DEPARTMENT OF CIVIL ENGINEERING
Mid Assignment / Quiz (*Spring 2020)*

Subject: Pavement Material Engineering Duration
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Semester: M.S (Civil Engineering)

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MS (CE)

Q. NO. (01)

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

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

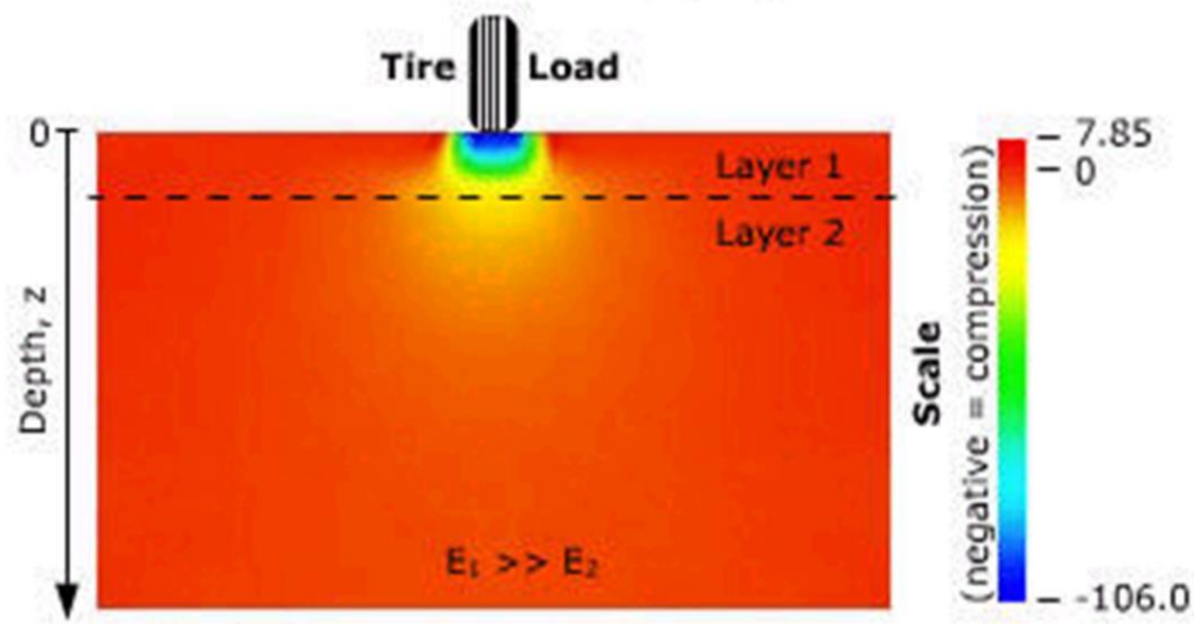


Figure. 1

<u>Que(01) Answer (1):</u>

The **pavement Condition Index (PCI)** is a numerical index between (0 and 100), which is used to indicate the general condition of a pavement section. The PCI is widely used in transportation civil engineering and asset management and many municipalities use it to measure their performance of their road infrastructure and their levels of service. Its statistical measure and requires manual survey of the pavement. This index was originally developed by the USA Army Corps of Engineers, but later it was standardized by the ASTM.

PCI is calculated based on the distresses observed during condition surveys (inspections). This information is used to determine the proper deduct values and to calculate the PCI values of pavement section.

The PCI history of a pavement section can help establish its rate of deterioration and identify future major rehabilitation needs. PCI values are also used in prioritizing, funding and executing Maintenance and Rehabilitation (M&R) on the pavement section

PCI Categorization:

The ASTM divides the PCI into seven classes as follow, but in practice a PCI lower than 40 is almost impossible.

PCI range	Class
85-100	Good
70-85	Satisfactory
55-70	Fair
40-55	Poor
25-40	Very poor
10-25	Serious
0-10	Failed

“In Figure.1 the Pavement is in Failure Condition”

Que(01) Answer (2):

What is Pavement:

A structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicles loads to the sub-grade.

Types of Pavement:

1. Flexible pavement:

- flexible pavement are those which on a whole have low or negligible flexural strength and rather flexible in their structure action under load.

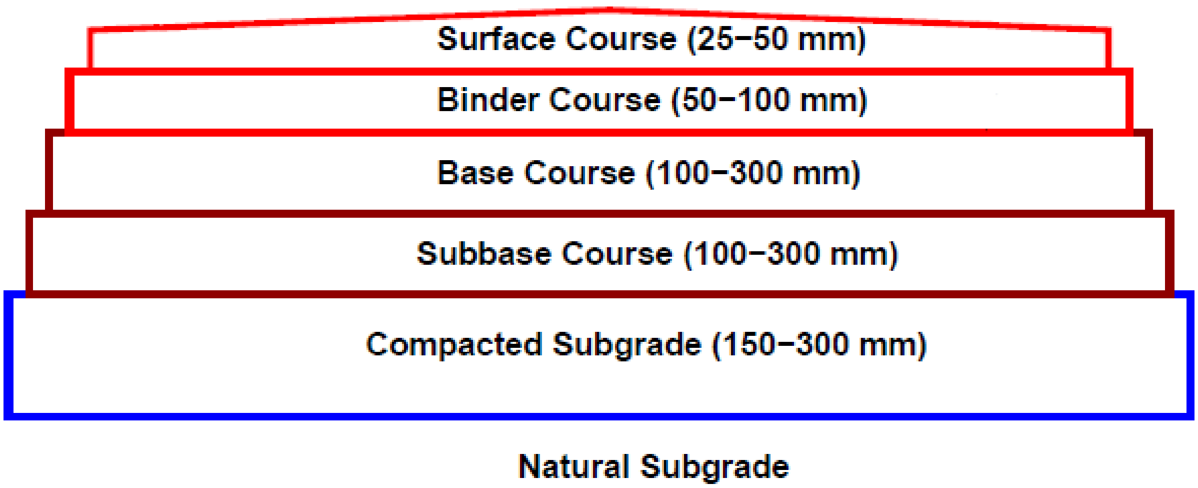
Load transfer:

