MID ASSIGNMENT / QUIZ
Spring 2020

PAVEMENT MATERIAL ENGINEERING

M.S (Civil Engineering)

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QUESTION NO 01.

1. Given Figure. 1 refers to which phenomena of the pavement conditions?

2. Find the phenomena and discus that phenomena / behaviour for flexible pavement with granular base and stabilized base.

ANSWER:

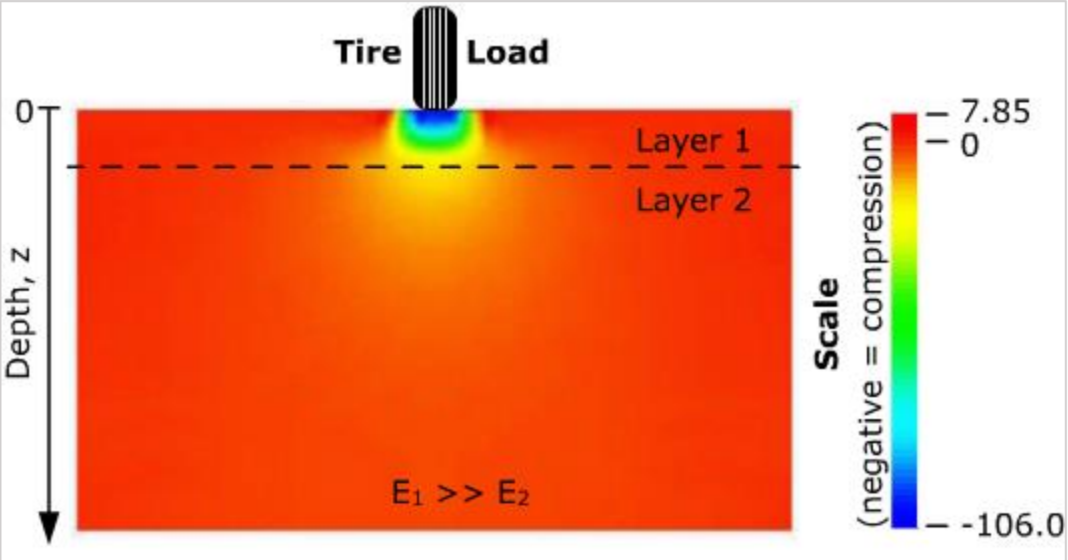


Figure. 1

The figure refers to the vertical stresses in the flexible pavement. This is a typical example of a two-layered system. The vertical stress on the top of subgrade is an important factor in pavement design. The function of a pavement is to reduce the vertical stress on the subgrade so that detrimental pavement deformations will not occur. The allowable vertical stress on a given subgrade depends on the strength or modulus of the subgrade. To combine the effect of stress and strength, the vertical compressive strain has been used most frequently as a design criterion. This simplification is valid for highway and airport pavements because the vertical strain is caused primarily by the vertical stress and the effect of horizontal stress is relatively small.

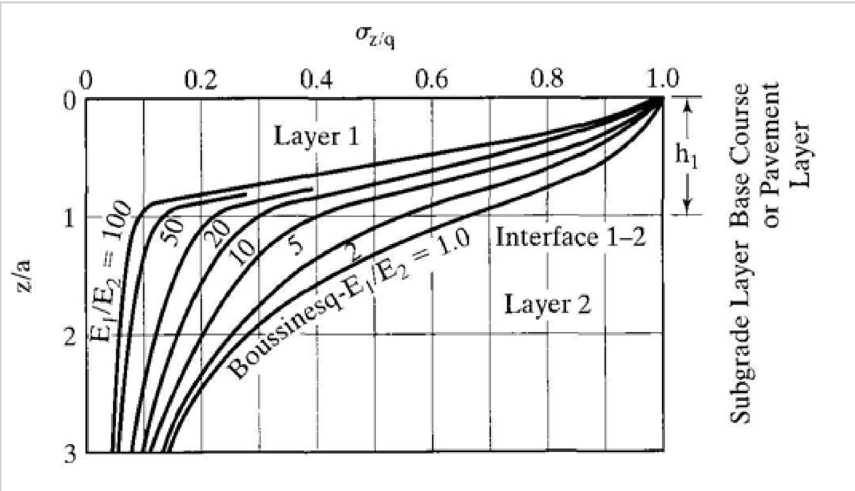


Figure. 2

The stresses in a two-layer system depend on the modulus ratio E1/E2 and the thickness–radius ratio h1/a. Vertical stress decreases considerably with increase in modular ratio. At the pavement–subgrade interface, the vertical stress is about 68% of the applied pressure if E1/E2 = 1, as indicated by Boussinesq's stress distribution, and reduces to about 8% of the applied pressure if E1/E2 = 100. For a given applied pressure q, the vertical stress increases with the increase in contact radius and decreases with the increase in thickness. The reason that the ratio a/h_1 instead of h_1/a was used is for the purpose of preparing influence charts for two-layer elastic foundations.

