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General Report for Theme Eight
Case Histories in Selection of Sites for Industrial Structures and Determination of Design

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The subject of this session is Case Histories in Selection of Sites and Determination of Design Soil Parameters. A total of seven (7) papers were available for review at the time of writing this report. I shall discuss briefly selected aspects of the papers, and will give personal opinions and comments on some aspects of the subject.

There are three papers, which directly deal with the selection of site based upon geotechnical considerations. In Paper 806, Cox presents an interesting case history of selecting a site for an industrial plant in a region of Karst topography. Three sites were considered for the project. Each site required extensive site improvement measures such as grouting of voids, sink hole repair, etc. Based upon the social and economic consideration, the geotechnical parameters were over-ruled and the site having the poorest geotechnical properties was selected. The paper illustrates that a geotechnical engineer can enable the optimization of a total design by enabling the trading off of economic, social and construction parameters.

I shall like to mention here that during the last two decades, the environmental and social forces have become so strong that these forces often over-rule the geotechnical considerations. Generally, it turns out that the purpose of the geotechnical investigations are not to find a site having the least expensive foundation system but to design a foundation system for a pre-determined site selected on the basis of social and environmental considerations (Selple, 1974).

In Paper 810, Sabtan and Shehata present the results of a reconnaissance study to locate a suitable site for a nuclear power plant in the mid-western area of Saudi Arabia. The authors studied three sites based on the U.S. Atomic Energy Commission Regulatory criteria. The various sites were ranked on the basis of a numerical evaluation system.

In Paper 809, Handa, Saran, Ramasamy, Rao and Parkash present the soil and foundation investigation of a multi-story building in northern India. The site is located on the foothills of the Himalayas. The testing program consisted of test borings including dynamic cone penetration tests, comprehensive laboratory testing including triaxial and consolidation tests, and field plate load tests. Based on the investigation, a cast-in-situ pile foundation system was used to support the building.

It is interesting to note that a plate load test was also a part of the testing program for this study. It is understood that in northern India the plate load test is used as a routine test during the geotechnical investigation studies.

In Paper 804, Wagner presents a case history, where the strength parameters determined during a geotechnical investigation were applied to an actual failure that took place prior to the investigation. Shear strength of an organic deposit was determined by several methods and the validity of the results was evaluated by studying the failure. The paper relates to the investigation of a dockwall failure in Milwaukee, Wisconsin. The failure occurred during the placement of a salt pile, the toe of which was at a distance of approximately 30 feet from the shore line. The failure occurred through the organic soils, which were overlain by fill deposits. The author discusses the differences in the shear strength values that were obtained using Dutch cone, vane shear and laboratory torsion method. The author analyses the shear strength data by evaluating the stability of the dockwall which must have a factor of safety of less than one at the time of the failure. Stability analysis was performed using the STABL program.

I would like to make a few comments about the data generated for the paper by Wagner. It is my experience that the organic silt and peat are generally very non-uniform in physical and engineering properties. I have seen that variation in moisture content from the same deposit may vary by several hundred percent within a few inches of vertical or lateral distance. Similarly, the shear strength exhibits significant variations within a short distance in the same deposit. Therefore, the representative average value to be used in analysis must be determined very carefully. It will be interesting to study the variations in natural moisture content data for these deposits.

I tend to agree with the author that the horizontal sand seams provided some reinforcement against shearing and will increase the field vane and Dutch cone values. It should also be noted that vane size also affects the values of shear strength determined in the field. Nevertheless, the horizontal sand seams should not have significant reinforcing effects at the time of the failure, as the failure surface will follow the line of least resistance and will avoid sand seams. It is my opinion that the failure model will be similar to a deep sliding block within the soft organic soils rather than a circular surface.