- load is transferred to the lower layer by grain to grain distribution.
- The wheel load acting on the pavement will be distributed to a wider area, and the stress decrease with the depth. Flexible pavement layers reflected the deformation of the lower layers on to the surface layer.

Typical layers of a Flexible Pavement:

Typical layers of a conventional flexible pavement include seal coat, surface course, track coat, binder course, prime coat, base coat, base course, compacted sub-grade, and natural sub-grade.

1. **Seal Coat** is a thin surface treatment used to water- proof the surface and to provide skid resistance.
2. **Track Coat** is a very high application of asphalt emulsion diluted with water. And it provides bonding between two layers of binder course.
3. **Prime Coat** is an application of low viscous cutback bitumen to an absorbent surface like granular bases on which binder layer is placed and provides bonding between two layers.
4. **Surface Coarse** is the layer directly in contact with traffic loads and are constructed with dense graded asphalt concrete.
5. **Binder Coarse** purpose is to distributed load to the base course. Binder course requires lesser quality of mix as compared to course above it.
6. **Base Course** provides additional load distribution and contributes to the sub-surface drainage.
7. **Sub-base Course** the primary functions are to provide structural support, improve drainage, and reduce the function of fines from the sub-grade in the pavement structure.
8. **Sub-grade** the top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layer above



Factor Affecting Pavement Design:

Design Wheel Load:

- **Maximum wheel load** it is used to determine the depth of the pavement required to ensure that the sub-grade soil does not fail.
- **Contact Pressure** it determines the contact area and the contact pressure between the wheel and the pavement surface, for simplicity elliptical contact area is consider to be circular.
- **Alex Configuration** the axle configuration is important to know the way in which the load is applied on the pavement surface.
- **Repetition of loads** each load application causes some deformation and the total deformation is the summation of all these.
- Although the pavement deformation due to single axis load is very small. The cumulative effect of number of load repetition is significant.
- Therefore, modern design is based on total number of standard axle load (usually 80 KN single axle)

Deflection on flexible pavement:

The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of this stress distribution characteristic, flexible pavements normally has many layers. Hence, the design of flexible pavement uses the concept of layered system. Based on this, flexible pavement may be constructed in a number of layers and the top layer has to be of best quality to sustain maximum compressive stress, in addition to wear and tear. The lower layers will experience lesser magnitude of stress and low quality material can be used. Flexible pavements are constructed using bituminous materials. These can be either in the form of surface treatments (such as bituminous surface treatments generally found on low volume roads) or, asphalt concrete surface courses (generally used on high volume roads such as national highways). Flexible pavement layers reflect the deformation of the lower layers on to the surface layer (e.g., if there is any undulation in sub-grade then it will be transferred to the surface layer). In the case of flexible pavement, the design is based on overall performance of flexible pavement, and the stresses produced should be kept well below the allowable stresses of each pavement layer.

Failure of flexible pavements:

The major flexible pavement failures are fatigue cracking, rutting, and thermal cracking. The fatigue cracking of flexible pavement is due to horizontal tensile strain at the bottom of the asphaltic concrete. The failure criterion relates allowable number of load repetitions to tensile strain and this relation can be determined in the laboratory *fatigue test* on asphaltic concrete specimens. Rutting occurs only on flexible pavements as indicated by permanent deformation or rut depth along wheel load path. Two design methods have been used to control rutting: one to limit the vertical compressive strain on the top of subgrade and other to limit rutting to a tolerable amount (12 mm normally). Thermal cracking includes both low-temperature cracking and thermal fatigue cracking.

2. Rigid pavements:

Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area below. A typical cross section of the rigid pavement is shown in Figure 3. Compared to flexible pavement, rigid pavements are placed either directly on the prepared sub-grade or on a single layer of granular or stabilized material. Since there is only one layer of material between the concrete and the sub-grade, this layer can be called as base or sub-base course.

