Geotechnical Measurements and Explorations

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Lecture No. # 31

Next page of your laboratory test is your compaction.

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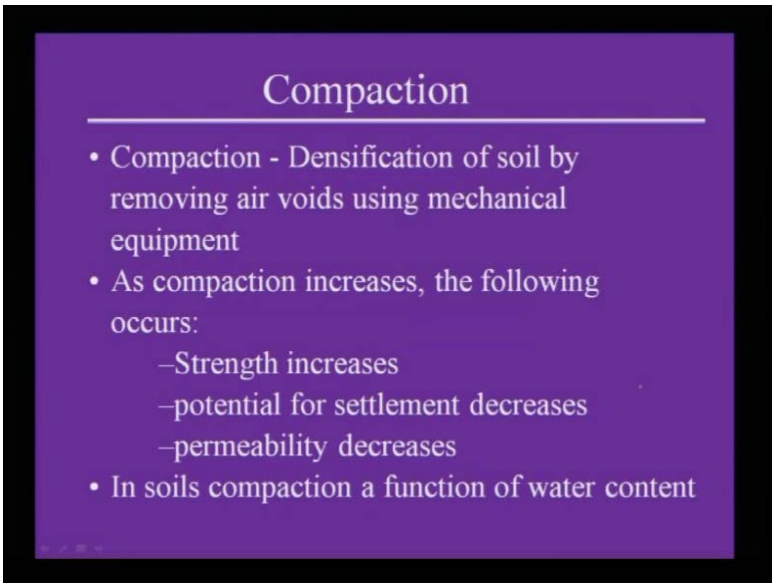

Compaction is densification of soil by removing air voids by means of mechanical equipment. The difference between compaction and consolidation is in this incase of consolidation, this is expulsion of air plus water. Primarily consolidation is expulsion of water but, in case of compaction it is densification of soil by removing air voids only using mechanical equipment. If I take the soil element, if I consider the soil it is solid, then water, then air. solid, water, air that means by means of compaction you are removing only air voids, airs from the voids using mechanical equipment. So, compaction increases the following, as the compaction increases the following occurs. Once is your first one your strength increases, second is your potential for settlement decreases and permeability decreases. The moment you increase the compaction the permeability decreases. In soil compaction is a function of water content.

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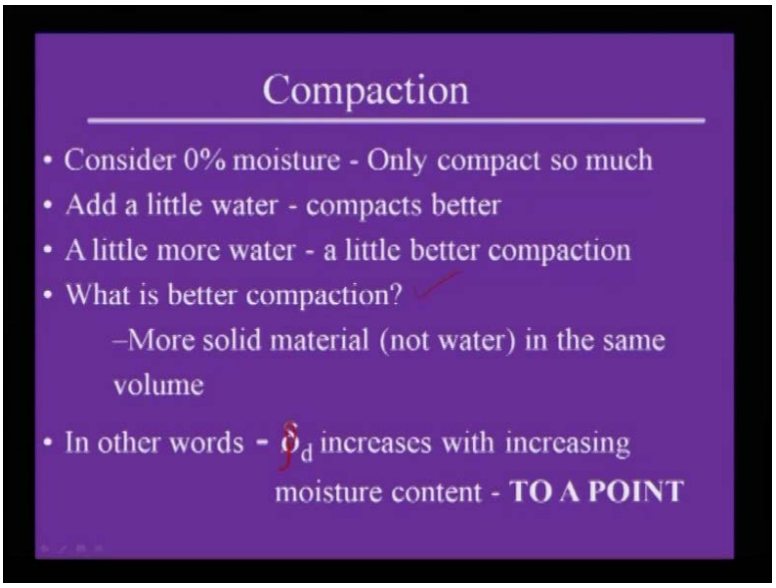

So, let us consider zero percent moisture. So, only compact so much add a little water that means with a zero percent of moisture if you compact as compare to with a little water it compacts better, then more water a little better compaction. What is better compaction? Means what do you mean by better compaction that means more solid materials not water in the same volume and in other word, delta rho d increases with increase in moisture content. This is dry density, this is not delta; this is dry density increases with increase in moisture content.

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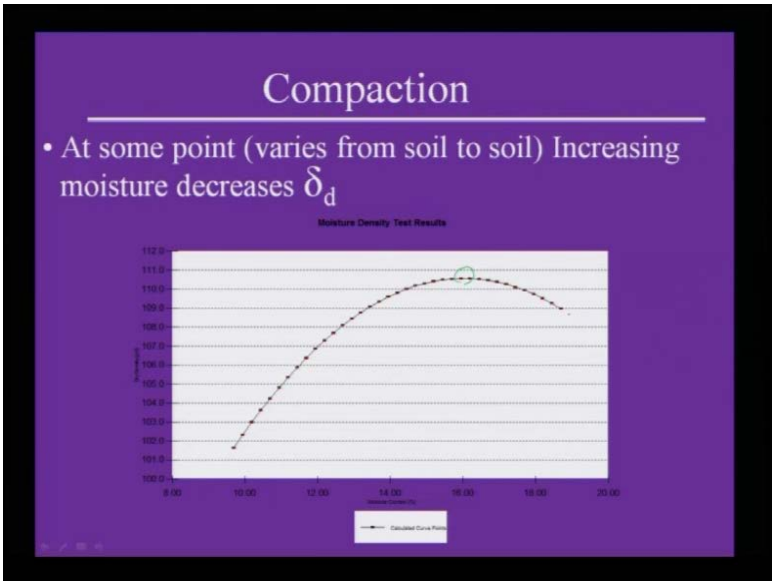

Now at some point if I plot this dry density rho d versus moisture content look at here at some point increasing moisture decreases with rho d or dry density that means, this with adding water in the soil if you want to compact this dry density it increases at certain point below this even if you add water it this, dry density will decrease.

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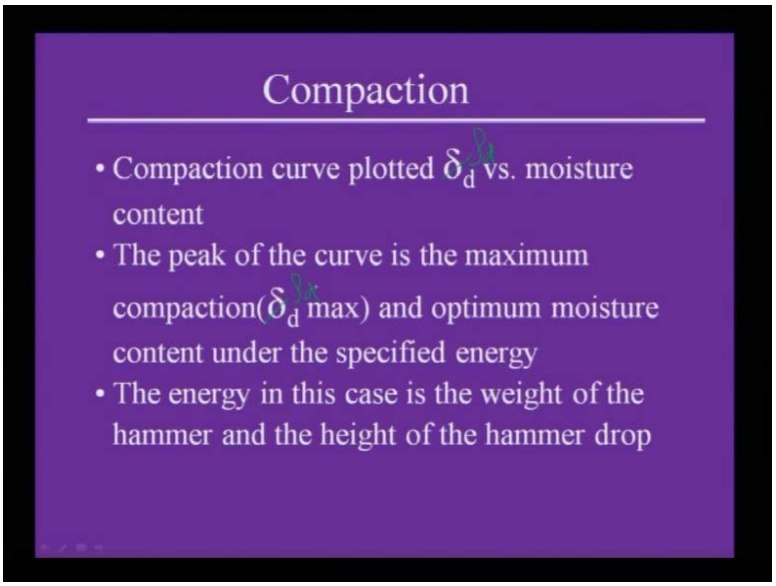

Compaction curve is plotted between rho d versus moisture content or dry density this is your rho d versus moisture content, peak of the curve is the maximum compaction and optimum moisture content under the specific energy. The energy in this case is the weight of the hammer and height of hammer drop. Energy, how do you apply the energy? By means of a weight of hammer and falling at a certain height this is called height of hammer drop.

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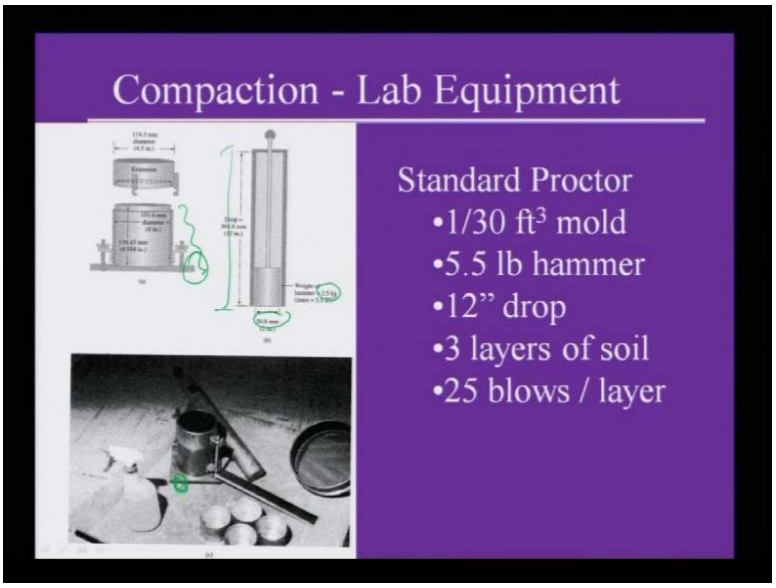

Now, this is the laboratory compaction equipment if you look at this standard proctor mold this is called standard proctor mold and it is basically 1 by 30 feet cube mold, 5.5 l b hammer and 12 inch drop. If you look at here this hammer, is your weight of hammer is 2.5 k g and this diameter of hammer is 50.8 m m and it is pulling up and falling at a height of 30 centimeter- or 304.8 m m and this is called a proctor mold, standard proctor mold. There are two molds one is your standard proctor mold, other is your modified proctor mold and this proctor mold has a base plate. If you look at here this is your base plate, if you look at here this is your base plate. With this base plate the standard proctor mold, this is your standard proctor mold diameter is 10 centimeter, height is your 11 centimeter means almost 10 centimeter by 10 centimeter you can say.

