Rec'd 5/8/81
J. Kane
11/83

NRC STAFF TESTIMONY OF H.N. SINGH, P.E. ON UNRESOLVED SAFETY ISSUES
(GEOTECHNICAL ENGINEERING)

Q1. Please state your name and position with the Corps of Engineers.

A. My name is Hari Narain Singh. I am a Civil Engineer with the U.S. Army Corps of Engineers, Detroit District.

Q2. Have you prepared a statement of your professional qualifications?

A. Yes. A copy of this statement is attached.

Q3. Please state the nature of the responsibilities that you have had with the Corps of Engineers before assuming your assignment of reviewing the geotechnical aspects of the Midland Nuclear Power Plant.

A. I worked in the Design Section of the Technical Branch, and was responsible for designing and reviewing designs of structures involving soil structure interaction such as sheet piles, earth anchors, friction and bearing piles, machine foundations, foundations for buildings. I was also responsible for design and review of designs of dikes for dredged material disposal facilities.

Q4. Please state the purpose of this testimony.

A. The purpose of this testimony is to apprise the Atomic Safety and Licensing Board (ASLB) of the safety related problems pertaining to geotechnical engineering, at the Midland Nuclear Power Plant Site.

Q5. When did the Corps of Engineers get involved and what were the areas of its review and the limits of their responsibilities?

A. According to Interagency Agreement No. NRC-03-79-167, which began on 25 September 1979, the U.S. Army Corps of Engineers is obligated to provide technical assistance to the U.S. Nuclear Regulatory Commission (NRC) as to Geotechnical Engineering concerns in reviewing and evaluating the Preliminary Safety Evaluation Report (PSAR) and the Final Safety Evaluation Report (FSAR) submitted by the applicant for a Construction Permit (CP) or Operating License (OL).

The reviews are to be conducted using the guidance contained in the NRC Regulatory Guides, industry standards, and the guidance and the acceptance criteria in the Standard Review Plan (SRP) in the areas of geotechnical responsibility. The approach outlined below was to be followed:

(i) Recommend requests for additional information or clarification based upon initial review and evaluation of the information provided by the applicant.

(ii) Evaluation of the responses provided by the applicant.

(iii) Attendance at meetings with the staff and the applicant to discuss and resolve outstanding issues, and audit the implementation of the applicant commitments.

(iv) Preparation of a Safety Evaluation Report (SER) input which describes the evaluation of the design of the applicant's safety related (and some non-safety related) systems.

(v) Attend meeting with the Advisory Committee on Reactor Safeguards (ACRS) and public hearings to assist the staff in explaining bases for conclusions and positions reached in the SER.

(vi) Preparation of input to SER supplements which further clarify and document systems evaluations in the SER based upon review by the ACRS.

Q6. What is Geotehnical Engineering? Why is it necessary to review the geotechnical aspects of the Midland Nuclear Power Plant?

A. Geotechnical Engineering is a branch of Civil Engineering which deals with the foundation of structures and the soil supporting them. It includes soil exploration study of soil properties under various environmental and loading conditions, soil-structure interaction and then by utilizing these information, determination of adequate foundations for structures.

A foundation is the part of a structure which serves to transmit to the soil beneath it, its own weight, the weight of the superstructure above it and any force which might act upon it. A foundation is therefore, the connecting link between a superstructure and the soil. A foundation should be designed to support the loads and moments acting on it and distribute the loads in a satisfactory manner over the contact surface of the soil layer over which it rests. In order to be satisfactory, this distribution must not produce excessive stresses within the soil mass at any depth beneath the foundation. The term excessive stress implies a force per unit area which would cause a complete rupture within the supporting soil mass and result in noticeable tilting and/or sinking of the structure as a whole. Stresses are also to be rated as excessive, if they cause a settlement of the supporting soil surface so uneven that the structure above it would crack or be otherwise damaged while undergoing deformations resulting from this uneven settlement. Thus, the importance of a foundation is self evident, since no structure can endure without an adequate foundation.

A foundation will naturally tend to follow any settlement of the soil on which it rests. In turn, the superstructure will follow the settlement of the foundation which supports it. Both will tend to equalize uneven settlements by resisting deformation and thereby transmitting more load to those parts of the soil surface which have settled least. No deformation of the soil surface benenath a structure can take place without a corresponding deformation of both the foundation and the superstructure above it. Undue deformation in a structure due to uneven settlement of the soil can occur if soil of variable

density and physical properties is supporting the structure. The undue deformation might cause serious cracking which will reduce the load carrying capacity of the structure.