In Paper 805, Gil and Vega present the case history of a foundation failure in Lima, Peru. For this project, geotechnical investigation was considered sufficient and the foundation design was considered adequate. However, the structure was constructed without sufficient construction control resulting in foundation failure. The failure was in the form of settlement, cracking of floor slabs and tilting of a pier. The site was located on an alluvial terrace with residual granitic material. In order to achieve design grades engineered fill, up to approximately 15 meters in thickness, was placed. The majority of the fill material was obtained from colluvial debris having 4 inch maximum rock size. The paper presents that the failure has occurred due to lateral varia-
tions in soil compaction beneath the base and placement of fill in an uncontrolled fashion. The paper is a classical example to emphasize the point that proper construction control is vital to the successful completion of the project. Had the fill been placed on a satisfactory subgrade with sufficient compaction utilizing proper methods, this problem could have been avoided. One of the points of interest in this paper is the types of materials used in fill. It appears that relatively large pieces of rocks were used to construct the fill. I request the authors to give some information regarding the weathering characteristics of these rocks. Construction of fill and embankments with weak rocks require special design and construction procedures. Considerable amounts of research work has been done in the USA in the last 15 years for constructing fills utilizing weak rocks (Lovell and Deo, 1984).

In Paper 807, Shitao, Siyi, Jobing and Kezhi, present an interesting case history of a common-sense approach of efficiently using the principles of land development to develop a town in an expansive-soil area. The general principles used in developing the town were: i) dividing the area according to different geological formations ii) using the land multi-levelly to account for topographic features and iii) using engineering measures to minimize damages due to expansive soils. Heavy and high buildings or underground structures were built in sections with great expansion and shrinkage potential, low structures were built in sections with small potential problems and buildings sensitive to non-uniform deformation were built on non-expansive soils.

In Paper 803, Fulan presents case histories in the selection of the site of a precision instrument factory. Based upon experimental data from repeated tests, the author provides antivibration distances in order to prevent vibration problems. The source of vibrations considered are train and automobile traffic, a forging hammer, and a compressor. The recommended antivibration distances can be reduced by providing isolation or antivibration trenches.

Based upon a review of the papers submitted in this conference, (this and the other sessions) it appears to me that for the determination of design soil parameters, more elaborate field and laboratory testing is performed in European and Asian countries than that in the USA. There may be two reasons for this:

1) Geotechnical data from other sites having similar geological characteristics is often available and can be used to interpret some data without detailed testing.

2) If there is competitive bidding for geotechnical services, and the scope of investigation is not well defined, there is tendency on the part of the consultant to reduce the number of expensive tests.

It will be interesting to learn from the geotechnical consultants working in various regions of the world about the practices they use to develop the scope of geotechnical investigations. It is unfortunate that in spite of the well-publicized limitations of the standard penetration test, especially for the clayey soils, this test is still considered the most important geotechnical parameter to develop foundation design.

REFERENCES


INVITED PRESENTATION
MADE BY DR. R.K. BHANDARI
ON THEME VIII

SOIL EXPLORATION SAMPLING AND FIELD TESTING PRACTICES IN INDIA

The unprecedented developmental and construction activity in the post-independence era in the Indian Subcontinent has brought about notable awareness amongst the geotechnical engineers regarding the need for refinements of site investigation tools and procedures as well as updating and updating equipment used in the laboratory. For many years, the Indian experiences are being codified faster than of most of us would even realise. The geographical spread being so great and the access to specialists for routine jobs being so difficult and expensive, the Indian Standards Institution has ventured codification in areas not so well understood. The tools, instruments, equipment, practices etc. related to soil exploration have been the concern of Indian Standards Institution, Indian Roads Congress and National Building Code of India.

India has recorded all round development in the geotechnical field. The focus has now shifted from concentrating on the best sites to those available; from doing all the tests that were possible and leaving the final choice to the designer to the purpose-oriented investigation; and from quantity to quality. The listing of relevant IS Codes is placed at the end of the presentation.

A State-of-the-Art report on the Soil Sampling practices in India Bhandari and Davis (1979) was made at the International Symposium on Soil Sampling held in Singapore. Further contribution from India on this topic was made to the writing of the International Manual on Sampling of Soft Clay published by ISSMFE's Subcommittee on Soil Sampling. The manual was released during the 1st International Conference held in Stockholm in 1981. Today, India has already made a beginning towards establishing Soil Data Banks in its Metropolitan cities. The work of establishing first soil data bank in Calcutta was taken up by the Department of Science and Technology, Government of India about four years ago. The effort is currently being spent in geotechnical mapping of the Calcutta region based on soil investigation reports, documented experiences and additional surveys. The success of this effort in Calcutta will hopefully pave the way for similar data banks to be established in Bombay, Delhi and Madras.

The geotechnical problems in India are as varied as the type of soil deposits. The vast tracts of highly expansive black cotton soils, soft clays, alluvial, boulder, soft clays, latrises, etc. pose a great challenge to the engineer's skill particularly in undisturbed sampling and testing.