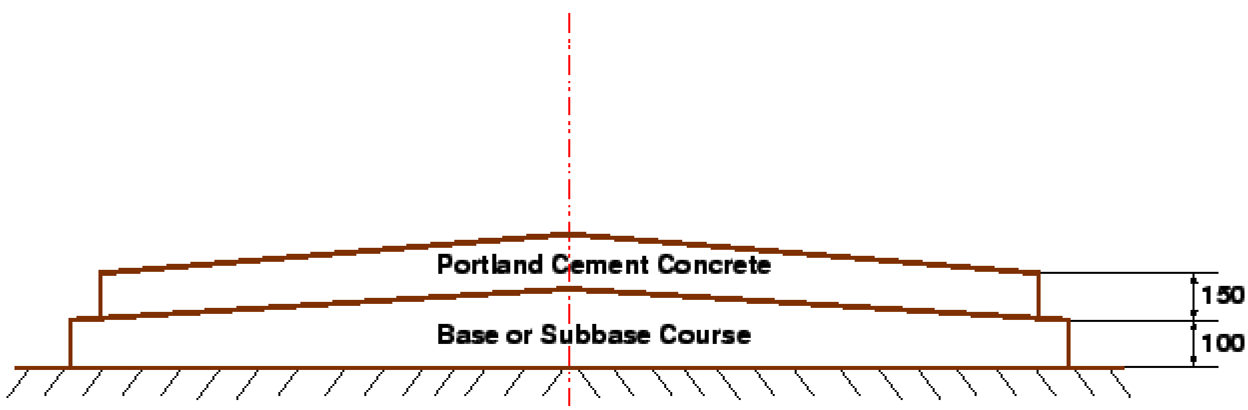


Figure 3: Typical Cross section of Rigid pavement

In rigid pavement, load is distributed by the slab action, and the pavement behaves like an elastic plate resting on a viscous medium (Figure 4). Rigid pavements are constructed by Portland cement concrete (PCC) and should be analyzed by plate theory instead of layer theory, assuming an elastic plate resting on viscous foundation. Plate theory is a simplified version of layer theory that assumes the concrete slab as a medium thick plate which is plane before loading and to remain plane after loading. Bending of the slab due to wheel load and temperature variation and the resulting tensile and flexural stress.

Types of Rigid Pavements

Rigid pavements can be classified into four types:

- Jointed plain concrete pavement (JPCP),
- Jointed reinforced concrete pavement (JRCP),
- Continuous reinforced concrete pavement (CRCP), and
- Pre-stressed concrete pavement (PCP).

- **Jointed Plain Concrete Pavement:** are plain cement concrete pavements constructed with closely spaced contraction joints. Dowel bars or aggregate interlocks are normally used for load transfer across joints. They normally has a joint spacing of 5 to 10m.

- **Jointed Reinforced Concrete Pavement:** Although reinforcements do not improve the structural capacity significantly, they can drastically increase the joint spacing to 10 to 30m. Dowel bars are required for load transfer. Reinforcements help to keep the slab together even after cracks.

- **Continuous Reinforced Concrete Pavement:** Complete elimination of joints are achieved by reinforcement.

Failure criteria of rigid pavements;

Traditionally fatigue cracking has been considered as the major, or only criterion for rigid pavement design. The allowable number of load repetitions to cause fatigue cracking depends on the stress ratio between flexural tensile stress and concrete modulus of rupture. Of late, pumping is identified as an important failure criterion. Pumping is the ejection of soil slurry through the joints and cracks of cement concrete pavement, caused during the downward movement of slab under the heavy wheel loads. Other major types of distress in rigid pavements include faulting, spalling, and deterioration.

Summary:

Pavements form the basic supporting structure in highway transportation. Each layer of pavement has a multitude of functions to perform which has to be duly considered during the design process. Different types of pavements can be adopted depending upon the traffic requirements. Improper design of pavements leads to early failure of pavements affecting the riding quality also.

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Que. 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.

1. Which steps (General Procedure) you would consider while soil investigation and preparation of Geotechnical Report.
2. Also elaborate the steps briefly in your own words.

Que(02) ANSWER (1):

WHAT IS THE NEED?

- To determine the type of foundation required for the proposed project at the site, i.e. shallow foundation or deep foundation.
- To make recommendations regarding the safe bearing capacity or pile load capacity.
- Ultimately, it is the subsoil that provides the ultimate support for the structures.

The three important aspect are;

1. **Planning:**
    - To minimize cost of exploration and yet give reliable data.
    - Decide on quantity and quality depending on type, size and importance of project and weather investigation is preliminary or detailed.

2. **Execution:**
    - Collection of disturbed and or undisturbed samples of subsurface strata from field.
    - Conducting in-situ tests of subsurface material and obtaining properties directly or indirectly.
    - Study of ground water condition and collection of sample for chemical analysis.
    - Laboratory testing on samples.

3. **Report writing:**
    - Description of site conditions – topographic features, hydraulic conditions, existing structures, etc. supplemented by plans/drawings.
    - Description of nature, type and importance of proposed construction.