To ensure safety against sinking, tilting, cracking of the safety related structures at the Midland Nuclear Power Plant, particularly due to the inadequate compaction of fill material, it is imperative to review the geotechnical aspects of all the Category-I structures deriving support from the plant fill.

Q7. State specifically, the names of the safety related structures which the Corps of Engineers were requested by the NRC to review. Also state specifically the geotechnical aspects reviewed to insure the safety of these structures, and the sources which furnished the Corps the review materials.

A. According to the interagency agreement between the Corps of Engineers and the NRC, the Corps of Engineers is obligated to review the geotechnical aspects of all safety related, Category-I structures under both static and dynamic conditions to the safe shut down and operating basis earthquakes. These structures include:

(i) Reactor Buildings
(ii) Auxiliary Building
(iii) Diesel Generator Building
(iv) Service Water Structure
(v) Diesel Fuel Storage Tanks
(vi) Borated Water Storage Tanks
(vii) Category-I Underground Piping System
(viii) Emergency Cooling Pond (enclosing dikes)

The geotechnical aspects reviewed included:

(a) A review of the site investigation program, both field and laboratory, to assure that an adequate determination of all surface conditions has been achieved including consideration of borrow sources. This may require recommendation for additional investigations to obtain the required data.

(b) Evaluations and recommendations pertaining to proposed design criteria.

(c) A review of the bearing capacity and settlement analyses performed by the applicant and, in many cases, the performance of independent bearing capacity analyses. A review of the slope stability of the Category-I dikes. A determination that the applicant has presented adequate bases to support design parameters used in its analyses.

(d) An evaluation of the stabilization technique proposed by the applicant to solve site foundation problems. Recommendations for stabilization.

(e) In regard to most cases, field trips were necessary to inspect the site, to observe sampling and testing of soil, and to evaluate the adequacy of the techniques and equipment.

The information to be reviewed was included in the Final Safety Analysis Report (FSAR) and the pertinent amendments to it, and in the responses to 10CFR 50.54(f) requests regarding the plant fill, which all were forwarded by the applicant to the Corps of Engineers. The review included an evaluation of information included in Sections 2.5, 3.7 and 3.8 of the FSAR and 10CFR 50.54(f) documents which addresses the adequacy of soil mechanics, earthquake engineering and the foundation engineering in order to assure the safe siting and operation of all the seismic safety related Category-I structures and conduits. The review was conducted in accordance with the NRC Standard Review Plans Section 2.5.1, 2.5.2 and 2.5.4. Specific guidance in review was obtained from the NRC Regulatory Guides 1.132, 1.138 and 1.70.

Q8. What were the results of your review of the materials pertinent to geotechnical engineering provided in the FSAR and in the applicant's responses to 10CFR 50.54(f) requests?

A. The geotechnical information pertaining to each of the Category I structure and conduit provided by the applicant in the FSAR and responses to 10CFR 50.54(f) requests were reviewed by the Detroit District Corps of Engineers. The details of the review comments are provided in the Corps of Engineers' Letter Report of 7 July 1980, and in the Corps of Engineers' review comments of 17 April 1981 on the applicant's Amendment 85 to the operating license requests and on Revision 10 to the 10CFR 50.54(f) requests. A brief description of the descrepancies noted for each structure is given below.

(a) Reactor Building Foundation.

The soils and foundation information pertaining to the Reactor Building provided in the FASR are based on the original design which assumes no site dewatering. Site dewatering is not proposed. The Corps' report of 7 July 1980 pointed out this descrepancy and requested the applicant (Question 39, 10CFR 50.54(f)) to discuss and provide analyses for settlements and bearing capacity for the foundation soils considering the effect of permanent dewatering proposed by the applicant to preclude liquefaction under the plant area. The applicant's response to question 39, 10CFR 50.54(f) is not acceptable. The Corps of Engineers' comments of 17 April 1981 on Amendment 85 provide the details.

(b) Diesel Generator Building.

The Diesel Generator Building was reported to have settled. The magnitude of the settlements varied from one end to another end along the length and the width of the building with maximum settlement at the southeast corner and the minimum at the northwest corner. The settlements measured in the time interval between 28 March 1978 and 19 January 1979 indicated a maximum settlement of 4.25 inches at the southeast corner and a minimum settlement of 2.09 inches (Fig 27-10 of 10CFR 50.54(f) responses). The settlements would

cause a warping of the structure's foundation. The settlements which occurred prior to 28 March 1978 were not reported in the responses to 10CFR 50.54(f) requests.