Penetrating testing such as SPT, Dynamic Cone Penetration Tests, Static Cone Penetration tests are extremely common in India particularly for cohesionless soils. For soft clays use of field vane is favoured. Black cotton soils which exhibits highly seasonal behaviour call for tube or block sampling and highly controlled tests in the laboratory. For boulder soils, full scale footing tests are usually recommended.

Whatever the degree of progress, the road is indeed tortuous and the destination still far away. The greatest difficulty in the path of progress is that the work still continues to be awarded on the lowest bid. The quality is the first casualty when the commercial interests creep in. Sometimes the contractors are not even well equipped or trained to undertake soil investigation work and naturally they end up with making "holes" rather than "bore holes".

The human resource in India being abundant, the automation in testing, data processing etc. is unlikely to catch up in field jobs for at least a decade more. Pressuremeter testing has recently been introduced by the Central Building Research Institute, Roorkee but the scope for introduction of computerized pressuremeter or self-boring pressuremeter in field jobs is considered remote for a few more years.

The International Standards Organisation, in its meeting held in Hague in 1981, has entrusted India with the responsibility of writing codes for ISO in the field of soil testing.

SOME IMPORTANT INDIAN STANDARD CODE OF PRACTICE FOR SOIL EXPLORATION AND FIELD TESTING OF SOILS

IS:1888-1982: Method of Load Test on Soils (Second Revision).
IS:9214-1979: Method of determination of modulus of Subgrade Reaction (k-value) of soils in field.
IS:4968 (Part III)-1976: Static Cone Penetration Test (First Revision).
IS:4434-1978: Code of Practice for in situ Vane Shear Test for Soils (First Revision).
IS:2720 (Part XXXIX/Sec.2)-1979: Direct Shear Test for Soils containing Gravel, in situ Shear Test.
IS:2720 (Part XXXII)-1970: North Dakota Cone Test.
IS:10442-1983: Specification for Earth Augers (Spiral Type).

The International Standards Organisation, in its meeting held in Hague in 1981, has entrusted India with the responsibility of writing codes for ISO in the field of soil testing.
Our appreciation is extended to the author for sharing the case histories concerning vibrations.

The case histories all pertain to use of isolation to reduce vibrations reaching sensitive equipment or instruments. The author described cases in which isolation was provided:

1) at the source
2) between the source and sensitive equipment, and
3) at the sensitive equipment.

There are specific conditions for which each of the three isolation procedures would be preferred. Cost, of course, would be significant factor in the determination of which isolation technique is preferable.

Other methods for reducing vibrations are available, but were beyond the scope of the paper. These include varying the mass of the foundation supporting the source and varying the frequency of the source. Alternatives, such as these, are not always feasible and in general, may be less effective than isolation.

The author presented tabulated data concerning the minimum separation distance between various vibration sources and instrumentation having various sensitivities. The data would be quite useful as a preliminary means for site evaluation.

Formulae were presented for calculating the attenuation of vibrations with distance. Use of equations indicates significant attenuation with distance. However, attenuation calculated by the equations would not be as great as calculated on the basis of the reciprocal of the square of the distance from the source.

For example, for a foundation, with a unit radius, situated at the ground surface on a soil with an "average K value" and a frequency of 100 Hz, the vibration amplitude would be reduced by successive single orders of magnitude at respective distances of approximately 7, 16, 27, 37 and 48 times the foundation radius. For embedded foundations, the attenuation would be more rapid. The formulae assume homogenous isotropic conditions, which may not always be valid.

The above paper describes the history of construction and methods of minimizing damage due to expansive soil in a district of main land China. The primary problems attributed to expansive soil were damage to foundations due to the shrinking and swelling of plastic clays and slope stability problems initiated by saturated expansive soils.