So, you just put it here at the base it has been by attached with this, this mold has been attached to the base. Once compaction has been done there is a extension plate or extension rod, extension of this mold, extension mold. It has been covered, so that more soil above this has been compacted, then it has been removed, then the soil in this compaction mold has been trimmed up. Now, the procedure we can see it.

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Look at this, in this laboratory this compaction mold, this is your base plate, this is your base plate and this is your standard proctor mold and this is your collar with fixing all add with the take soil sample and add some water then place it and compact it with pulling this

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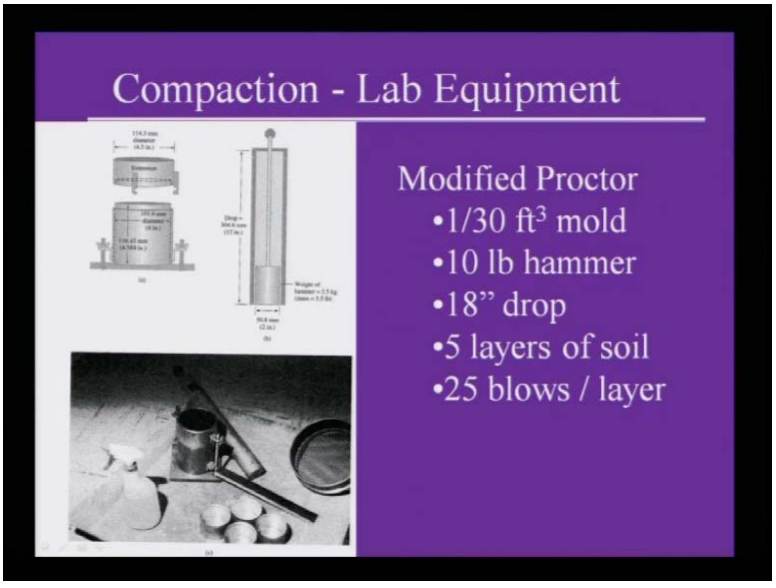

if you go back here with pulling this hammer up to a height of 304.8 m m, height of fall is 30 centimeter and average you allow

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it should fall around periphery, soil will be compacted.

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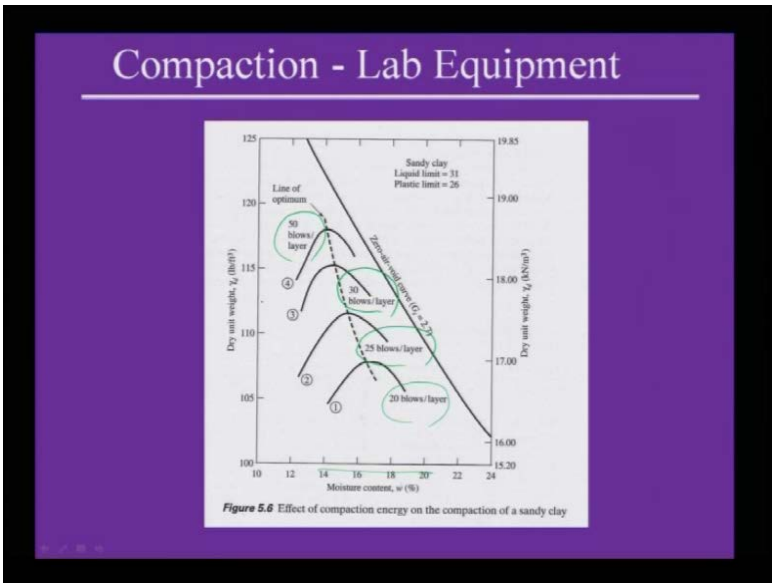

Now, if you look at this. This is a typical effect of compaction energy on compaction of a sandy clay. Look at here with this moisture content varying from 14 to 20 this moisture content remains constant the variation for 20 blows of layer, for 20 blows per layer and 30 blows per layer, 50 blows per layer. If you look at this, this is your line of optimum. Now, how many number of blows per layer you are going to use and why?

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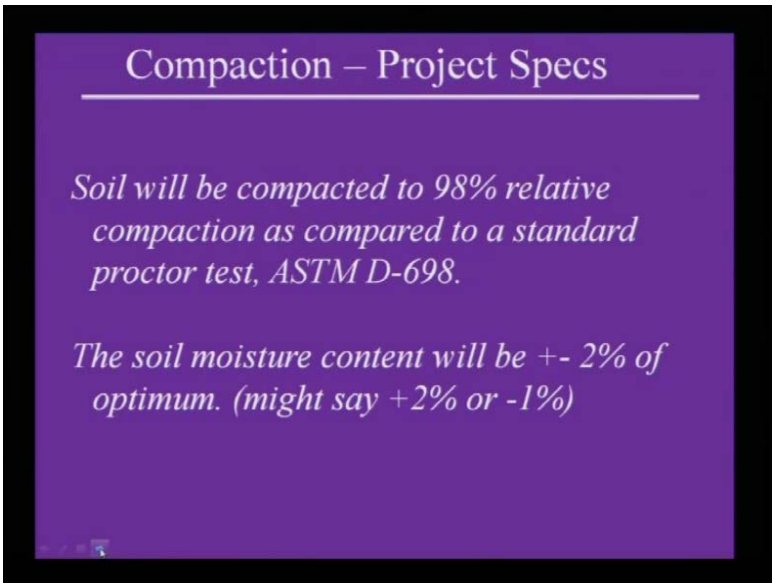

As per this a s t m standard soil will be compacted to 98 percent of relative compaction as compared to a standard proctor test and the soil moisture content will be plus minus 2 percent of optimum. It may be plus side, it may be minus side.

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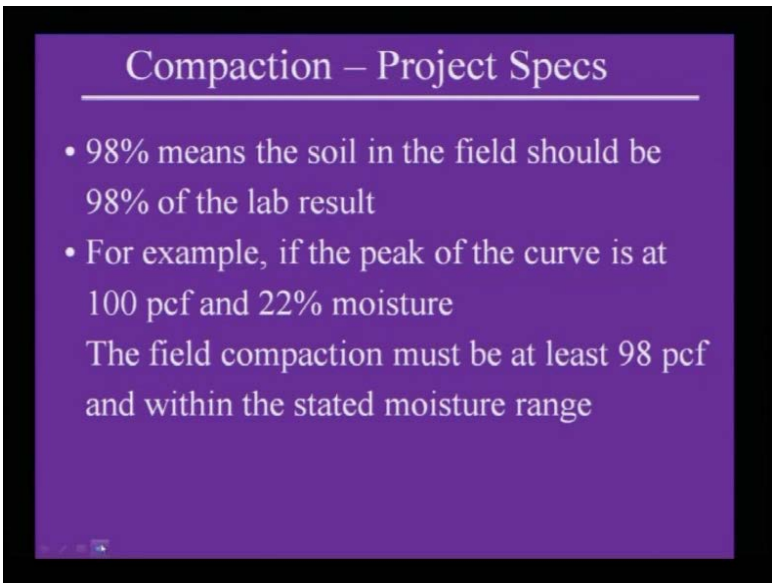

98 percent means the soil in the field should be 98 percent of lab result. 98 percent means whatever you are going to do compaction in the field, it should be 98 percent the compaction in the lab for example, if the peak of the curve is at 100 pascal per cubic feet,

so, and 22 percent moisture content, the field compaction must be at least 98 p c f and within the standard moisture range. That means this moisture range is your plus minus 2 percent of this moisture range.