- Description of field and lab tests carried out.
- Analysis and discussion of data collected
- Preparation of charts, tables, graphs, etc.
- Calculation performed
- Recommendations

SITE INVESTIGATION:

A Complete Site Investigation will consist of:

- Preliminary work
  - Collecting general information and already existing data such as study of geology, seismic maps, etc. at or near site.
  - Study site history – if previously used as quarry, agricultural land, industrial unit, etc.
- Site Reconnaissance: Actual site inspection.
  - To judge general suitability various tests and
  - Decide exploration techniques
  -

METHODS OF EXPLORATION

- Direct methods: trail pits or trenches
- Semi-direct methods: Borings
- Indirect methods: penetration tests, Geophysical methods

DIRECT AND SEMI DIRECT METHODS

- **Tests pits**
  - Adopted for mirror structures, small buildings
  - Suitable up to small depth (<2m)
  - Geotechnical characteristics of disturbed samples
- **Boring**
  - Used for exploration at greater depths where direct methods fail
  - Provides both disturbed as well as undisturbed samples depending upon the method of boring
  - **The different type of boring method are;**
  - ➢ **Augur boring:**

a. this method is fast and economical.
b. suitable for soft to stiff cohesive soils.
c. soil sample collected is disturbed.
d. not suitable for very hard or cemented soils, very soils, as then the flow into the hole can occur.
e. Used for advancing borehole into the ground.
f. Suitable when the borehole is kept dry and unsupported.
g. Hand operated (3-5m) or power driven.
h. Post hole and helical augur.
i. Rotating and pressing mechanism.

j. Testing of samples collected in the augur.

- **Wash boring:**

Suitability;

a. exploration below GWT
b. For all soils accept gravel and boulder

Technique;

a. Making of hole short depth using an auger
b. Installation of casing pipe (manually/power)
c. Installation of tripod, pulley and winch
d. Hollow drill bit screwed to a hollow drill rod connected to a rope passing over a pulley
e. The hollow drill bit assembly placed in the hole
f. Water is forced through the swivel and the drilling rod using a pump
g. The rods are rotated and also moved up and down either manually or with a mechanized rig
h. The suspension is led to a setting tank where the soil particle settle
i. Water collected in the sump is re-circulated again

Limitation;

a. Very disturbed sample
b. Cannot be used for evaluation of engineering properties
c. Sample can be extracted by replacing the drilling bit with a sampler

- **Rotary drilling:**

a. Suitable for rock strata and can also be used for sands and silt
b. Method is fast in rock formation
c. Drill bit fixed to drill rod is rotated by power
d. The soil collected in the drill bit can be removed and boring is continued
e. Water/Bentonite slurry can be forced under pressure through the drill rod
f. Rock cores may be obtained by using suitable diamond drill bit

- **Percussion drilling**

a. Suitable for hard soil and soft rock where augur boring and wash boring cannot be employed
b. Hole is made using augur
c. Installation of casing pipe
d. Heavy drill bit called 'Churn bit' is attached to drill rods
e. Bore hole is extended by repeated blows of the drill bit using winch system
f. Water is forced through the drill rod assembly for breaking stiff soil or rock
g. Slurry removed by bailers
h. Method cannot be used in loose sand and is slow in plasticity

i. Formation gets badly disturbed by impact

PLANNING AN EXPLORATION PROGRAMME

Include:

- Site plan of the area
- A layout plan of proposed structure with column location expected loads
- Location of bore holes and fields tests
    - SPT, Vane shear test
- Planning of other field tests
    - SCPT, DCPT, Plate Load Test
- Bore log data and different laboratory tests for evaluation of strength and compressibility characteristics of different soil
    - Grain size, specific gravity, plasticity, tri axial shear test, consolidation test
- Spacing of boring
    - Depend on type, size, weight of proposed structure

Name of Project	Spacing (m)
Highway	300-600
Earth dam	30-60
Barrow pits	30-120
Multistory building	15-30
Single story building	30-90

- Depth of boring:
    - Type of structure
    - Should penetrate all strata that could consolidate
    - For bridge and tall building the boring should extend to rock
    - 1.5 times the width of footing below foundation level
    - For embankment and dam 0.5 – 2 times the height
    - Single storey 3.5 m
    - Double storey 6.5 m

SOIL SAMPLING

In general soil samples are:

- **Disturbed sample:** In such sample natural soil structure is modified or destroyed
    - If water content and mineral content are also modified then it is a non-representative or remolded sample
    - If water content and mineral content are not modified then it is representative sample
- **Undisturbed sample:** Natural soil structure, water and mineral content are preserved
    - For the purpose of atterberg's limit, specific gravity, grain size analysis either representative or undisturbed sample should be used
    - Undisturbed sample are desired for coefficient of permeability, consolidation parameter and shear strength parameter,

FIELD METHODS TO DETERMINE BEARING CAPACITY OF SOIL

- **Plate load test**
    - Determination of allowable bearing capacity of sub soil
    - Suitable for gravel/builder strata when SPT and DCPT does not give dependent result
    - Also used to determine the modulus of subgrade reaction (K) useful for design of pavements

- **Standard penetration test (SPT)**
    - Determined of in-situ parameters of soil
    - Determined of bearing capacity

- **Static cone penetration test (SCPT)**
    - Most useful where soil properties gets disturbed by boring/blows
    - Useful on very soft and loose soil where transportation of heavy equipment required for SPT and DCPT test may not be possible
    - Useful for determination of bearing capacity at different depths below foundation level
    - Skin friction values required to be used for determining the length of piles

- **Dynamic cone penetration test (DCPT)**

- **Field vane shear test**
    - Determined of in-situ shear strength of standard clay of very soft to medium consistency
    - Difficulty in sampling and underestimate of shear strength of such soil in laboratory

- Undrained strength both in undisturbed and remolded samples are obtained for estimating the sensitivity of the soil.