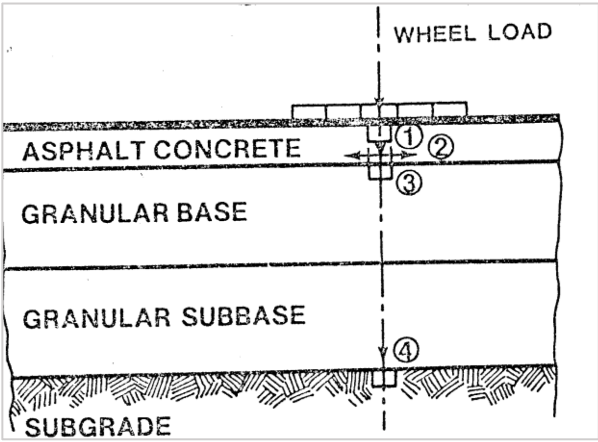


Figure. 3 Flexible Pavement with Granular Base

When a flexible pavement is constructed with a granular base on top of sub base and surfaced with asphaltic layer (as shown in above figure), the following strains at different location can occur with application of load:

1. Compressive Strain
2. Tensile Strain
3. Compressive Strain
4. Compressive Strain

At point-1, the top portion of the asphaltic layer experiences compressive strain while the lower portion is in tension (point-2) and hence causes tensile strain which will eventually lead to fatigue cracking of the pavement. The top portion of granular base layer will be in compression (point-3) and may cause rutting due to the strain. With the application of heavy load, the top of the subgrade may experience excessive vertical stresses and can cause compressive strain consequently causing permanent deformation or depression in pavement.

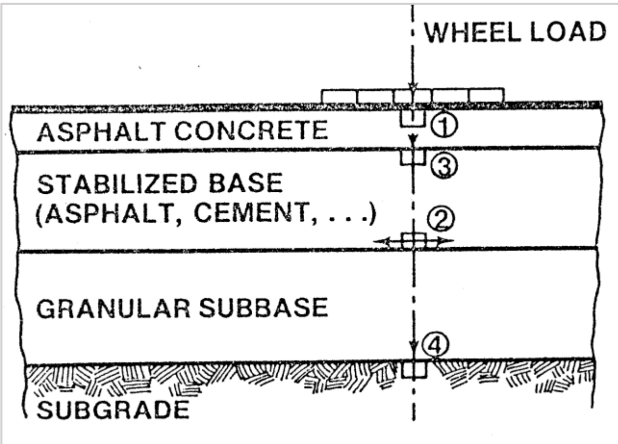


Figure. 3 Flexible Pavement with Stabilized Base

When a flexible pavement is constructed with a stabilized base on top of sub base and surfaced with asphaltic layer (as shown in above figure), the following strains at different location can occur with the load application:

1. Compressive Strain
2. Tensile Strain
3. Compressive Strain
4. Compressive Strain

In this type of pavement, the tensile strain occurs at the lower portion of the stabilized base (point-3) which may lead to fatigue or bottom up cracking. Here, the compressive strain will arise on the top of asphaltic layer (point-1), stabilized base (point-2) and subgrade top (point-4) which may consequently cause permanent deformation/ rutting in the pavement.

QUESTION NO 02:

Being a material design expert, if client department award you the consultancy for preparation of the geotechnical report for the upcoming road project. Which steps (General Procedure) you would consider while soil investigation and preparation of Geotechnical Report. Also elaborate the steps briefly in your own words.

ANSWER:

SOIL INVESTIGATION REPORT:

The results of soil exploration, including field investigation and testing, as well as the laboratory test results and their analysis, along with suitable recommendations, are presented in the form of a soil investigation report. The soil investigation report is an important legal document that is used as the basis for design of foundations or earth structures as well as their construction. The report also forms the basis for investigating any potential instability or failure of the structure during its life. As such, the soil investigation report should be prepared with utmost care.