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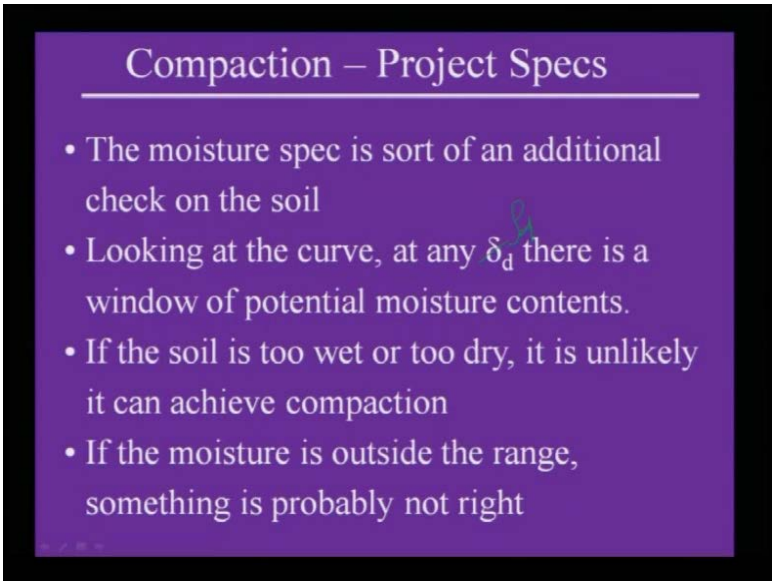

The moisture specific is sort of an additional check on the soil looking at the curve, at any density rho d there is a window of potential moisture content. If the soil is too wet or too dry it is unlikely it can achieve compaction. Proctor does not guarantee quality.

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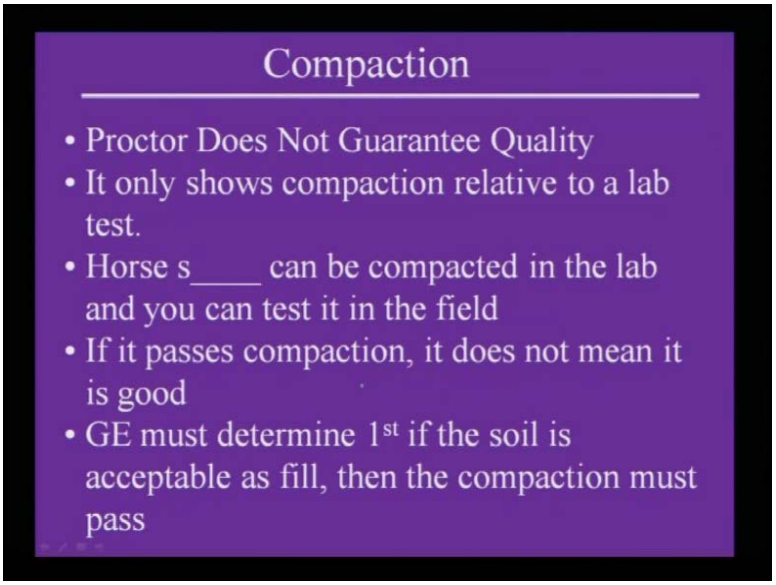

It only shows the compaction relative to the lab test means proctor test whatever you are doing in the laboratory, this is a very small test. It does not give you any guarantee of the quality to be maintained in the field, it only give this compactive compaction relative. Relative compaction it only gives and in geotechnical engineer must determine first if the soil is acceptable as fill, then compaction must be a pass means if you, if pass passes compaction it does not mean it is good.

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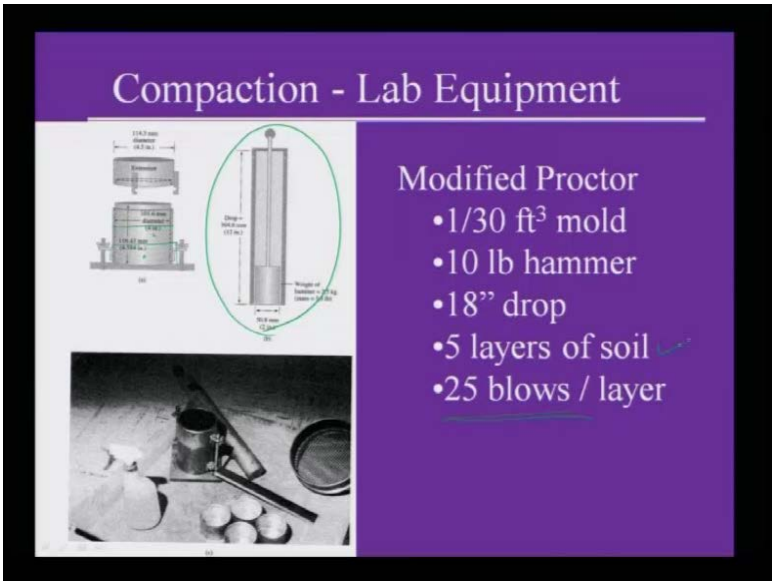

Now, if I go back to the original one this if I show it says as per the a s t m standard it says if this is the compaction mold, how you are going to do the compaction? That means in this compaction mold whatever soil sample you take it, you divide into three parts first part of the soil height you measure, first part of the soil to be filled and each layer means three layers. I divide entire soil to be filled inside the compaction mold in three layers, each layer has to be compacted means given 25 blows. 25 blows by means of hammer means here it is 25 blows, here it is 25 blows, here it is 25 blows. This is as per the specification given by American Society of testing materials at least you consider 3 to 5 layers. So, 5 layers is better, so you consider 5 layers of soil.

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Look at here, if I take the soil sample from here, this soil sample has been compacted inside the compaction by 5 layers.

So, each layer will be compacted to given 25 number of blows. That means, once you pick it, leave it, it is one blow. Like this you give equally distributed 25 number of blows with this by means of hammer and falling weight.

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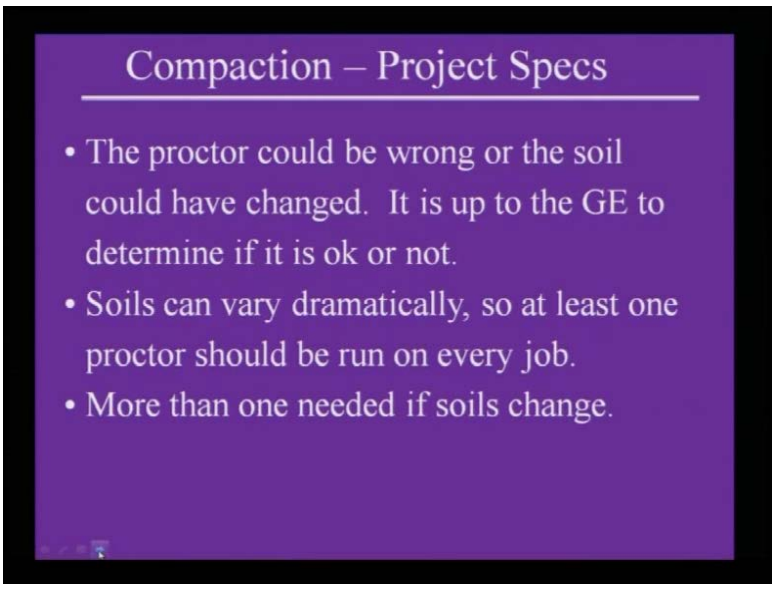

The proctor could be wrong or the soil could have changed, it is up to the geotechnical engineer to determine if it is ok or not. It does not mean that proctor compaction test will

give the accurate result. It may be wrong, it may be right. It is only the geotechnical engineer to decide based on your laboratory study. Soils can vary dramatically so at least one proctor should be run on every job more than one needed if soil changes that means if soil property changes from place to place then you can go for more compaction test or more proctor test.

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Generally, the lower the plasticity index, lower the plasticity index this is for clay the higher the relative density the better the soil will be for compaction.

Once lower the plasticity index, plasticity index is nothing but, p I is nothing but, which is equal to liquid limit, liquid limit minus plastic limit. Lower the plasticity index means the clay fractions are less that means it is possibility that you will get higher relative density and soil will be better compacted. Locally, if clay soil used as fill, if you use clay soil as a fill material then some rock of gravel size or slightly larger will be make a better engineering fill that means, if you are using this local soil you mix with some gravel, some stone inside, so it will make better compaction. A qualified geotechnical engineer should be hired

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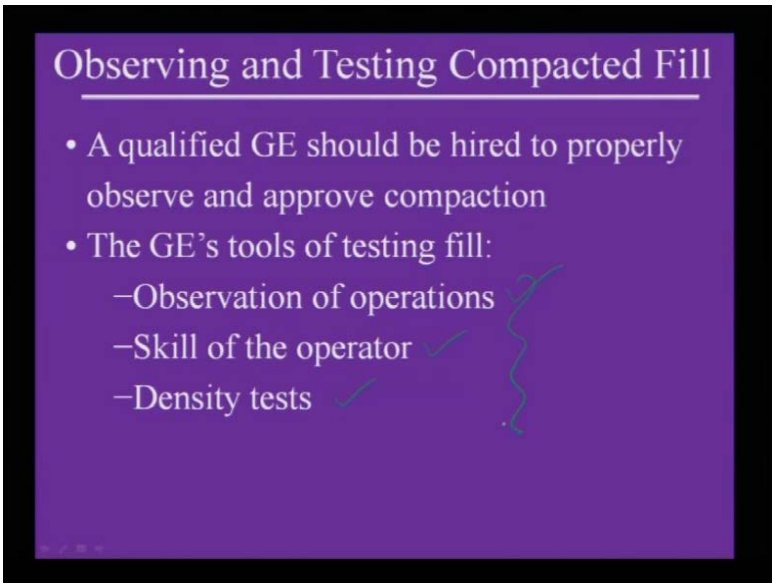

to properly observe and approve this compaction. The geotechnical engineers tool of testing fill is observation of operations, how this operation has been done, skill of operators and density test. This three has to be maintained.