Que(02) ANSWER (2):

Elaborate the steps briefly in your own words;

- The general topography of the site as it affects foundation design and construction. e.g surface configuration, adjacent property, the presence of watercourses, ponds, hedges, trees, rocs outcrops, etc and the available access for construction vehicles and plants.
- The location of buried services such as electric power, television and telephone cables, water mains, and sewers.
- The general geology of the area with particular reference to the main geological formation underlying the site and the possibility of substances from mineral extraction or other causes.
- The previous history and use of the including information on any defects or failures of existing or former buildings attributable to foundation conditions, and the possibility of contamination of the site by toxic waste materials.
- Any special features such as the possibility of earth-quakes or climatic changes such as flooding, seasonal swelling and shrinkage, permafrost, or soil erosion.
- The availability and quality of local constructional materials such as concrete aggregates, buildings and road stone, and water for constructional purposes.
- For maritime or river structure information on normal spring and neap tide ranges, extreme high and low tidal ranges and river levels, seasonal river levels and discharges. Velocity of tidal and river currents, wave action, and other hydrographic and meteorological data.
- A detailed record of the soil and rocks strata and ground water conditions within the zone affected by foundation bearing pressure and construction operations, or of any deeper strata affecting the site condition in any way.
- Results of field and laboratory tests on soil and rock sample appropriate to the particular foundation design or constructional problems.
- Results of chemical analysis on soil, fill materials, and ground water to determine possible deleterious effects on foundation structures
- Results of chemical and bacteriological analysis on contaminated soils, fill materials, and gas emulsions to determine health hazard risks

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Que. 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.

1. Please elaborate the Figure in your own words in detail.

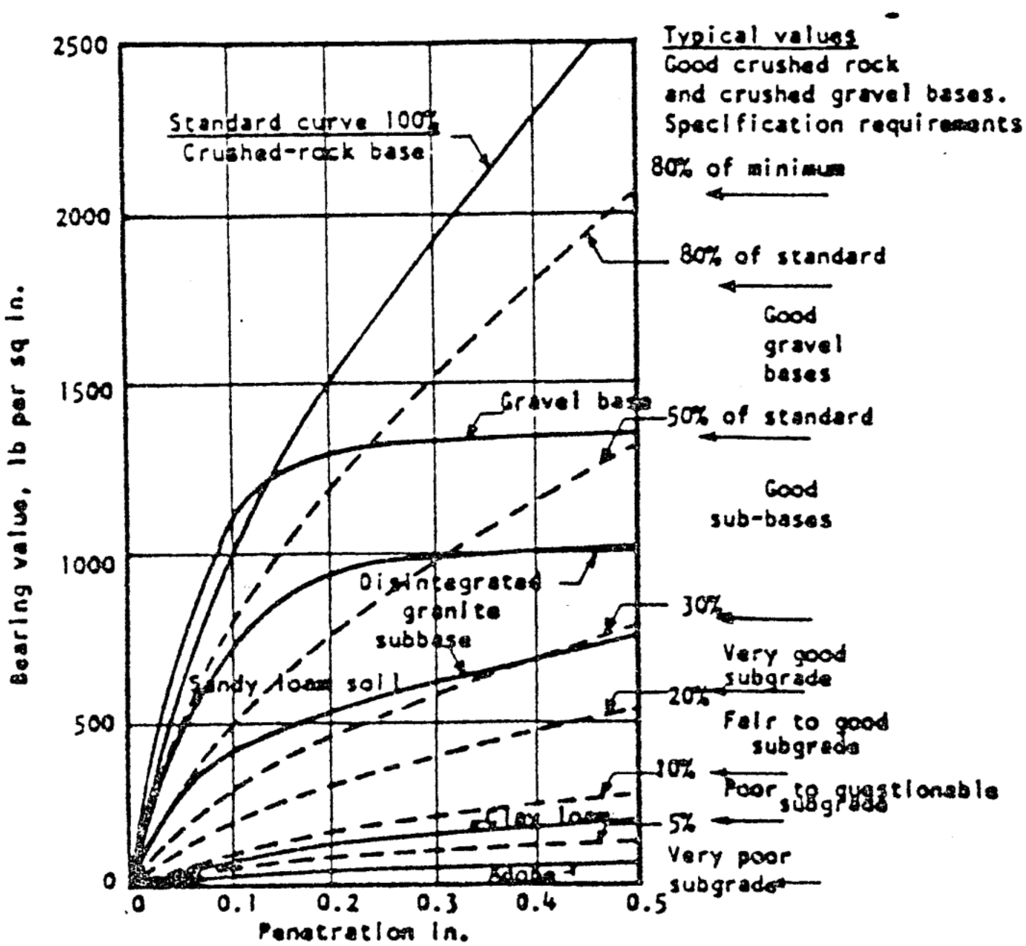

Figure 2-1.7. CBR Testing Procedure and Load-Penetration Curves for Typical Soils.

Que(03) Answer:

Definition of CBR:

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min, to that required for the corresponding penetration of a standard material. The California bearing ratio test (CBR Test) is a penetration test developed by California State Highway Department (U.S.A) for evaluating the bearing capacity of subgrade soil for design of flexible pavement.