In an effort to determine the cause of the excessive differential settlements, the applicant began a soil exploration program which indicated soil fill of very substandard compaction. As indicated by the blowcounts of the standard penetration test, the quality of the fill material varied from loose sand to dense sand and from soft clay to stiff clay, indicating very poorly compacted soil.

The applicant preloaded the area inside the building and a 20' wide area immediately outside the outer walls of the building with a 20' high sand pile (2.2 kips per square foot) to accelerate the settlements and to achieve a stable foundation prior to making connection to the building with outside pipe lines. As a result of this preloading, the building settled further with a total maximum settlement of 7.45" (4.25"+3.2") at southeast corner and a total minimum settlement of 3.49" (2.09+1.5) at northwest corner. The settlement data at the corners obtained after the surcharge indicated warping of the foundation still existed.

With the changed density of the fill material due to preloading on which the Diesel Generater Building is founded, the soils and foundation information pertaining to this building provided in the FSAR are no longer valid. The bearing capacity, settlement predictions for the 40 year plant lifespan must be reevaluated on the basis of the soil paramenters obtained from the test results on representative soil samples taken from the actual fill material.

In response to 10CFR 50.54(f) requests, the applicant has furnished information regarding settlements and bearing capacity of soils under the footings of the Diesel Generator Building. The Corps of Engineers in there report of 7 July 1980 requested additional information needed to evaluate the adequacy of the foundation of the Diesel Generator Building and others. The information needed was explicitly spelled out in the 7 July 1980 report which was transmitted to the applicant on 4 August 1980 by the NRC. The applicant responded to the request through its Amendment 85 to the operating license request and Revision 10 to 10CFR 50.54(f). The details provided in the applicant response were not adquate to evaluate the stabitily of the structure. The Corps of Engineers comments of 16 April 1981 on Amendment 85 and Revision 10 to 10CFR 50.54(f) shows the reasons for the applicant's response not being adequate.

In addition, I would like to inform the Board, that severe damage to the integrity of the structure has already been done due to the settlements caused by the weight of the structure and the additional settlements caused by the preloading. Many diagonal tension cracks have appeared on the east wall of the structure indicating the structure has been subjected to servere stresses and strains due to differential settlements. There is no guarantee that these cracks have stabilized and would not propagate when the structure will be subject to enviromental loads (earthquake, tornado, servere termperature variations, wind load etc.) in future.

(c) Service Water Building Foundation.

The Sevice Water Building is founded partly on the original ground and partly on the fill material. The foundation elevation for the portion of the structure founded on original ground is 587.00 and that for the portion on fill material is 617.00. The walls of the portion founded on fill cracked indicating settlement of the building. The applicant as in case of the Diesel Generater Building began a soil investigation program which indicated some poorly compacted soil underneath the foundation. As per applicant's MCAR 24 Interim Report 6, June 11, 1979, the fill material was summarized as soft to very stiff clay and loose to very dense sand backfill. Some areas of the fill material under the northern part of the structure have not been sufficiently compacted.

As a corrective action, the applicant proposed to support the north wall on 16 underpinning piles driven into the glacial till through predrilled holes in the fill material. The design capacity of each piles was to be 100 tons. The piles were to be placed a few inches away from the outside face of the north wall and was to be connected with the wall with shear connection or other mode dowels. Figure 83 of the applicant's MCAR 24 Interim Report 6 shows the preliminary arrangement of the underpinning system.

The Corps of Engineers performed the preliminary review of the applicant's proposal and wanted more information to check the adequacy of the proposal to carry the loads under the static and seismic conditions. The information required to complete the review was included in the Corps of Engineers' letter report of 7 July 1980 (Question 40, 10CFR 50.54(f)). A copy of the report was trasmitted to the applicant by the NRC on 4 August 1980 for its response. The applicant's response to question 40, Amendment 85 to the operating license request, and revision 10 to 10CFR 50.54(f) was reviewed. The information provided by the applicant was found to be inadquate. The Corps of Engineers review comments of 16 April 1981 on Amendment 85 shows the details of the information still required.

(d) Auxiliary Building Electrical Penetration Areas Feedwater Isolation Value Pits.