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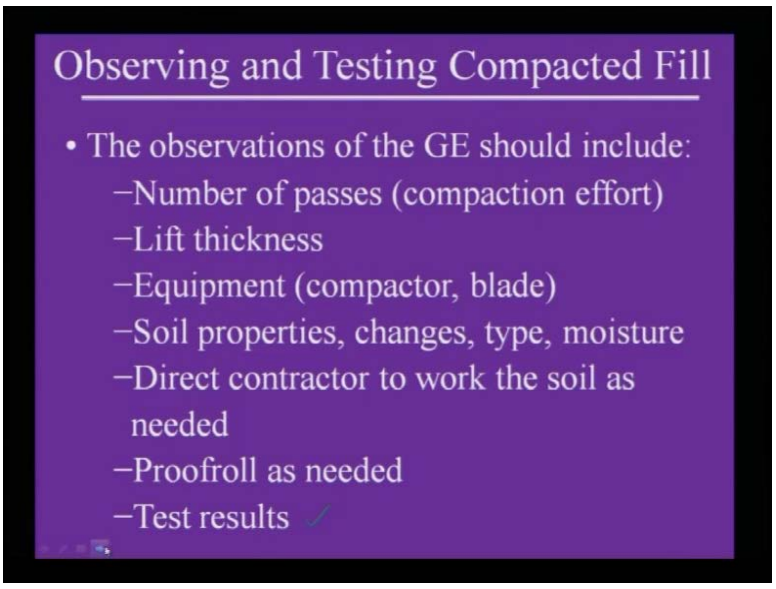

Then observation, observing and testing compacted field number of passes means compaction effort then lift thickness. Then what are the equipments? Compactor and blade, soil properties changes type and moisture direct contractor to work the soil as needed proof roll as needed and also test results.

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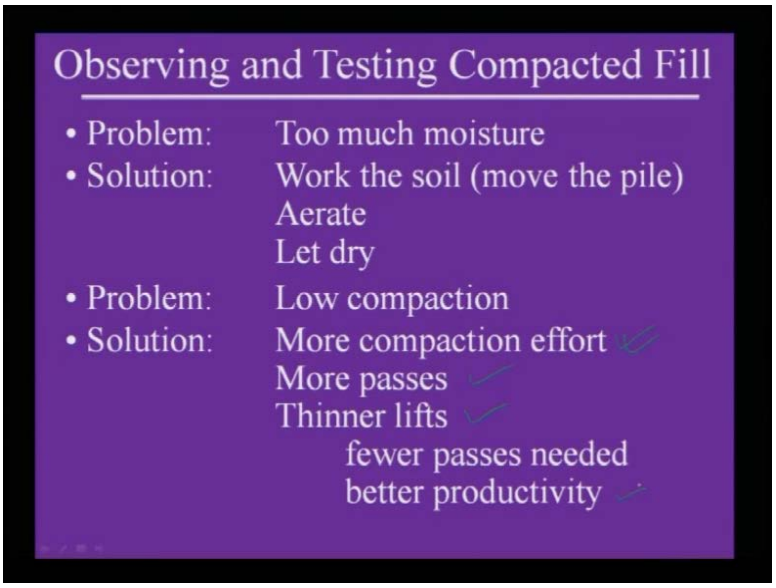

Problem, too much moisture. Solution, work the soil, aerate and let it dry that means if too much moisture content is there in the field in the soil has to be worked so that it become dry. Problem, low compaction, if there is a low compaction that means you have to apply more compaction efforts by means of rollers or compactors or more passes or thinner lifts, fewer passes needed better productivity.

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Look at this, observing and testing compacted fill. This is a ground, how it has been compacted if you look at here how it has been compacted by means of roller then look at this proof rolling looking for stability and no pumping.

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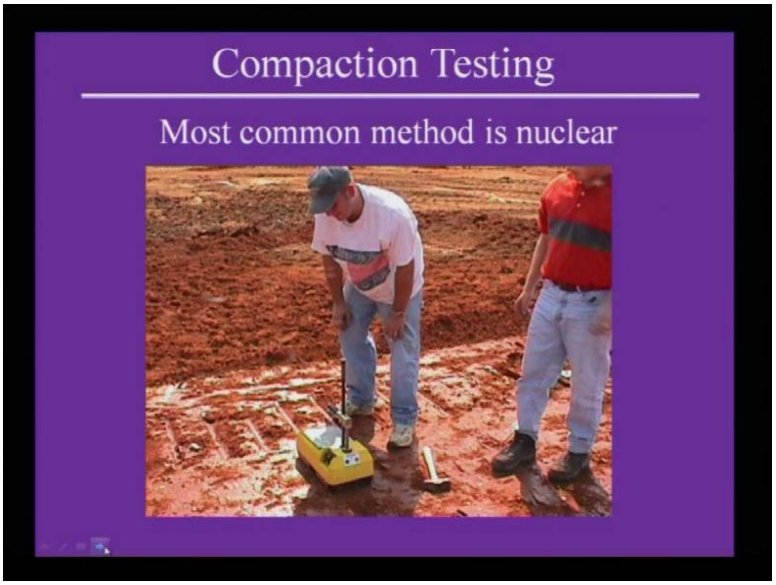

Most common method is your nuclear method of compaction testing. How by means of nuclear method the compaction testing has been measured or done.

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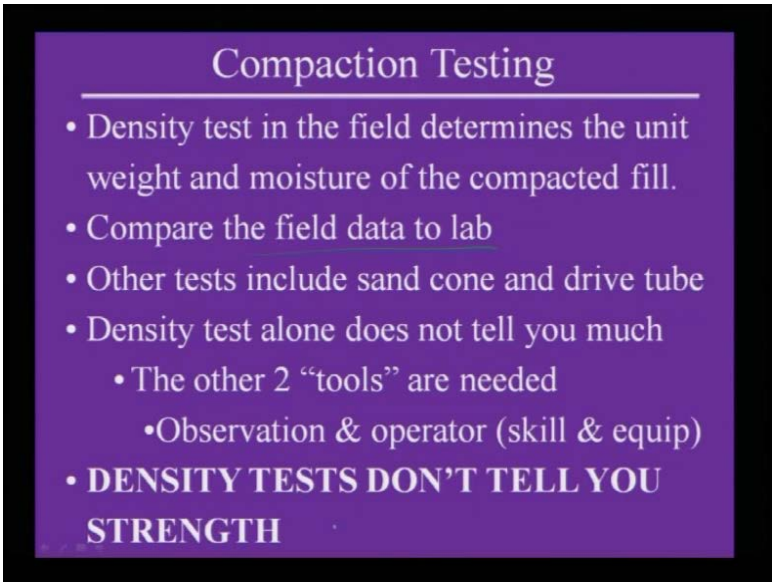

Density test in field determines the unit weight and moisture of the compacted fill that means in field if you go for density test, you can find it out compaction relative density

as well as what is the moisture content during this compaction. Compare once you do the density test, field density test by means of nuclear test in the field, compare the field density data with your lab. Other test includes sand cone and drive tube. Density test alone does not tell you much about this observation and operators. Density test do not tell you the strength, remember whatever the density test you are doing that only gives relative density and moisture content, it does not give the strength of the soil achieved.