Test are carried out of natural or compacted soils in water soaked or un- soaked conditions and the results so obtained are compared with the curves of standard test to have an idea of the soil strength of the subgrade soil.

CBR= (Test load/ Standard load) 100%

- CBR at 0.1 = 850/1050 x 100 = 80.9%
- CBR at 0.2 = 1200/150 x 100 = 80%
- So CBR = 80%
- This CBR value are used with aspherical test to determine the thickness of pavement and its compact layer.

CBR is easily to use and widely throughout the world use;

- **5%** below figure 2-1.7 which shows the result of CBR in which penetration is in X-direction and bearing capacity on Y-direction and Y-direction. It shows the percentage resistance statistic from 5% to 100% the graph can be explained in general stages or steps.
- **5%** the 5% are or below 5% clayey soil having very low bearing capacity they are in loose stage its bearing capacity is less **500 Psi** and penetration ranges from 0.1-0.5 in
- **10%** from 5 – 10 % CBR ratio the range in clayey loose particles to clayey particles this particle is in range of poor to questionable subgrade they also have CBR value less than **500 psi.**
- **20%** these particles are sandy and in loose start CBR value is up to 20% and its value is up to 500 psi and penetration is 0.5 exact at 20% resistance of CBR. They are fair to good subgrade.
- **30%** the CBR resistance of disintegrated granite substance is up to 30% and its penetration is above 500 psi to 700 psi they are very good sub-graded particles.
- **50%** the particles ranges from 30% to 50% CBR resistance they are good subbase and are gravel particles its bearing value is in between 1300 psi at 0.5 in penetration of 50% penetration resistance.

- **80%** (50% - 80%) these are good gravel base its penetration value from 0.25 to 0.5 in at 80% exact penetration resistance having 2200 psi of bearing value.
- **100%** good crushed rock and crushed gravel bases having penetration resistance 100% and its crushing bearing value ranges from 2000 psi – 2500 psi at having maximum penetration 0.45 at exactly 2500 psi.

APPARATUS:

- Mold
- Steel cutting collar
- Spacer disc

CBR TEST PROCEDURE:

- Normally 3 Specimens each of about 7 kg must be compacted so that their compacted densities ranges from 95% to 100% generally with 10, 30 and 65 blows.
- Weight of empty mold.
- Add water to the first specimen (compact it in five layer by giving 10 blows per layer)
- After compaction, remove the collar and level the surface.
- Take sample for determination of moisture content.
- Weight of mold + compacted specimen.
- Place the mold in the soaking tank for four days (Ignore this step in case of un soaked CBR)
- Take other samples and apply different blows and repeat the whole process.
- After four days, measure the swell reading and find percentage swell.
- Remove the mold from the tank and allow water to drain.
- Then place the specimen under the penetration piston and place surcharge load of 10lb.
- Apply the load and note the percentage load values.
- Draw the graphs between the penetration (in) and penetration load (in) and find the value of CBR.
- Draw the graph between the percentage CBR and Dry Density, and find CBR at required degree of compaction.

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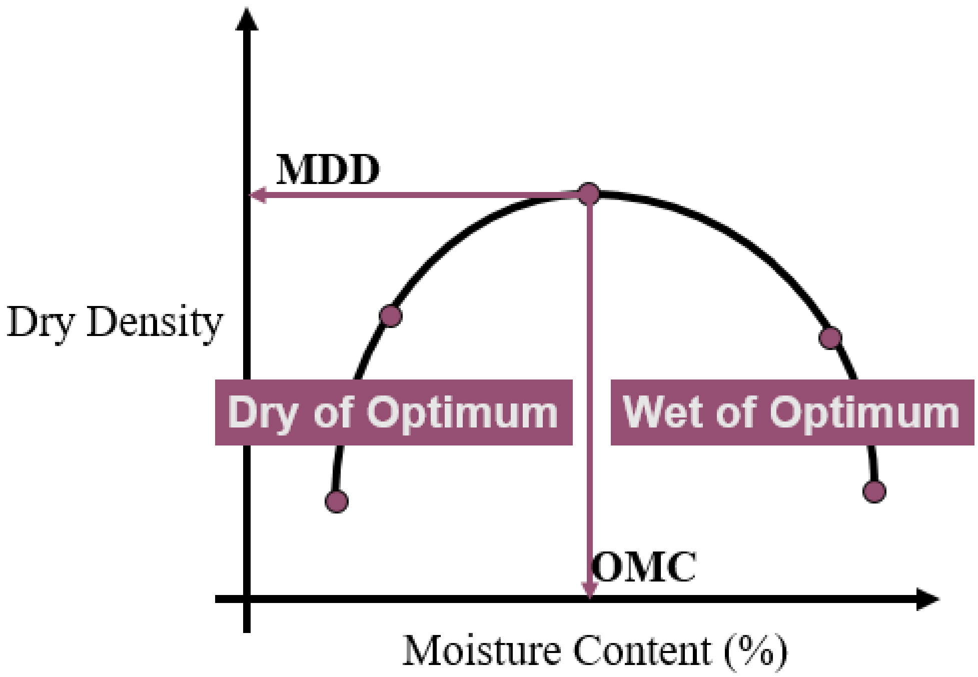
Q. NO. (04)