Preparation of a geotechnical investigation report is an engineering art, and professional experience plays its due role in documentation. The soil investigation report should be clear and precise, without any scope for ambiguity in the estimate of soil parameters, analysis, and interpretation as well as recommendations. The quality of a soil investigation report essentially depends on the geotechnical investigation – a well-planned and properly executed geotechnical investigation with necessary field and laboratory testing and sampling coupled with judicious analysis is a prerequisite for a good geotechnical investigation report.

PURPOSE & OBJECTIVES OF GEOTECHNICAL INVESTIGATION REPORT:

1. To ensure a safe and economical design of foundation.
2. To minimize settlement and heave or any such problems during the life of the structure.
3. To predict and adopt measures to control possible construction problems.
4. To investigate into potential failure of existing structures to evolve an alternate design.

ESSENTIALS OF GEOTECHNICAL INVESTIGATION REPORT:

1. Details of the proposed structure.
2. Site conditions, including geological and topographical features.
3. History of land use.
4. Details of the adjacent structure(s).
5. Details of field investigations, including field testing and sampling.
6. Laboratory test results.

VOLUMES OF GEOTECHNICAL INVESTIGATION REPORT:

There can be a voluminous report and can consist of two volumes.

- Volume I, is the main body of the report and contains the main text, summarized data sheets, location maps indicating the geographical location of the site, proposed structure, various field tests and sampling, soil profiles, etc.
- Volume II contains the supporting calculations pertinent to the data in Volume I, data of field, laboratory tests and investigations, etc.

GENERAL PROCEDURE/STANDARD FORMAT:

1. Title Page
2. Table of Content
3. Client's Requirements
4. Introduction.
5. Objectives of the geotechnical investigations.
6. Details of the proposed structure
7. Site conditions.
8. Field investigations & Laboratory Tests:
9. Soil profile and Site Plan
10. Analysis and interpretation of the results.
11. Foundation alternatives.
12. Graphs
13. Conclusions and Recommendations.
14. Limitations and uncertainties of soil exploration.
15. Annexure.

EXPLANATION:

TITLE PAGE

The title page of the report includes the name of the company, its address, principle investigator who has worked on the report and other relevant details of the company e.g. logo. It also includes the name of the Project, location of the project and the period of work. Client name and submission dates may also be mentioned on the title page as per requirement.

TABLE OF CONTENT:

It contains the List of chapters or sections of the report for easy going through. A separate list of graphs, figures or annexes may also be included the report.

CLIENT'S REQUIREMENTS

This is the section where the requirements and objectives of the client are listed. Here, all the information required by the client from this particular investigation is described and the names of the tests needed to collect that information are listed. In short, the scope of report is defined here, like what this report is going to achieve.

INTRODUCTION:

This section indicates the client company and the project for which geotechnical investigations are carried out, its location, the name(s) of the case investigator(s), the main objective or context of the geotechnical investigations, and the reference to the work order by the client company.

OBJECTIVES OF THE GEOTECHNICAL INVESTIGATIONS:

This section gives the detailed objectives for which the geotechnical investigations are being carried out. If the case investigator feels that the scope is inadequate, the same should be clearly stated, which will become important when the soil or foundation is found to behave differently from the predictions of the report due to inadequate geotechnical investigations.

DETAILS OF THE PROPOSED STRUCTURE:

This section gives the type and number of the proposed structure(s) in the site, along with the extent of its area. This also specifies the nature of the structure, that is, whether sensitive or non-sensitive, or light or heavy, and the nature of its use and possible loads and discharges that the underlying formation will be subjected to from the proposed structure. The location of the proposed structure should also be shown in the site plan.

SITE CONDITIONS:

This section gives the nature of the ground surface at the site, whether undulating or flat. If the ground is highly uneven, reference should be made to a relatively permanent datum from which the depth to various soil strata and the sampling are measured. This section presents a brief account of the geology and morphology of the area, including the presence of a hill or valley water courses or ponds, and cultivated land within and outside the site. It also gives information about the land use history of the site, existence of any old structure or mines within or in the neighbourhood of the site, and also any other observations or findings during field visit which is useful in deciding the design parameters. This section also provides a survey map showing the geographical location of the site and the proposed structure.