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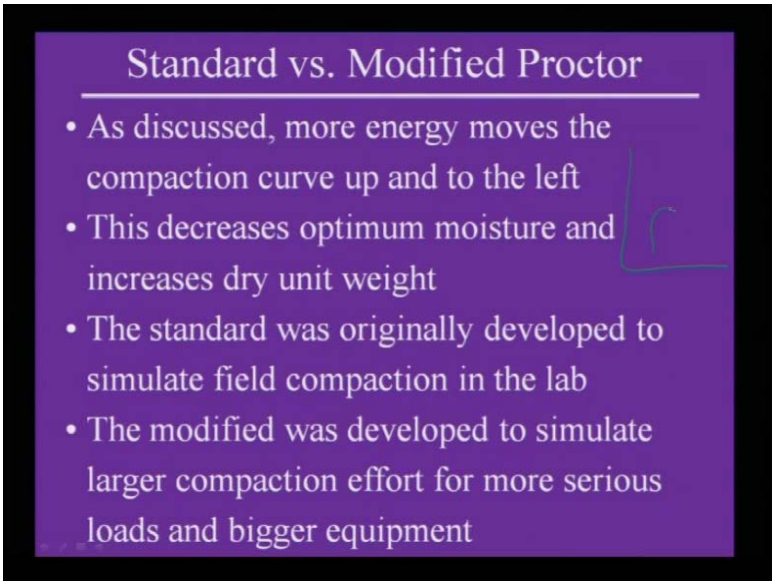

More energy moves the compaction curve up and to the left, that means it is more energy if I provide it curve will be moves up and towards the left, if you see it

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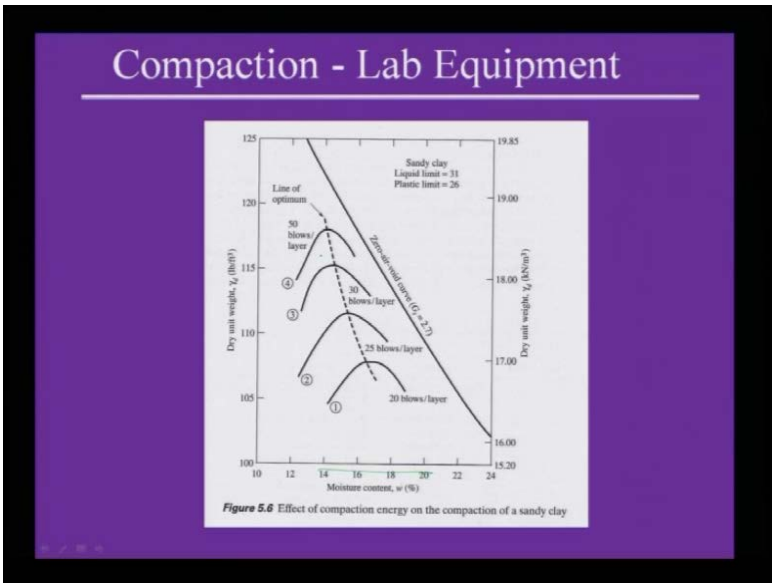

more energy has been applied in this case. One case 20 blows, other is your 25 blows, 30 blows, 50 blows more energy that means it shifted up the compaction curve is moving up and also it shifted towards the left, towards the left slightly towards the left.

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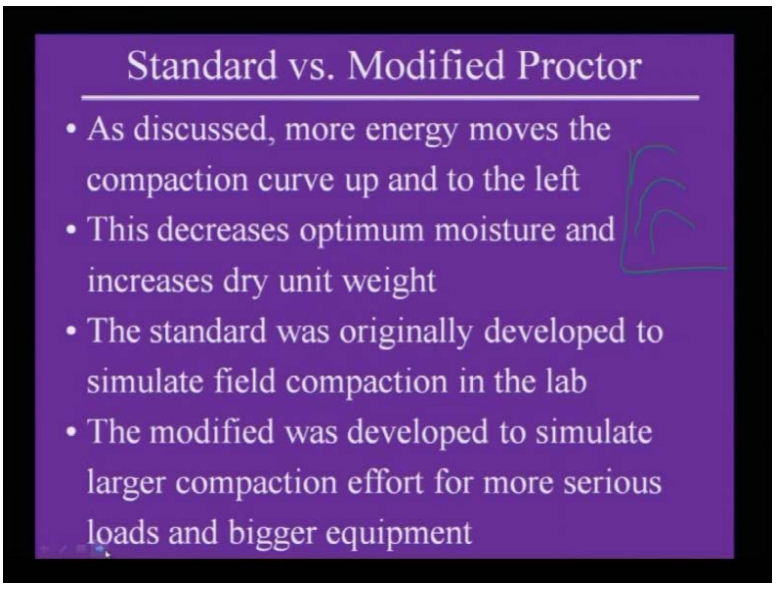

This decreases optimum moisture content, once more energy you apply that means it moves towards the left that means optimum moisture content decreases and increase the dry unit weight. The standard was originally developed to simulate field compaction in

the lab, the modified was developed to simulate larger compaction effort for serious loads and bigger equipments.

Now, this standard proctor compaction test has been modified as modified proctor compaction test.

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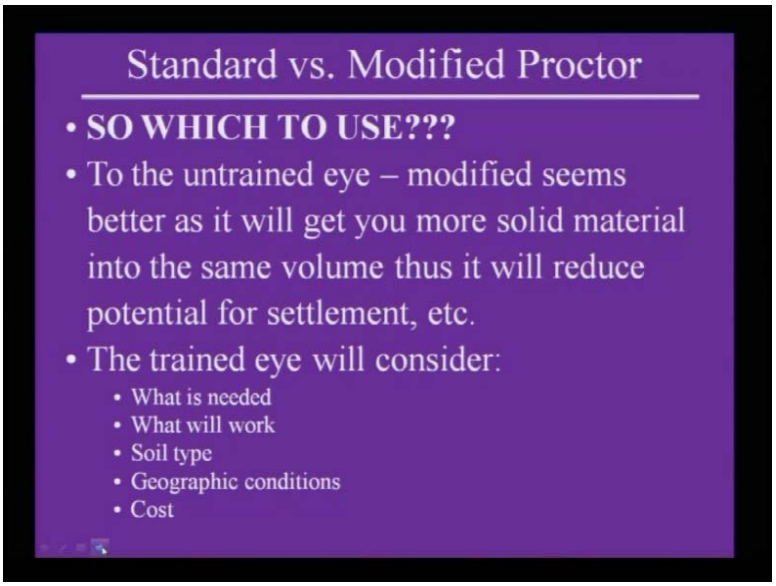

So, which to use? Whether you are going to use standard proctor test or modified proctor test? To the untrained eye modified seems better as it will get you more solid material into the same volume thus it will reduce you potential for settlement e t c, the trained eye will consider what is needed what will work and soil type geographic conditions and cost.

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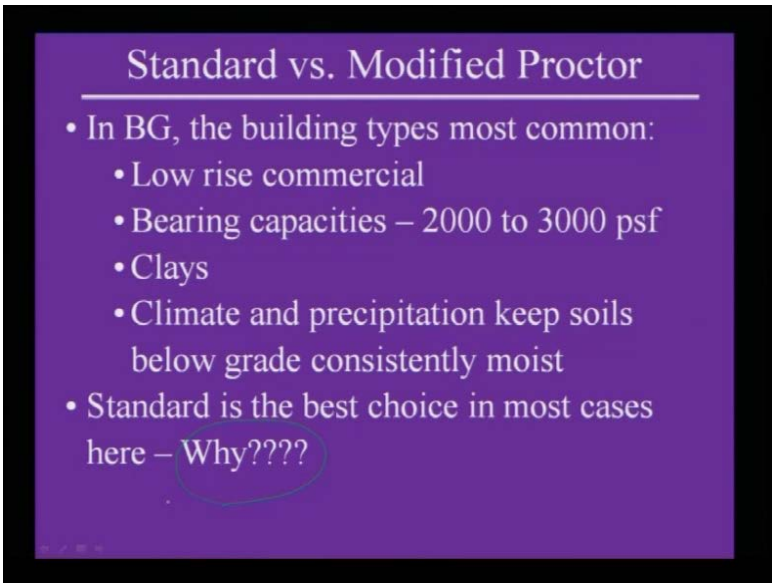

Bearing capacity generally it will be 2000 to 3000 pascal per square, climate and precipitation keep soils below grade consistency moist, standard is the best choice in most of the cases, standard proctor mold is the best choice in most of the cases and why you think you tell why this standard proctor test is better choice than your modified proctor test?

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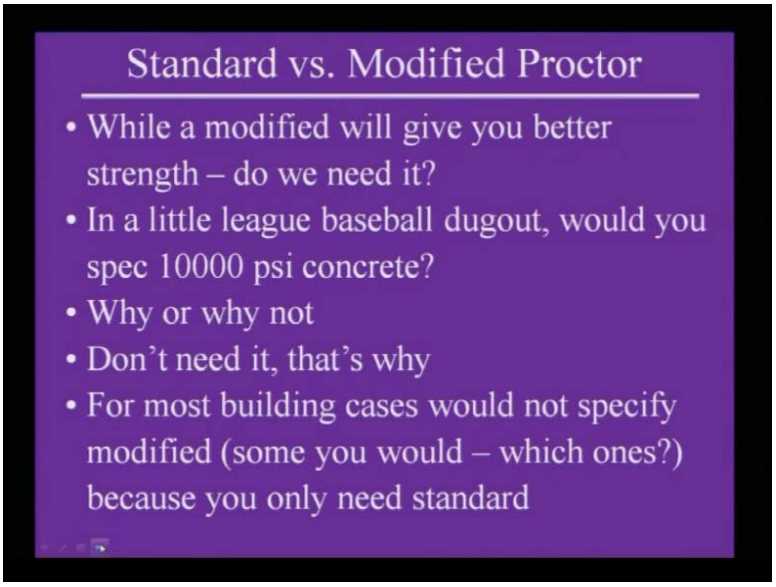

While a modified will give you better strength in a little why or why not does not need that is why for most of the most the building cases would not specify modify because

you only need standard that means in modify cases the energy applied it should be higher and it should be also applied for different difficult soils that means is best way for a normal building or normal field or normal construction site, if you want for compaction then to use only standard proctor test than your modified.