This paper did a very thorough job of describing the problems with expansive soils in this particular district of main land China. It also presented a discussion of construction solutions for dealing with expansive soil problems. However, there was very little discussion of methods for identifying areas and types dominated by expansive soils utilizing common testing techniques. It is suggested that it would be of value in this area to collect soil samples, either by hand auger, or small drilling rig to enable comprehensive determination of Atterberg limits and moisture content; thereby, classifying, identifying, and quantifying the depth, type, and range of the expansive soils. In addition, if this problem is of a general nature to an entire province, it may be worthwhile to do some mineralogical analysis on these soils and identify their primary expansive constituents (i.e., mineralogical type, chert, etc.). Based on these analyses, other solutions might be developed for dealing with expansive soils. For example, the use of lime as a soil amendment to fix the expansive soils. The mixing of the soil and lime would be very easily accomplished utilizing hand methods. Lime stabilization of the soil in conjunction with improved drainage should prove to be a practical solution for low bearing buildings. In conclusion, the authors should be congratulated for presenting their comprehensive description of expansive soil problems and solutions in their area.
The analysis of annual recharge appears reasonable, provided that the assumption of no significant recharge from off-site through the rock is valid. The calculated flow rate is surprisingly low. Did observations, that were made on the site during the study, substantiate the design assumptions?

Will the fill that is required to level the site be placed above any of the springs or water seeps? If so, some means of maintaining flow, such as a system of drainlines would be required to avoid causing a groundwater accumulation in the bedrock fracture zones.

Lastly, there are questions regarding the sinkhole repair. Were the sinkholes always wider at the top than at the bottom? If not, it may have been impossible for the rock fragment fill to have wedged into place. Further, the lean concrete would not have been secure. Were foundations placed directly on the repaired sinkholes?

This paper presents a comprehensive discussion of a slope failure in a soil of relatively high organic content due to the surcharge loading of the soil deposit by a salt storage pile. The area of the failure is located adjacent to Lake Michigan. The paper very thoroughly describes the steps taken in the analysis.

The paper describes the failure of a dock wall at the port of Milwaukee. However, the paper does not describe or mention the dock wall, although Figure 1 does illustrate a proposed dock wall. The only point to this criticism is that it may have been of interest to analyze the potential for a gravity retaining wall to resist the potential failure. Even though the latter would seem to have been of little value due to the depth of the organic deposit. However, the configuration, size, and role of the dock wall and the stability of the slope is an unanswered question. It was of interest to see the comparison of results of Dutch cone testing, field vane testing, and laboratory torvane testing. This data would be useful for anyone attempting an analysis utilizing one of these techniques. Finally, I found it unfortunate, and my sympathies are extended to the author, that despite the comprehensive continuous testing, the failure plane was not located. Location of the failure plane in at least one sample would have provided an exact indication of the failure surface and would have clarified the exact mechanism of this particular slope failure.
The authors are to be congratulated for presenting a case study of a practical problem in deep foundations. The paper describes the geotechnical investigation and foundation design at the site of a multi-storage building in Dehradun City, India. The paper compares the predicted load capacity of cast-in-place piles to the results of actual pile load tests performed at the site.

This paper provided a comprehensive description of a typical foundation design from exploration through design decision, and finally, foundation testing. However, the inclusion of several details would have increased the value of the paper. The size and area of the proposed building is not stated. It appears from the sectional elevation (Figure 2) that a basement is also proposed at the site. If this was the case, was the option of providing a floating foundation evaluated? The provision of a floating foundation would have reduced the final contact stress on the compressible clay layer and would have also reduced the thickness of the compressible stratum below the foundation. The results of the pile load tests as compared to the design calculations presented in this paper are comparable to results the reviewer has experienced in several of his own designs. Finally, this writer would like to suggest that it would have been easier for some English speaking readers if the commonly used equivalence of "Nalla" (creek or ravine) and "Kankar" (pebbles) were also presented.

Author's Reply to Discussion by Alan Wagner

Thank you for the valuable discussion on my paper. The following is the author's reply to the discussion:

Vibration propagation in soil takes the form of wave propagation. The law of the vibration propagation depends on the wave patterns in the soil at different distances from the source and on the propagation law of the wave patterns.

It is known from theoretical analysis that when a point source is applied on the surface of a semi-infinite elastic medium, the longitudinal and transverse waves propagate in the form of \( r^{-2} \) in the vicinity of the source while the Rayleigh wave propagates in the form of \( r^{-\frac{1}{2}} \) in areas comparatively far from the source.

In actual conditions, however, soil is not a homogeneous and isotropic medium. Therefore, the attenuation of elastic waves in short distance is in the form of \( r^{-\frac{1}{2}} \) instead of \( r^{-2} \).

(here \( r \) is the distance from the source)