FIELD INVESTIGATIONS AND LABORATORY TESTS:

In this section general information regarding the location of the site is discussed as well as what tools, techniques and methods were used in the whole process of this geotechnical investigation. The report discusses which tests were used to collect which type of information, how samples were collected, what safety or precautionary measures were taken and how the tests were conducted in the field and in the laboratory. The report writer can also add a summary of the results of different tests that were conducted e.g. values of sieve analysis or Atterberg's limits of soil samples. A list of relevant field tests may include following soil tests:

1. Borehole drilling activity
2. Standard penetration test

A list of relevant laboratory tests for geotechnical investigation of soil are as follows:

1. Determination of moisture content and bulk density
2. Atterberg's limits
3. Particle size distribution by sieve analysis
4. Unconfined compression testing

A detailed explanation of all the results obtained through the test must be provided in this section.

SOIL PROFILE AND SITE PLAN:

Site plan is a sketch of the site showing all the relevant physical features around the building site, like drains, existing buildings, road, open spaces etc. The drawing should also show the location of the boreholes, if bore holes have been dug. Soil stratification at each borehole, based on the colour of the drilling fluid and soil fragments and observation of the soil samples as well as on the analysis of field and laboratory tests, is reported in this section. The depth to the top of each stratum and the thickness of each stratum for each borehole should be specified. The depth to the top of soft and hard rock should be reported in this section, along with the degree of weathering. The soil and rock profile should be presented in the form of a bore log for each borehole and enclosed as an annexure. The variation in the soil or rock profile across adjacent bore logs or test pits is brought out and the logs are presented such that they join the profiles at various borehole locations.

ANALYSIS AND INTERPRETATION OF RESULTS:

The results obtained from the field investigations, laboratory testing, and safe bearing capacity (SBC) computation as well as specific observations during the field investigations are thoroughly reviewed in this section vis-a-vis the soil classification based on the laboratory tests and field observations. The general characteristics of the soil and the nature and extent of their variation over the site should be conclusively described. The anticipated design and construction problems and the influence of soil characteristics (such as shear strength, compressibility, swelling, and GWT) and seepage should be brought out in this section.

FOUNDATION ALTERNATIVES:

The nature and magnitude of the loads from various portions of the proposed structure, the soil profile, and the soil characteristics at different depths, should be used as guidelines in working on suitable foundation alternatives for the structure and in taking a judicious decision based on the strength, economic, and long-term stability considerations.

GRAPHS

This is the section where all the results obtained are graphed and shared with the client. These graphs may include grain size distribution curve, results of the liquid limit, plasticity chart, SPT results etc. for all types of soils encountered at the required depth at the site.

CONCLUSION AND RECOMMENDATION:

In this section, the report writer suggests recommendations in the light of the results of this geotechnical investigation. The investigator recommends the number of storeys that can be built, the type of foundation, and the bearing capacity to use at the required depth. It also explains what other measures and precautions should be taken in laying of foundations, drainage and sewerage systems e.g. suggestions are shared on how to comply with the results of the tests in construction activities. In the end, the scope of the whole process and limitations of the results are also added here.

LIMITATIONS AND UNCERTAINTIES OF SOIL EXPLORATION:

This section clearly specifies the limitations and uncertainties of the soil exploration due to possible inadequate budget, inadequate scope and/or objectives of the soil exploration, or difficult or variable soil or site conditions. Specific recommendation of the case investigator for further investigation/exploration to address the cited limitations should be specified.

ANNEXURE:

All the data related to the geotechnical investigation cited in the report as well as the supporting calculations, maps, drawings, and photographs are enclosed in the annexure in a logical sequential order, with clear reference number as cited in the report.

QUESTION NO 03:

The below Figure. 2-1.7 refers to the CBR results showing penetration of the piston in X-axis and bearing value on Y-axis. At y-axis right side of the graph, it shows ranges in percentage from 5% to 100% referring to different degrees of the subgrade (any material) quality in reference to CBR test. Please elaborate the Figure in your own words in detail.