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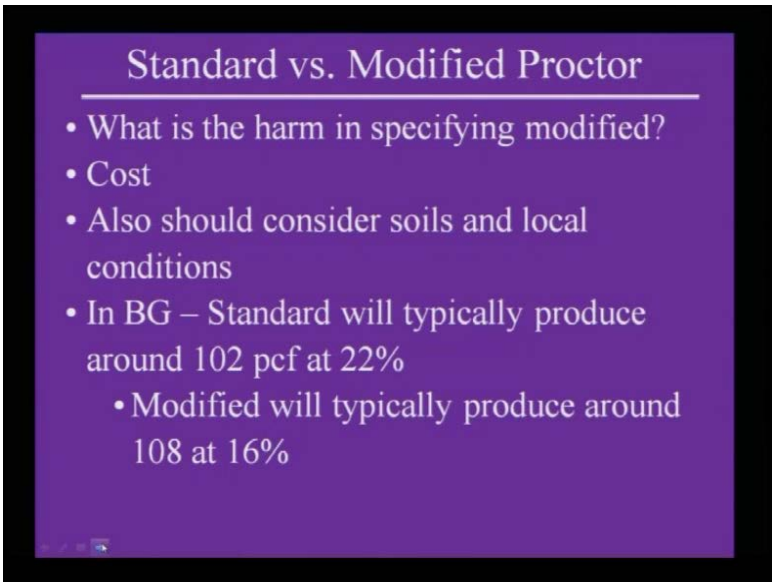

What is the harm? Next question is what is the harm means specifying modified? What will happen if I specify modify proctor test? Harm is the cost will be higher, also should consider soils and local conditions. Standard, will typically produce around you see in typical soil it will produce 102 pascal per per cubic feet at 22 percent, modified will typically produce around 108 at 16 percent moisture content.

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With a lot of compaction effort, moisture might get down to 20 percent. If you apply more compaction effort, the moisture content it may possible, it may go below 20 percent. To meet a modified, will need to get down to 17 to 18 percent, almost impossible to do. It can double or even triple time needed. If you go for modified compaction consider the situation before choosing standard or modified. These are all comparison, whatever I said it if I repeat it once again means why I am going to use standard and modified, which one we are going to decide at what conditions. What are the drawbacks, in case of modified? In case of modified the compaction effect will be more, so your moisture content you are getting around below 20 percent which is not possible in the field to compact up, not possible means it is very difficult to get also, you decide first where you are going to use means where it is required? What purpose the compaction is there if it is a simple building, simple field then you go for standard. If it is a complicated one then maybe you can choose your modified proctor test.

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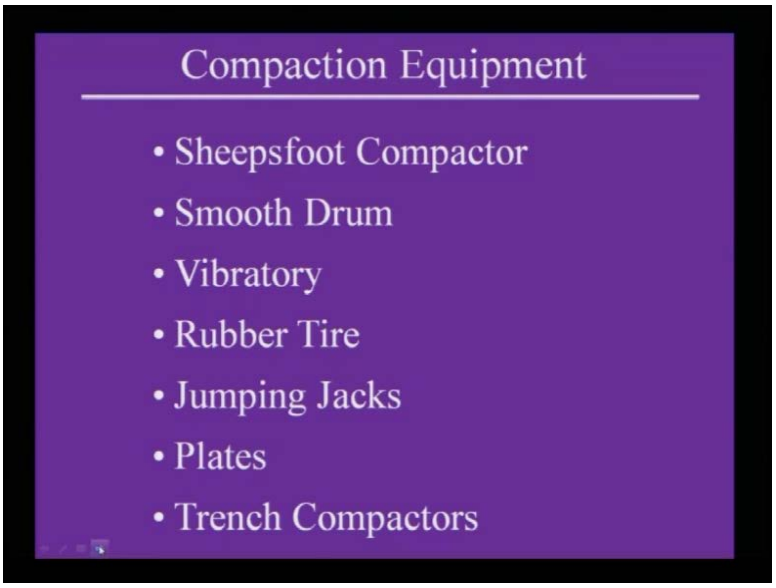

Now, what are the compaction equipments? Compaction equipments if I look at this if I classify this compaction equipment based on their functions first one is your sheeps foot compactor, second is your smooth drum, third is your vibratory, fourth is your rubber tire, fifth is your jumping jacks, sixth is your plates, seventh is your trench compactors.

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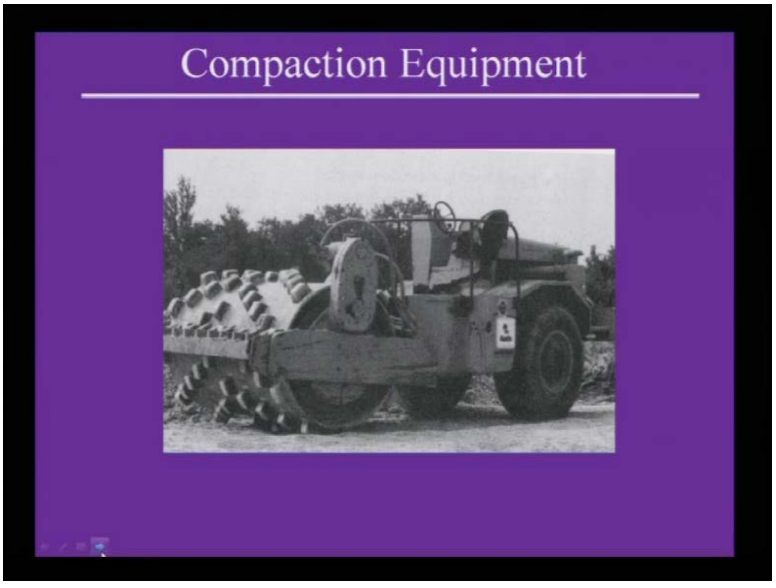

Now, what is this? If you look at here, what is this? This is your sheep foot, then go to this, this is your compaction equipment, this is your simple one smooth drum, third one is your smooth drum. Smooth drum means a drum is there, it is very smooth. You just

place over and roll it, smooth drum. Both the cases are this is your smooth drum it is basically used for road construction for bitumen, it place smoothly look at this, these are all sheeps foot means there are some foots are there coming out inside the drum, it will penetrate inside the ground. If it is kind of a clay soil these kind of equipments to be used.

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Now, look at this vibratory compactor by means of using loose sand. Suppose, there is a loose sand is there by using vibrator, this is your vibrator you place it.

So, it will vibrate loose sand particularly loose sand this vibration has been done so that it will compact particularly clay soils sheeps foot rollers generally used.

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This is a case of of sheepsfoot rollers, sheepsfoot compactor smooth drum I say for road constructions and bitumen, their vibratory for loose sands and this is for cohesive soils. If you look at this is one case of sheepsfoot then again this is a sheepsfoot, this may be a dented, this may be denting above this, it may be a triangular denting or may be a square shape smooth drum, another smooth drum, sheepsfoot vibratory, again vibratory, small vibratory. Look at this how this compaction has been done by sheepsfoot, this will penetrate inside, inside the ground. You look at here, this will penetrate inside the ground for better compaction. Smooth drum this has equipment, one driver is there. It will place over this, particularly this road construction in between, it is a smooth, the surface is smooth it will only pass this load is there, with this load it will only pass over this.

Again, this is a smooth drum case. Different types of smooth drum depending upon the how much load compactive effort you need? What is the compactive effort you need depending upon that this smooth roller, smooth drum is there.

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Vibratory compactor must it is as I said vibratory compactor, it is most effective in cohesionless soil. I have shown you the vibratory compactor, if you look at here vibratory compactor it is most suitable for sand, we call as a cohesionless soil. Can help in clay but, not as much as means same roller if I compare with this will it be possible vibratory compactor, can it be useful for clay? Yes, it can be useful but clay has addition factor. So, what will happen? Clay soil will, some part of the clay soil will be stick to the roller. To avoid that this sheepsfoot roller has been used. Smooth drum as I said smooth drum for asphalt, asphalt means for road construction for finish grade in soils, not good for initial compaction in soil. Look at this differentiation which compaction equipment you are going to use, what kind of soil, what kind of compaction it is there?

