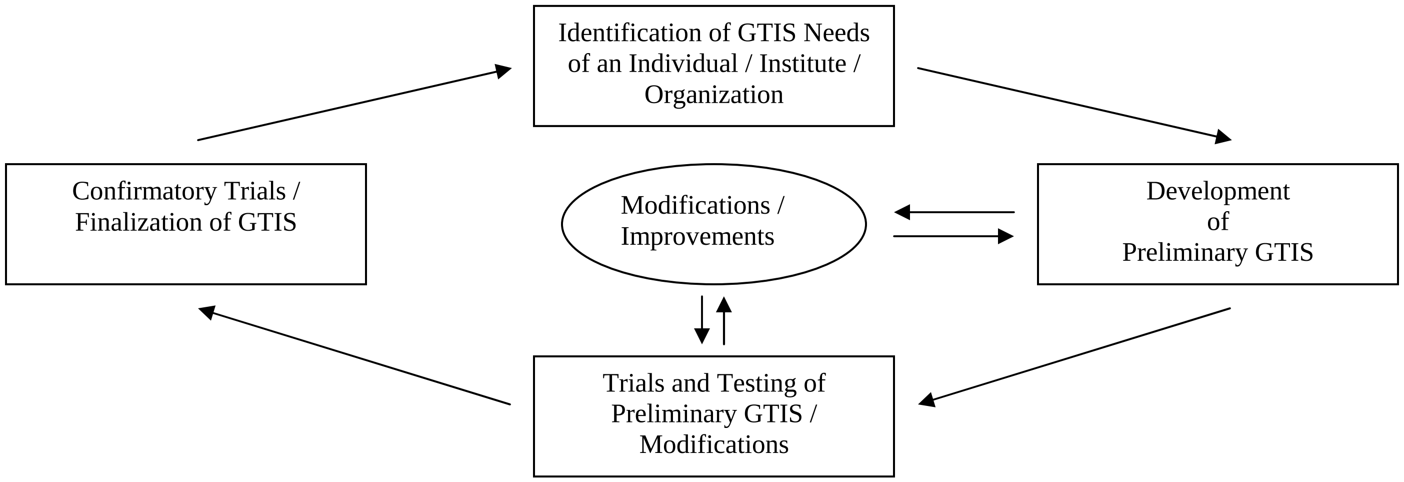


Fig.9. Development cycle of a GTIS

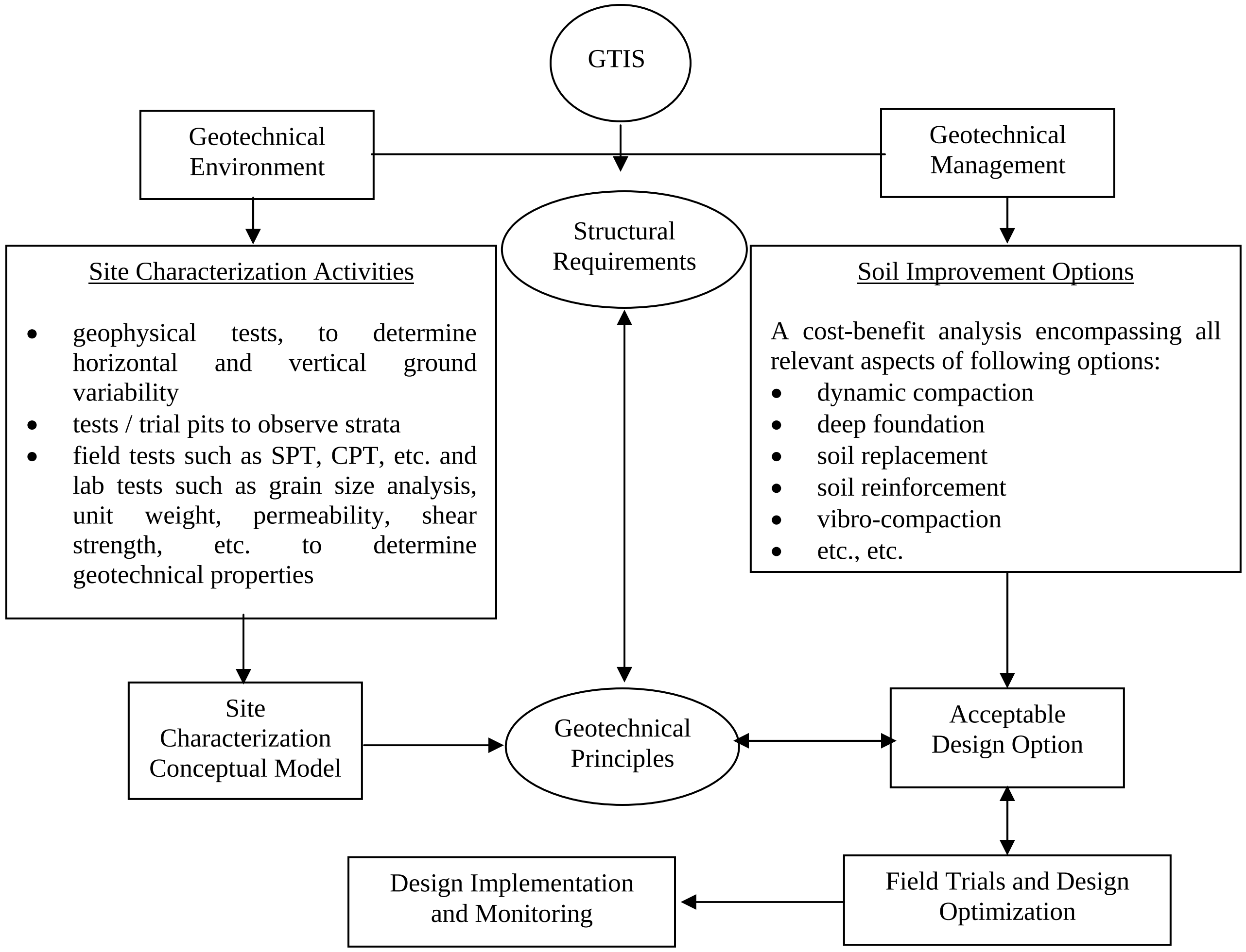


Fig.10. Parameters of a soil improvement GTIS

- think and reason
- use reason to solve problem
- learn or understand from experience
- acquire and apply knowledge
- exhibit creativity and imagination
- deal with complex or perplexing situations
- respond quickly and successfully to new situations
- recognize the relative importance of elements in a situation
- handle ambiguous, incomplete, or erroneous information

Development of a GTAIS

GTAIS can be developed for the analysis of causative factors of almost all simple to most complicated geotechnical problems to formulate most suitable remedial solutions. A simple GTAIS can be developed by an individual using simple Microsoft applications while a complex GTAIS may require a panel of very experienced geotechnical engineers, a team of software and hardware engineers. An example of the development of a very simple GTAIS is discussed in the ensuing paragraphs.

GTAIS for Landslide Hazard Assessment and Landslide Risk Mapping

Naeemuddin. [2007], developed an artificial intelligence system for "Landslide Hazard Assessment" and development of "Landslide Risk Mapping" of an urban town of Murree in Pakistan. The data for development of this GTAIS was gathered from concerned departments in the town and from various case histories of landslides. The data from case histories provided an insight to the effectiveness of the landslide counter measures and was very helpful in the development of GTAIS. The process of development included study of the existing geotechnical environment and identification of causative factors and is discussed briefly.

Geotechnical environment. Geologically, the town lies on the southern tip of the Himalayan range and is composed of alternating layers of shale and sandstone. The roads, residential, and commercial buildings in this town are mostly on hill-slopes and are prone to frequent landslides. The increase in deforestation activities due to uncontrolled urbanization and poor maintenance of roads is a constant catalyst to the frequency of landslides. The large influx of tourists in summer season results in increased use of water in hotels and rest houses which due to poor drainage conditions raises the saturation level in the slopes. The on-set of monsoon and tourist season simultaneously has put the town under a constant threat to landslides in the future.