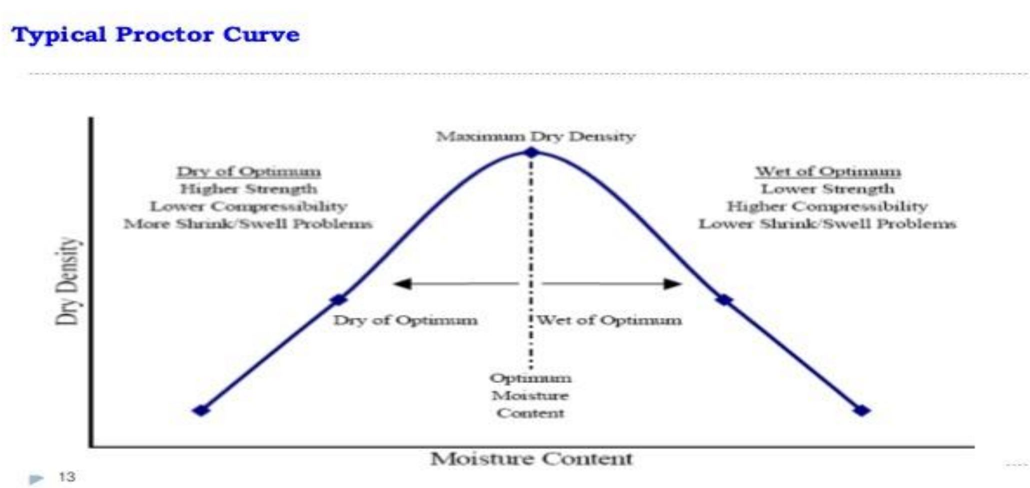
1. In the Figure given below what is Dry of optimum and Wet of optimum? Explain?
2. What are effects of compaction on Engineering properties of soil? Details.



Que (04) Answer(1):

General principle of compaction:

- The compaction process has significant differences for cohesive soil versus cohesion less soils.
- The major difference is cohesive soils are typically very moisture dependent and cohesion less soils are not.
- As the water content increase from dry of optimum to wet of optimum he believed that the water acted as a lubricant between the soil particles.
- The addition of more water continued to the compaction process until the water began replacing the air voids.
- At this point compaction process was complete and the addition of more compactive energy would not result in a denser soil.
- If a small amount of water is added to a soil that is then compacted, the soil will have a certain until weight.
- If the moisture content of the same soil is generally increased and the energy of compaction is the same, the dry until weight of the soil will gradually increase.
- The reason is that water acts as a lubricant between the soil particles and under compaction it helps to rearrange the solid particles into a denser state.
- The increase in dry unit weight with increase of moisture content for a soil will reach a limiting value beyond which the further addition of water to soil will result in reduction in dry unit weight.
- The moisture content at which the maximum der unit weight is obtained is referred to as the optimum moisture content.



- Compaction along the moisture density curve from dry to wet as a four- steps process.

1. First, the soil particles become hydrated as water is absorbed.
2. Second, the water begins to act as a lubricant helping to rearrange the soil particles into a denser state until optimum moisture content is reached.
3. Third, the addition of water causes the soil to swell because the soil now has excess water.
4. Finally, the soil approaches saturation as more water is added.

- Compaction of a soil dry optimum moisture content results is a flocculated soil structure that has high shear strength and permeability.
- Compaction of a soil wet of optimum moisture content results in a soil with a dispersed soil structure that has low shear strength and permeability.

Dry of Optimum vs. Wet of Optimum Compaction Characteristics

Property	Compaction
1. Structure	
A. Particles arrangement	Dry side more than random
B. Water Deficiency	Dry side more efficiency therefor imbibe more water, swell more, have lower pore pressure.
C. Performance	Dry side structure sensitive to change.
2. Permeability	
A. Magnitude	Dry side more permeable
B. Performance	Dry side more permeability reduced much more by permeation.
3. Compressibility	
A. Magnitude	Wet side more compressible in low- pressure range, dry side in high – pressure range.
B. Rate	Dry side consolidation more rapidly.
C. Rebound	Wet side rebound per compression greater.
4. Strength	
A. As molded a. Undrained b. Drained	 Dry side much higher. Dry side somewhat higher.
B. After saturation a. Undrained b. Drained	 Dry side somewhat higher if swelling prevented; wet side can be higher if swelling permitted. Dry side about the same or slightly greater.
C. Pore water pressure at failure	Wet side higher
D. Stress – strain modulus	Dry side much greater
E. Sensitivity	Dry side more apt to be sensitive

Que (04) Answer (2):

INTRODUCTION:

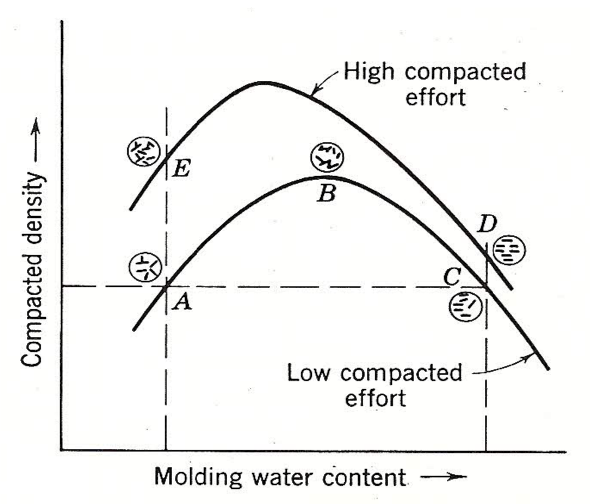
- Compaction means pressing of the soil particles close to each other by mechanical methods.
- Air is expelled from soil mass and mass density is increased.
- It is done to improve the engineering properties
- Like shear strength, stability etc…
- Reduce compressibility and permeability.