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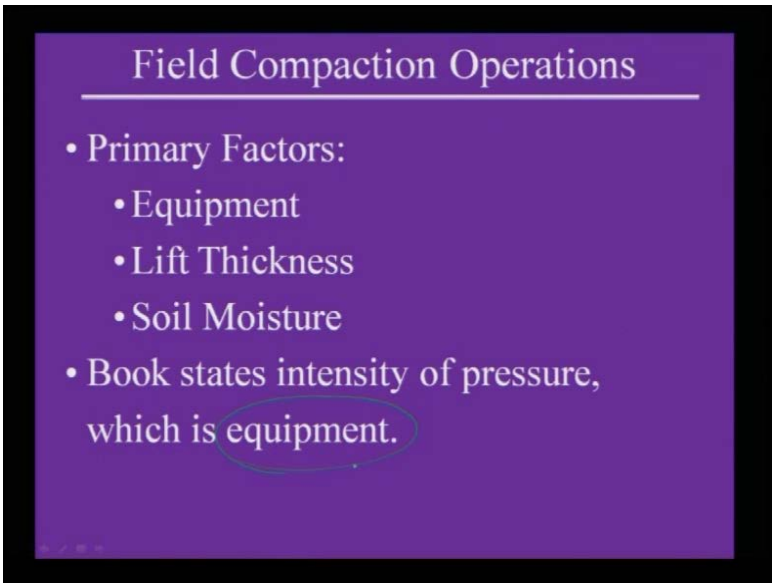

Primary factors, equipment, lift thickness and soil moisture. This effect, this particularly effect your field compaction operation that means first one is your equipment, second is your lift thickness, third is your soil moisture. State of intensity of pressure which is nothing but, will come from this equipment.

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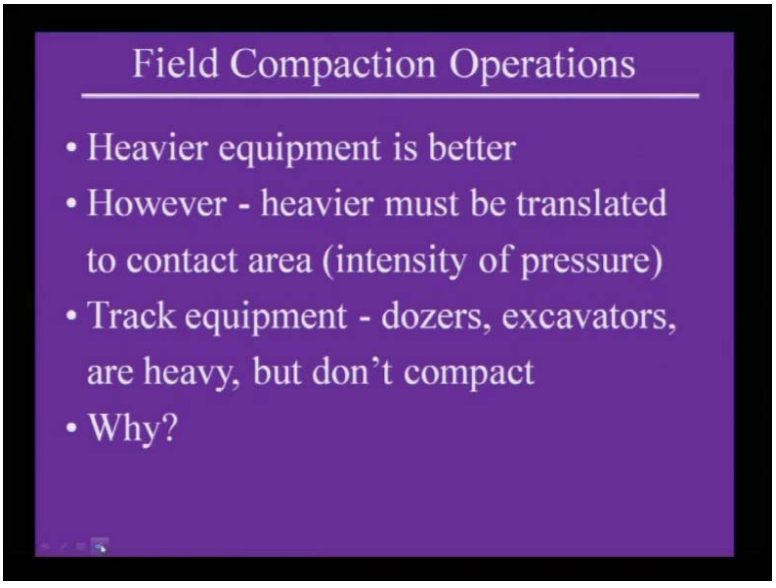

Heavier equipment is generally preferred or better however heavier must be translated to contact area that means intensity of pressure, track equipment that means dozers,

excavators are heavy but, remember it do not compact. If you consider this, these are my equipment in the field like dozer, excavator. It, excavator means it will excavate.

So, it will not compact.

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Why? Means if you look at this field compaction operation better compaction comes from what is your one.

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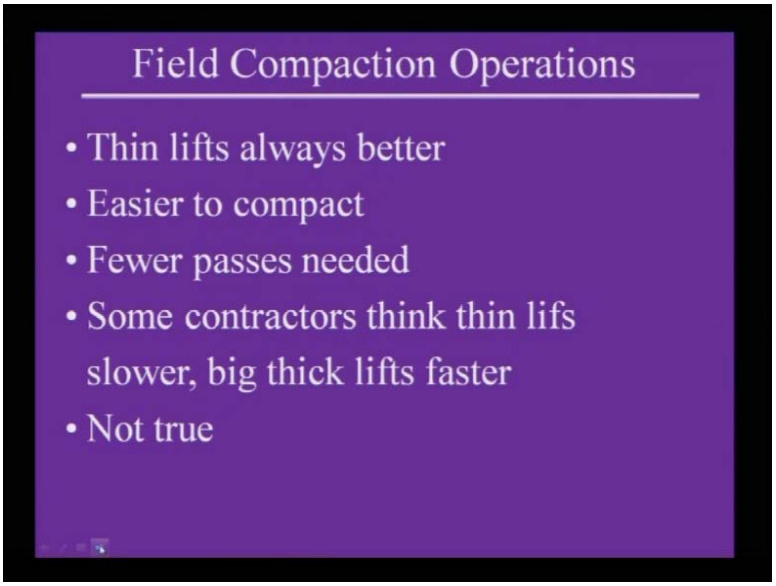

Thin lifts always gives better, what is you second easier to compact then less number of pass. Pass means

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how many times smooth drum you are passing over this surface? One time, two time, three, four time because it has certain load, so less number of passes you have so it will give better compaction.

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Field compaction operation, imagine filling a hole. Just imagine you are filing a hole, it will take X amount of truck load whether you place 2 foot lifts or 2 inch lifts it is X truck

load, thinner lifts spread farther that means less stop and reverse time, less passes to compact 2 than your 2 means less passes will be compact better. Thin lifts, thin lifts almost compacted by truck or scrapers.

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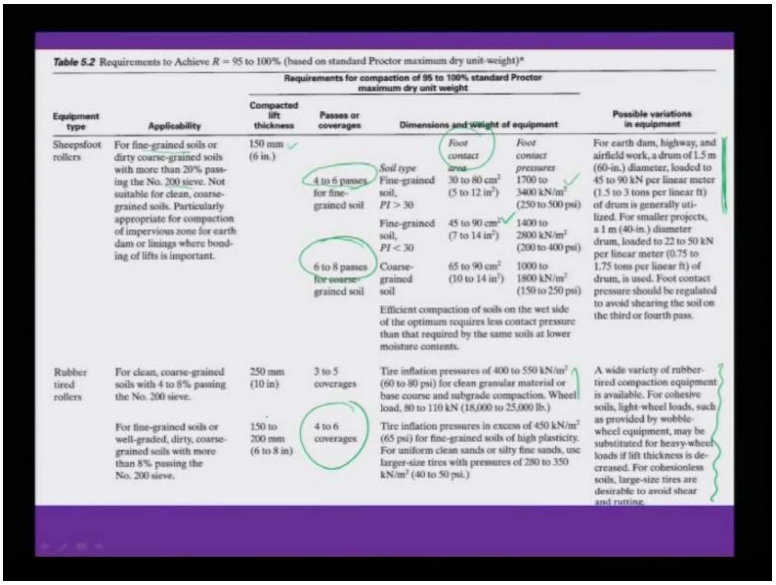

Table 5.2 Requirements to Achieve $R = 95$ to 100% (based on standard Proctor maximum dry unit weight)*

Equipment type	Applicability	Requirements for compaction of 95 to 100% standard Proctor maximum dry unit weight: Compacted lift thickness	Passes or coverages	Dimensions and weight of equipment			Possible variations in equipment
				Soil type	*Foot contact area*	*Foot contact pressures*	
Sheepsfoot rollers	For fine-grained soils or dirty coarse-grained soils with more than 20% passing the No. 200 sieve. Not suitable for clean, coarse-grained soils. Particularly appropriate for compaction of impervious zone for earth dam or linings where bonding of lifts is important.	150 mm (6 in.)	4 to 6 passes for fine-grained soil	Fine-grained soil, $PI > 30$	30 to 80 cm^2 (5 to 12 in^2)	1700 to 3400 kN/m^2 (250 to 500 psi)	For earth dam, highway, and airfield work, a drum of 1.5 m (60-in.) diameter, loaded to 45 to 90 kN per linear meter (1.5 to 3 tons per linear ft) of drum is generally utilized. For smaller projects, a 1 m (40-in.) diameter drum, loaded to 22 to 50 kN per linear meter (0.75 to 1.75 tons per linear ft) of drum, is used. Foot contact pressure should be regulated to avoid shearing the soil on the third or fourth pass.
				Fine-grained soil, $PI < 30$	45 to 90 cm^2 (7 to 14 in^2)	1400 to 2800 kN/m^2 (200 to 400 psi)	
			6 to 8 passes for coarse-grained soil	Coarse-grained soil	65 to 90 cm^2 (10 to 14 in^2)	1000 to 1800 kN/m^2 (150 to 250 psi)	
				Efficient compaction of soils on the wet side of the optimum requires less contact pressure than that required by the same soils at lower moisture contents.			
Rubber tired rollers	For clean, coarse-grained soils with 4 to 8% passing the No. 200 sieve.	250 mm (10 in)	3 to 5 coverages	Tire inflation pressures of 400 to 550 kN/m^2 (60 to 80 psi) for clean granular material or base course and subgrade compaction. Wheel load, 80 to 110 kN (18,000 to 25,000 lb.)			A wide variety of rubber-tired compaction equipment is available. For cohesive soils, light-wheel loads, such as provided by wobble-wheel equipment, may be substituted for heavy-wheel loads if lift thickness is decreased. For cohesionless soils, large-size tires are desirable to avoid shear and rutting.
	For fine-grained soils or well-graded, dirty, coarse-grained soils with more than 8% passing the No. 200 sieve.	150 to 200 mm (6 to 8 in)	4 to 6 coverages	Tire inflation pressures in excess of 450 kN/m^2 (65 psi) for fine-grained soils of high plasticity. For uniform clean sands or silty fine sands, use larger-size tires with pressures of 280 to 350 kN/m^2 (40 to 50 psi.)			