The Electrical Penetration Areas (EPA) and the Feedwater Isolation Valve Pits (FIVP) for the Reactor Units 1 and 2 are founded on the plant fill area. The Reactor Buildings and the main body of the Auxiliary Building are founded on glacial till. A soil investigation by the applicant for all Category-I Structures founded on fill material, after the discovery of the excessive settlements of the Diesel Generator Building, indicated layers of loose sand and soft clay (MCAR 24, Interim Report 6, page 3) in the soil mass under the Electrical Penetaration Area and the Feedwater Isolation Value Pits. The applicant, on page 4 of MCAR 24, Interim Report 6, concluded that approximately 15 feet of the backfill material under the Electrical Penetration Areas and the Feedwater Isolation Valve Pits has not been sufficently compacted.

Because of the poor soil conditions (loose sand and soft clay) attributed to inadequate compaction, the actual soil parameters (shear strength parameters, compressibility coefficients) of the soil are not the same or better than the assumed design soil parameters provided in the FSAR. The values of ultimate bearing capacity provided in Table 2.5-14 of the FSAR for the EPA and FIVP are not valid. Also the settlement values for these structures provided in the FSAR would change. As a matter of fact, the effects of the poor soil conditions under the foundations have already become visible in the form of cracks in the walls of the structures, and the structures have partially lost their structural integrity. The capability of these structures to withstand environmental loads (earthquake, tornado, etc. ) is questionable.

As a corrective action, the applicant has proposed the following actions:

The unsuitable backfill materials (inadequiately compacted materials) under the Feedwater Isolation Valve Pits of both Units 1 and 2 will be removed and be replaced by lean concrete (fc'=2000 p.s.i.). The Electrical Penetration Areas will be supported on caissons. The caissons will be provided under the structures at their free ends (near their junctions with the FIVP), and at the other ends, supports to the EPA will be provided by the control tower with which they are built monolithicly.

The Corps of Engineers found the applicant proposal at a conceptual stage and requested the applicant to furnish analyses for capacity of caissons, soil parameters used in the analyses, construction plans and specifications etc. for a complete review to determine the adequacy of the proposal. The details of the information requested are given in the Corps of Engineers' Letter Report of 7 July 1980. The NRC transmitted this report to the applicant on 4 August 1980 for its response. The applicant's response to the Corps request regarding the Auxiliary Building EPA and FIVP (Question 42 of the letter report) was reviewed and the information furnished by the applicant was not adequate to evaluate the adequacy of the applicant's proposal. The Corps of Engineers review comments of 15 April 1981 on Amendment 85 shows the needed information, and the analyses to complete evaluation of the proposal.

(e) Borated Water Tanks,

The Borated Water Tanks were built on the fill material despite the numerous evidences that compaction of fill material was questionable (settlements of the Diesel Generator Building, cracking of the Service Water Building and portions of the Auxiliary Building founded on the fill materials). Prior to their construction, the NRC through Question No.6, 10CFR 50.54(f) requested the applicant to provide justification for constructing the safety-related tanks on the questionable fill material.

Based on some preliminary soil investigation, the applicant concluded that the soil conditions in the area where the tanks were founded would be adequate, and it completed the construction of the tanks. The Corps of Engineers reviewed the applicant's response to Question 6 and 31, 10CFR 50.54(f) which pertain to foundations of the two Borated Water Tanks, and requested soil information needed to evaluate the adequacy of the tanks foundation. The

details of the requests are included in the Corps of Engineers Letter Report of 7 July 1980. The NRC transmitted the Corps' requests to the applicant on 4 August 1981 for its response. The applicant's response to the requested information as to the tanks (Question 43) was reviewed by the Corps of Engineers and was found to be inadequate to complete the review. The soil modulus of subgrade reactions used by the applicant to analyze the ring beam foundations of the tanks was not compatible with the type of soil conditions prevailing under the Borated Water Tanks. It appears that the applicant has performed no test to evaluate the variationin the modulus of subgrade reaction because of the varying density of the soils along the depth as well as across the diameters of the tanks as indicated by the borings. The details of the discrepancies noticed in the applicant's response to the Corps of Engineers' request of 7 July are included in the Corps review comments of 16 April 1981 on Amendment 85. It has been reported recently that the ring beams of both the tanks have cracked severely when the tanks were filled with water to perform load tests of the foundation soil.

(f) Underground Diesel Fuel Tank Foundation Design.