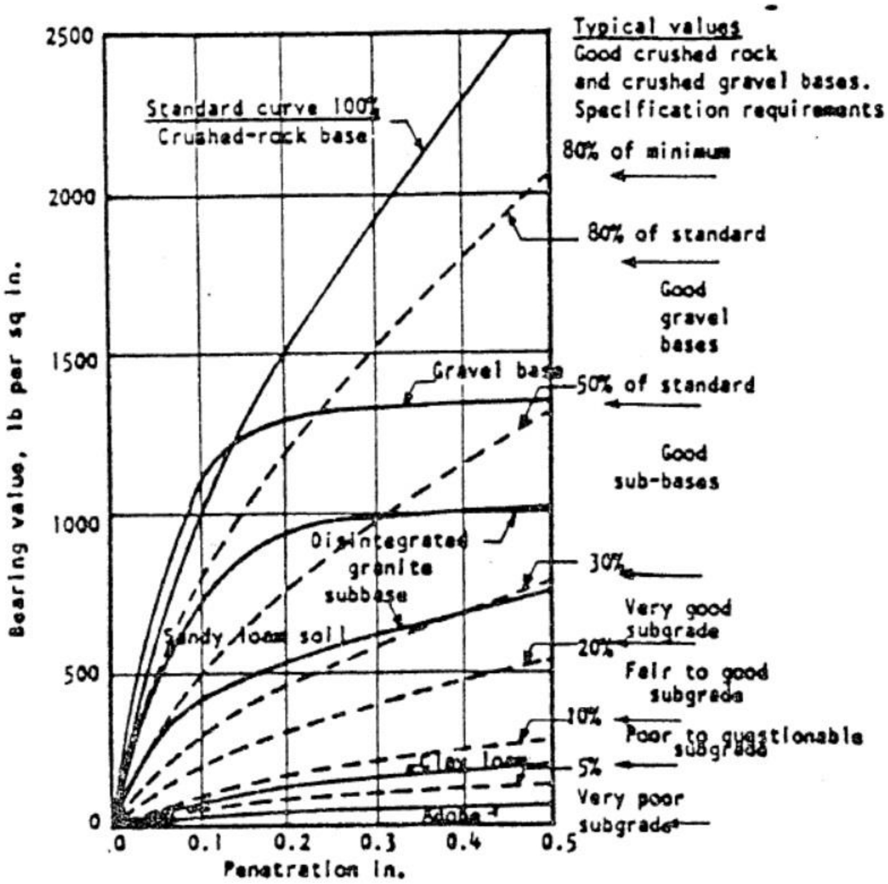
ANSWER:

CALIFORNIA BEARING RATIO (CBR)

The California Bearing Ratio (CBR) test is a simple strength test that compares the bearing capacity of a material with that of a well-graded crushed stone (thus, a high-quality crushed stone material should have a CBR @ 100%).

LOAD PENETRATION CURVE:

The plotting of CBR values is in the Load Penetration Curve.



The given Figure shows the load penetration curves. The bearing values in lb. / sq^{2} is given on the y axis, while piston penetration in inches is given on x-axis. The right side of the y axis shows the percentage ranges of CBR values of different materials. The figure also shows the CBR requirement of different pavement layers. The top steeper curve is of high-quality crushed stone having CBR of 100%. The second solid curve in the figure is for gravel base having CBR more than 50%. This curve is followed by that of disintegrated granite subbase with CBR around 40%. The fourth solid curve from the top is typical for sandy loam soil with CBR about 30%. The figure elaborates that the clayey loam soil will have CBR value between 5% to 10% and that the material with CBR value less than 5% should be treated as a poor subgrade. The material having CBR between 10% to 20% is a good subgrade while a very good subgrade material will have CBR greater than 20%. It can also be deduced from the figure that good gravel bases and good sub base material should have CBR values more than 80% and 50% respectively.

QUESTION NO 4:

1. **In Figure given below what is Dry of optimum and Wet of optimum? Explain?**
2. **What are effects of compaction on Engineering properties of soil? Details.**

ANSWER:

COMPACTION

Compaction means pressing of the soil particles close to each other by mechanical methods. Air is expelled from soil mass and mass density is increased. It is done to improve the engineering properties Like shear strength, stability etc. Reduces compressibility and permeability. Compaction is the process of expulsion of air from the voids present in the soil. In the construction field, it is an important process as it improves the engineering properties of soil to a great magnitude. Effects of compaction on different properties of the soil are explained in this article.

MOISTURE CONTENT

Water content or moisture content is the quantity of water contained in a material, such as soil.

OPTIMUM MOISTURE CONTENT (OMC)

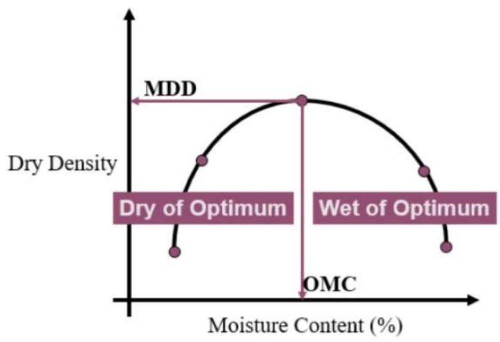
The water content at which a soil can be compacted to the maximum dry unit weight by a given compaction effort is called optimum water content. It is known that the soil becomes dense when it undergoes compaction. To facilitate easy compaction, some amount of water is added to the soil and the water content at which the maximum dry density of soil can be obtained is known as optimum moisture content. The Proctor compaction test (PCT) is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.