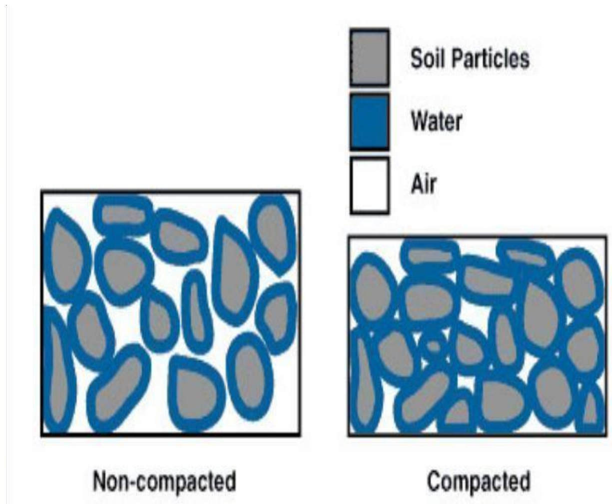
EFFECTS OF COMPACTI0N:

- Now we will discuss about effects of compaction on the properties of soil. The following properties are effected…
    - Soil structure
    - Permeability
    - Swelling
    - Pore water pressure
    - Shrinkage
    - Compressibility
    - Stress–strain relationship
    - Shear strength
        - Shear strength at molded water content
        - Shear strength after saturation

EFFECT ON SOIL STRUCTURE:

- The water content at which the soil is compacted plays an important role in the soil structure.
- Soils compacted at water content less than optimum water content have flocculated structure.
- Soils compacted at water content more the optimum water content have dispersed structure.





- At Point A, the water content is low and attractive forces are predominant, so results in flocculated structure.
- As the water content is increased beyond optimum, the repulsive forces increase and particles get oriented into a dispersed structure.

EFFECT ON PERMEABILITY:

- Permeability of soil depends on void size.
- As water content increases, there is an improved orientation of particles resulting in reduction of void size and permeability.
- Above optimum water content, the permeability slightly increases.
- If compactive effort is increased, the permeability decreases due to increased dry density.

EFFECT ON SWELLING:

- The effect of compaction is to reduce void space.
- Hence swelling is slightly reduced.
- Further soil compacted dry of optimum exhibits greater swell than compacted on wet side because of random orientation and deficiency of water.

EFFECT ON PORE WATER PRESSURE:

- It is defined as pressure of ground water held within a rock or soil, in gaps between particles (pores).
- The pore water pressure for soil compacted dry of optimum is therefore less than that for the same soil compacted wet of optimum.

EFFECT ON SHRINKAGE:

- Soils compacted dry of optimum shrink less when compared to compacted wet of optimum.
- The soils compacted wet of optimum shrink more because the soil particles in dispersed structure can pack more efficiently.

EFFECT ON COMPRESSIBILITY:

- The flocculated structure on the dry side of optimum offers greater resistance to compression than the dispersed structure on wet side.
- So, the soils compacted dry of optimum are less compressible.

EFFECT ON STRAIN-STRESS RELATIONSHIP:

- 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

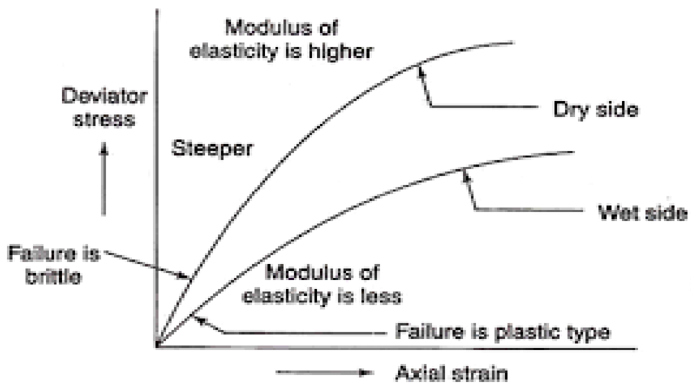


Fig. 10.6 Stress-strain relationship

EFFECT ON SHEAR STRENGTH:

- In general, 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.

SUMMARY:

S.NO	DRY SIDE	WET SIDE
STRUCTURE	MORE RANDOM	MORE ORIENTTED
PERMEABILITY	MORE PERMEABLE	LESS PERMEABLE
COMPRESIBILITY	MORE COMPRESSIBLE IN HIGH PRESSURE RANGE	MORE COMPRESSIBLE IN LOW PERESSURE RANGE
SWELLING	SWELL MORE	SHRINK MORE
STRENGTH	HIGHER	LESSER