This is a summarize means to achieve 95 to 100 percent of density based on standard proctor maximum dry unit weight, it has been taken from some of the paper. Let us start with one by one. Sheepsfoot rollers where it is applicable, I have shown you this equipment. Applicability means particularly what kind of soil, sheepsfoot rollers applicable basically for fine grained soils as I say clay is a fine grained soil or dirty coarse grained soil with more than 20 percent passing, this sieve is 200 m m, not suitable for and again it is suitable for fine grained soil. Then which soil it is not suitable? It is not suitable for clean coarse grained soils.

Now, compacted lift thickness. What is the lift thickness? 150 m m. Now, if you see look the passes or coverage, how many passes? How many number of times you pass it? Generally for the soil it preferred 4 to 6 number of passes and soil type fine grained soil, plasticity index greater than 30, foot contact area is 5 to 12 in square, at foot contact pressure generally maintained 1700 to 3400 kilo newton per meter square. If plasticity index is less than 30, fine grained soil the foot contact that means how much foot has been contact, this foot contact is 45 to 90 centimeter square and the contact pressure is about 1400 to 2800 kilo newton per square. Possible vibration in equipment for earth

dam, highway, airfield, a drum of 1.5 meter diameter loaded to 45 to 90 kilo newton per linear meter of drum is generally utilized. You see the size, size of the drum has been specified, if you are using for earth dam, highway particularly aerodrome, airfield work what should be your size of you drum you are going to use?

Now, for coarse grained coarse grained soils with fines if you are using this sheepsfoot rollers then what are the passes? The passes permissible passes generally it gives better result that is your 6 to 8 passes. Then come to next one is your rubber tired rollers. Rubber has been placed over the drum, so rubber has been tired with this rollers, it has been used particularly for clean and coarse grained soil. Remember for clean and coarse grained soil.

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If you look at this rubber tired I can show you in this equipment this is your rubber tired this rollers, compacted lift thickness is your 250 m m, generally passage is your 3 to 5 coverage, 3 times to 5 times you pass it and this is a specification of pressure and how much is your variety of this rubber you are going to use? For fine grained soils or well graded soil, generally the pass will be 4 to 6.

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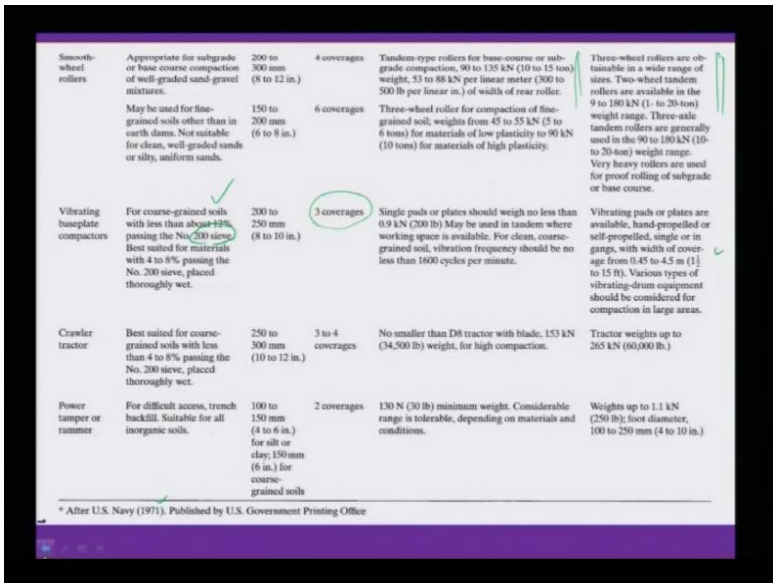

Smooth-wheel rollers	Appropriate for subgrade or base course compaction of well-graded sand-gravel mixtures.	200 to 300 mm (8 to 12 in.)	4 coverages	Tandem-type rollers for base-course or sub-grade compaction, 90 to 135 kN (10 to 15 ton) weight, 53 to 88 kN per linear meter (300 to 500 lb per linear in.) of width of rear roller.	Three-wheel rollers are obtainable in a wide range of sizes. Two-wheel tandem rollers are available in the 9 to 180 kN (1- to 20-ton) weight range. Three-axle tandem rollers are generally used in the 90 to 180 kN (10- to 20-ton) weight range. Very heavy rollers are used for proof rolling of subgrade or base course.
	May be used for fine-grained soils other than in earth dams. Not suitable for clean, well-graded sands or silty, uniform sands.	150 to 200 mm (6 to 8 in.)	6 coverages	Three-wheel roller for compaction of fine-grained soil; weights from 45 to 55 kN (5 to 6 tons) for materials of low plasticity to 90 kN (10 tons) for materials of high plasticity.	
Vibrating baseplate compactors	For coarse-grained soils with less than about 12% passing the No. 200 sieve. Best suited for materials with 4 to 8% passing the No. 200 sieve, placed thoroughly wet.	200 to 250 mm (8 to 10 in.)	3 coverages	Single pads or plates should weigh no less than 0.9 kN (200 lb) May be used in tandem where working space is available. For clean, coarse-grained soil, vibration frequency should be no less than 1600 cycles per minute.	Vibrating pads or plates are available, hand-propelled or self-propelled, single or in gangs, with width of coverage from 0.45 to 4.5 m (1½ to 15 ft). Various types of vibrating-drum equipment should be considered for compaction in large areas.
Crawler tractor	Best suited for coarse-grained soils with less than 4 to 8% passing the No. 200 sieve, placed thoroughly wet.	250 to 300 mm (10 to 12 in.)	3 to 4 coverages	No smaller than D8 tractor with blade, 153 kN (34,500 lb) weight, for high compaction.	Tractor weights up to 265 kN (60,000 lb.)
Power tamper or rammer	For difficult access, trench backfill. Suitable for all inorganic soils.	100 to 150 mm (4 to 6 in.) for silt or clay; 150 mm (6 in.) for coarse-grained soils	2 coverages	130 N (30 lb) minimum weight. Considerable range is tolerable, depending on materials and conditions.	Weights up to 1.1 kN (250 lb); foot diameter, 100 to 250 mm (4 to 10 in.)

* After U.S. Navy (1971). Published by U.S. Government Printing Office

Now, next is your smooth wheel rollers. If you look at your smooth wheel rollers, it is appropriate for sub grade or base course compaction. As I said for smooth drum earlier I have shown you the smooth drum, this is your smooth drum. In this case where it is applicable? Smooth wheel rollers, it is appropriate for sub grade or base course compaction for road construction sub grade or base course compaction of well graded sand gravel mixture. Generally, how many times, how many passes you want to give? Generally 4 passes will be enough. So, these are all your compactive effort what is the pressure these are given this in details then vibratory base plate compactor. A base plate will be there, a plate has to be there it has to be vibrate. So, in this case basically it has been used particularly for coarse grained soils with less than about 12 percent passing I a sieve of 200, that means coarse grained of soil where this 12 percent of only soil is passing through 200 m m sieve, 200 micron sieve in that case you will go for your vibratory base plate compactor.

So, this passes. Generally you are going to provide 3 passes and these are the details of single pads or plates, should weigh means not less than 0.9 kilo newton and this is about vibrating pads and these are all tractors and powered tamper rammer means if you look at this from here there are basically 3 types of equipments generally preferred. One is your sheepsfoot rollers for fine grained soils, rubber rollers this is for your for clean or coarse grained soils and your smooth drum or smooth wheel rollers, this is for your basically road construction or sub grade or base course compactions. These are all

details, where you are going to use and what are the number of passes you are going to do and detail dimension, what is the pressure coming to this roller.

These are all details has been given, this has been taken from US navy 1971, that is all about this compaction laboratory as well as field and about this compacting equipment, compaction equipments and different equipments and where it is going to be use, that is all. Thank you.