DRY DENSITY

Dry density of a soil is the ratio of total dry mass of soil to the total volume of soil. Dry density is related to the degree of compaction of soil mass. If degree of compaction will be more then dry density of that soil mass will be more.

THE COMPACTION CURVE:

The curve is called 'moisture content-dry density curve' or simply compaction curve. The moisture content corresponding to ascending part of compaction curve is marked as the dry side of optimum and that corresponding to the descending part as the wet side of optimum.



DRY OF OPTIMUM:

When the amount of water added, is less than the optimum moisture content then it is called as dry of optimum compaction. Dry of Optimum is before the attainment of the maximum dry density (MDD).

WET OF OPTIMUM:

When the amount of water added, is more than the optimum moisture content then it is called as wet of optimum compaction. Wet of Optimum is after the attainment of the maximum dry density (MDD).

NORMAL PRACTICE:

Normal practice is to compact the soil dry of optimum. Compact the soil wet of optimum for swelling (expansive) soils, soil liners for solid waste landfills, and projects where soil volume changes from changes in soil moisture conditions are intolerable.

EFFECTS OF COMPACTION ON ENGINEERING PROPERTIES OF SOIL:

When a soil is compacted, it changes its engineering properties and thereby behaves differently. Some of the engineering properties which changes on application of compaction effort is briefly described below.

1. Permeability
2. Compressibility
3. Shear strength
4. Soil structure
5. Swelling of soil
6. Shrinkage of soil
7. Pore water pressure
8. Stress-strain behaviour

PERMEABILITY

The effect of compaction is to decrease the permeability. Compaction reduces the voids present in the soil hence permeability also reduces. In the case of fine-grained soils, it has been found that for the same dry density soil compacted wet of optimum will be less permeable than that of compacted dry of optimum.

COMPRESSIBILITY

The Compressibility of compacted soil varies according to the amount of pressure applied. For low-pressure range, compressibility is more for soils which are compacted to wet of optimum than soil compacted to dry of optimum. Similarly, for high-pressure ranges, compressibility is more for soils which are compacted to dry of optimum than soil compacted to wet of optimum.

SHEAR STRENGTH:

The soils compacted dry of optimum have a higher shear strength than wet of optimum at lower strains. However at large strains the flocculated structure of soil is broken and ultimate strength will be equal for both dry and wet sides.

SOIL STRUCTURE

Soils compacted to dry of optimum have flocculated structure due to the attraction between soil particles because of low water content. Soils compacted to wet of optimum have dispersed structure due to repulsive force between soil particles because of high water content.

SWELLING OF SOIL

When the soil is compacted to dry of optimum, the soil is in need of water and it swells easily when contacted with water. When water is compacted to wet of optimum, the soil particles are oriented in a dispersed manner and swelling does not occur. So, to avoid swelling, soils should be compacted to wet of optimum.

SHRINKAGE OF SOIL

Shrinkage is more for the soil compacted to wet of optimum than dry of optimum. In case of dry of optimum compaction, soil particles are in random orientation and they are in stable condition. But in case of wet of optimum, soil particles are in parallel orientation and they are unstable which makes it easy for packing of particles causing shrinkage.

PORE WATER PRESSURE

Pore water pressure is high for those soil whose water content is high. Hence, soils compacted to wet of optimum compaction will exhibit more pore water pressure than soil compacted dry of optimum.

STRESS STRAIN BEHAVIOR:

The soil compacted dry of optimum have steeper stress-strain curve than those on wet side. The strength and modulus of elasticity of soil on dry side of optimum will be high. Soil compacted dry of optimum shows brittle failure. And soils compacted on wet side experience increased strain

PROPERTY	DRY SIDE	WET SIDE
Permeability	More Permeable	Less Permeable
Compressibility	More in High Pressure Range	More in Low Pressure Range
Shear Strength	Higher	Lesser
Structure	More Random	More Oriented
Swelling	Swell More	Swell Less
Shrinkage	Shrink Less	Shrink More
Pore Water Pressure	Less Pore Water Pressure	More Pore Water Pressure
Stress Strain Curve	Steeper stress-strain curve	Flatter stress-strain curve