Causative factors. The causative factors of landslides were enormous and complex. The causative factors affecting landslides were broadly grouped as following:

- geological
- hydrological
- environmental
- seismological
- structures; their type and age etc.
- protective measures

Artificial intelligence system. The contribution of each factor towards landslide risk varies with the change in season, size of population, environmental conditions, etc. The artificial intelligence system used for Landslide Hazard Assessment and Landslide Risk Mapping is the "Fuzzy Logic" technique since its method of reasoning resembles human reasoning that allows for approximate values and inferences (fuzzy logic) and incomplete or ambiguous data (fuzzy data) instead of relying only on crisp data, such as binary (yes/no) choices, O' Brian A. James. [1996]. With the help of this artificial intelligence, it became possible to assess the hazard and mapping of risk in short span of time. A risk assessment map of one of the portion is shown in Fig. 11.

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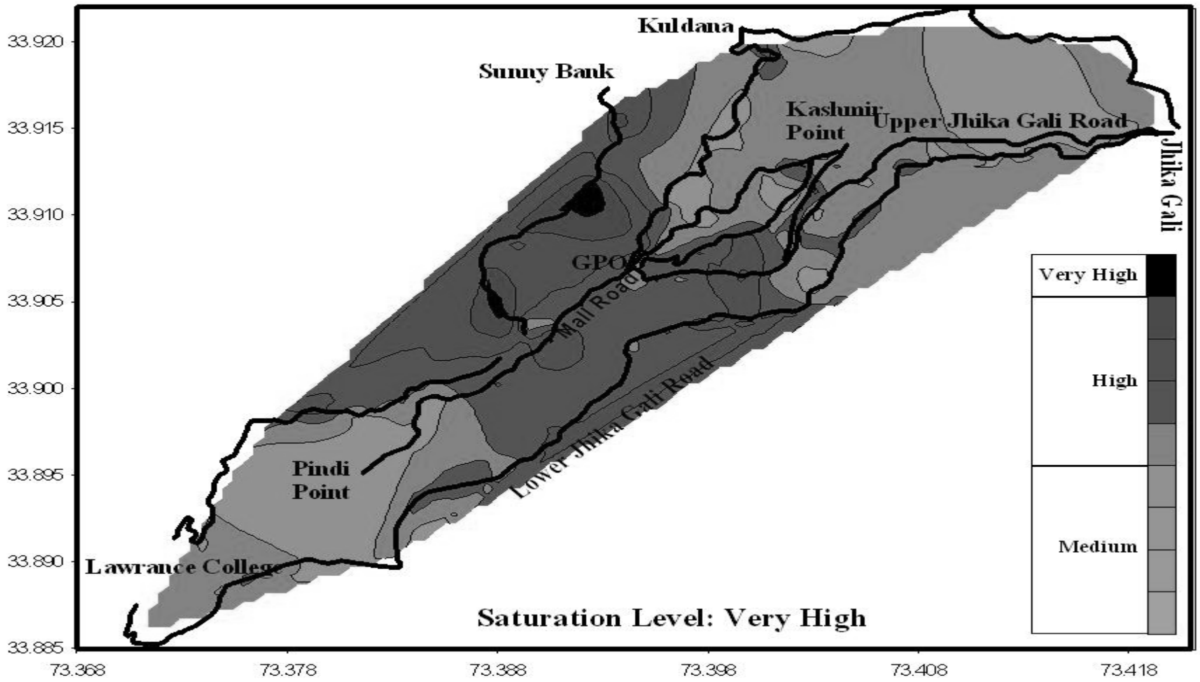

Fig.11. Landslide risk assessment map developed using artificial intelligence system based on fuzzy logic technique