The Underground Diesel Fuel Tanks are buried in the questionable fill materials, and are anchored to concrete pads with their bottom elevation at 612.00. The tanks are covered with fill material. The Corps of Engineers has reviewed the information submitted by the applicant in response to NRC Question 31, 10CFR 50.54(f) and to the Corps of Engineers' requests forwarded to the applicant on 4 August 1980. The applicant's response was not satisfactory. The applicant must demonstrate by analysis that the tanks are safe against uplift pressure. Also, a settlement analysis of the tanks due to seismic events is necessary because some of the boring logs indicate a layer of loose sand below the pads. The details of the information required to complete the review are given in the Corps of Engineers comments of 16 April 1981 on Amendment 85.

(g) Underground Utilities

Because of the questionable plant area fill discovered after the excessive settlements of the Diesel Generator Building, it became necessary to investigate for the additional stresses developed in the Seismic Category I pipings due to the settlements of the fill material. Because of the natural soil structure interaction between the piping and the surrounding soils, the pipes conformed to the configuration of the settling soil mass resulting in bending of the pipes, introducing bending stresses in the pipes beyond the permissible limits.

The Corps of Engineers evaluated the stresses in one of the pipes (26" dia OHBC-54) using the information furnished by the applicant in response to the 10CFR 50.54(f) requests. As shown in the Corps of Engineers Letter Report of 7 July 1980, the stresses developed due to curvature caused by the settlements was found to be 130 KSI exceeding the permissible limit by more than 100%. A copy of the Corps of Engineers Letter Report was forwarded to the applicant by the NRC on 4 August 1980. But the applicant has not yet responded to the Corps of Engineers evaluation of the underground piping stresses.

The plant fill around the Diesel Generator Building was consolidated under the preload, therefore, the Category-I water circulating piping within this area were subjected to additional settlements. The Corps of Engineers requested the applicant to perform a thorough inspection of these piping with video cameras and sensing divices for possible areas of crackings and openings. The applicant's response to this request (Amendment 85 and Revision 10 to 10CFR 50.54(f)) was not satisfactory. As stated in the Corps of Engineers' review comments of 16 April 1981 on Amendment 85, it not possible to evaluate the adequacy of the piping in absence of the requested information.

During the site visit on 19 February 1980, the Corps of Engineers representatives observed three instances of what appeared to be degradation of rattlespace at the penetrations of Category-I piping through concrete walls. The Corps of Engineers Letter Report of 7 July 1980 explains these descrepancies in detail and requests information from the applicant to evaluate the adequacy of the rattlespaces.

The applicant's response received through Amendment 85 to the operating license request, and Revision 10 to 10CFR 50.54(f) was reviewed by the Corps of Engineers and some discrepancies in the applicant's information were noticed. The Corps of Engineers' comments of 16 April 1981 show the discrepancies noticed and the clarifications required from the applicant.

The stability of the two reinforced concrete discharge pipes which exit the Service Water Pump Structure, run along either side of the Emergency Cooling Water Reservior, and ultimately enter into the reservior, have not been demonstrated by the applicant to be adequate. The Corps of Engineers' Letter Report of 7 July shows the information required by the Corps to complete review of the stability of these pipes. The applicant's response to this request was very unsatisfactory. The applicant has not used the proper soil parameters to analyze the stability of dike's bases from which these pipes derive their support. The Corps of engineers review comments of 16 April 1981 on Amendment 85 shows the details of information still needed to complete the review.

(h) Cooling Pond.

A detailed review of the FSAR has indicated that the applicant has taken no record sampling during construction of the dikes to verify the design assumptions as to the soil shear strength parameters. It has performed no field control tests for compacted soil in the dikes above elevation 620+. Thus, the applicant has not demonstrated that the required compaction of the fill material in the dikes has been achieved. In recognition that the type of the embankment fill and the compaction control used to construct the dikes for the cooling pond were the same as for the problem plant fill, the Corps of Engineers requested reasonable assurance that slopes of the Category-I Emergency Cooling Pond (baffle dike and main dike) are stable under both the static and the dynamic loads. The details of the information required to evaluate the stability of the dikes, slopes and the Category-I pipes buried under the slopes are given in the Corps of Engineers' Letter Report of 7 July

1980, which was transmitted to the applicant by the NRC on 4 August 1980. The applicant's response was received through Amerndment 85 to the operating licence request and Revision 10 to 10CFR 50.54(f) requests. The Corps of Engineers reviewed the response and found the information provided in the response inadequate for the review. The Corps of Engineers' review comments of 16 April 1981 on Amendment 85 show the discrepancies and the information needed by the Corps to complete the evaluation of the stability of the slopes and the concrete discharge pipes.

The operating Cooling Pond Dikes are not Category I Structures. However, a high level of safety should be requred for these dikes unless it can be assured that a failure will not: (a) endanger public health and properties, (b) result in an assault on the environment (c) impair needed emergency access to the plant power block.

(i) Site Dewatering.

The applicant's soil exploration of the plant fill indicated layers of loose sand under several Category-I Structures, which are subject to liquefaction under siesmic events. To eliminate the possiblity of liquefaction, the applicant proposed to lower the water table to an elevation of 595 by a permanent dewatering device. Most of the loose sand layers were above elevation 610.

The Corps of Engineers reviewed the materials furnished by the applicant as to the permanent dewatering and requested additional information as outlined in its Letter Report of 7 July 1980. The information furnished by the applicant in response to the Corps request was mostly satisfactory. However, some minor discrepancies still exist. The Corps' review comments of 16 April 1981 Amendment 85 show the discrepancies noticed. It is emperative to resolve the discrepancies to assure adequate dewatering.

(j) Seismic Analysis of the Structures on Plant Fill Materials.

The applicant's seismic analyses were reviewed by the Corps of Engineers. The methods of analysis followed appeared satisfactory, however, certain parameters such as damping ratio (actual damping as a percent of critical damping) and shear modulus of the soil used in the analyses were not known to the reviewers. The shear modulus computed using the shear wave velocity provides a very low strain shear modulus and is not applicable to seismic events. The applicant has to clarity these points.

(9) Did Corps of Engineers request soil exploration and testing? If so what were the reasons for the request?

The soil exploration and testing were initially requested by the Corps of Engineers in its letter of 27 March 1980 to Dr. Robert E. Jackson of the NRC and were later revised in its letter of 16 April 1980.

Because of the inadequately compacted plant fill materials, the physical properties (shear strength parameters, compressibility coefficients, etc.) of

the fill materials have degraded from those used in the design of the foundations of the several Category I structures and the piping deriving its support from the plant fill. Also, the load on the soil mass below the footings would be considerably increased due to proposed permanent dewatering of the site. The effects of degraded physical properties of the soil are apparent from the excessive settlements of the Diesel Generator Building and the crackings of the walls of the several Category-I Structures (Service Water Structure, Auxiliary Building, Diesel Generator Building) founded on the inadequately compacted fill.

In view of these facts, it was imperative to determine the actual soil properties of the plant fill and reevaluate the bearing capacity of the foundation soils and the predicted settlements of the structures, using the actual soil parameters. The bearing capacity and settlement information provided in FSAR no longer valid because of the changes in the soil physical properties and the increased load on the soil mass due to dewatering. The Corps of Engineers requested the applicant to perform consolidation tests and triaxial shear tests on undisturbed samples taken form the plant fill area where Category-I structures are located.

(10) What is an undisturbed sample and why is it necessary to test undisturbed samples?

Preconstruction site investigations are required to determine geotechnical conditions that affect the feasibility of a project, design, cost, performance, and ultimate safety of the structure. It is necessary that the investigations be adequate in terms of thoroughness, suitability of methods used, and quality of execution of the work to assure that all important conditions have been detected and reliably evaluated. An important phase of any site investigation is obtaining high quality, undisturbed samples of subsurface materials. In the case of the Midland Nuclear Power Plant, because of the changed soil conditions due to inadequate compaction, testing of undistrubed samples is imperative to ascertain the actual soil design parameters.

In the current state of the art of soil sampling, the term undisturbed sample means a sample that is obtained and handled by methods designed to minimize the disturbance to the sample that might occur during the sampling, handling, shipping, storage, extrusion, specimen preparation for testing and the laboratory setup processes. In fact, there is no such thing as truly undistrubed sample, primarily for two reasons: (1) a sampling tube displaces a certain amount of soil which inevitably produces strain and some distrubance to the sample; and (2) even in perfect sampling, and imaginary process that eliminates disturbance due to soil displacement, the state of the stress into the soil sample undergoes a complex, and of some degree indeterminate history of change during sampling and handling .

The purpose of obtaining soil samples and testing them, is to determine the physical properties of the soils which are going to provide support for the structures to be built. The importance of the structure dictate the quality of the soil information to be obtained from the test results. For ordinary

structures where public safety is not threatened in case of any failure, a very high quality undisturbed soil sample may not be necessary. But in the case of a Nuclear Power Plant where the failure of the structures involved in the plant must be guarded at all costs, it is imperative to have the highest quality undisturbed soil samples for testing to obtain the physical properties the soils possesses in its natural state under the foundation.