TREATMENT OF INDIAN REGUR SOIL ACCORDING TO AMERICAN HIGHWAY STANDARDS

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Chandoobhai Manibhai Patel

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Gail C. Blomquist
Major professor

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TREATMENT OF INDIAN REGUR SOIL ACCORDING TO AMERICAN HIGHWAY STANDARDS

By

Chandoobhai Manibhai Patel

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INTRODUCTION:

Heavy clay soils have often been found difficult to handle in road construction. The difficulty mainly lies in providing stable road base in these soils, due to their characteristics. These characteristics are evaluated by measurements of the Atterberg Limits and Mechanical Analysis of Determinations.

Engineers in India have often met with this kind of problem in Regur soils or well known as Black Cotton Soil which are similar to Houston black clay and Merced clays of the United States.

The purpose of the study is an attempt to make a comparison of soils of the Regur type of India with similar soils of the Rendiza group of the United States employing the standard A.A.SHo classification tests.

The author has attempted to compare the characteristics of two soil samples from United States, namely, Houston black clay and Merced clay, with those of two samples of Regur soils from India.

REVIEW OF LITERATURE:

Physical characteristics of Soil Affecting Road Construction.

For purposes of road construction, Regur has long been held to be very treacherous soil; and the designs adopted have been costly. When the soil is dry, it withstandd very high bearing pressure and presents a smooth riding surface which will carry the heaviest motor vehicles. After heavy rains, vehicular traffic becomes impossible since the soil softens and will not support the weight of a man. In the moist state, the soil looses its cohesion and becomes almost fluid, its bearing capacity is reduced to approximately four or five pounds per square inch. The soil has a high expansion coefficient and when confined between wing walls of a bridge, under a rigid pavement, or under a floor, it will exert extreme vertical pressure.[2] It is reported that on one occasion a heavy reinforced concrete beam, fourteen inches wide and eleven and one half inches deep, which was rigidly fixed to reinforced concrete piles driven well into the hard soil on seven feet six inch centers, which reposed on Regur soil between the piles, cracked in the upper (non-reinforced) section due to the vertical pressure exerted by the Regur soil on wetting. In dry periods the water evaporates and the soil shrinks and forms wide fissures which often extend to considerable depths.

METHOD OF STABILIZING REGUR SOIL:

In India, soil stabilizing methods have been practiced from very early times for road constructions. Although modern scientific methods were unknown, engineers did from practical experience, practice some of the modern stabilizing principles, without knowing the "why or wherefore" of them. In the Tanjore Delta,[1] which has the greatest mileage of maintained earth roads in Southern India, the predominating soil is silty clay. This soil is suitable for brick making and, therefore, not a true Regur soil, though possessing many Regur soil characteristics. The normal methods of maintaining these roads is ploughing the surface, spreading sand over the ploughed surface, and raking the sand into the surface for a number of days until the surface has been consolidated by traffic. The engineers by experience know when the road bed required additional sand and adjust the surface conditions until the bed materials conform approximately to the condition of optimum moisture. The roads have thus been well maintained for years.

On roads of Regur soils, the same processes have been practiced for many years. Before World War I, this method was used entirely for adapting Regur soils to stabilization, to fit them to receive a macadam surface under favorable conditions.

A macadam surface required many years of this treatment on the subgrade to insure any degree of an all weather road. Where moorum soils existed at shallow depths below the Regur soils, lesser quantities of sand were required for stabilization then on deep Regur soils. In one instance, a layer of six inches of sand, incorporated on a ploughed surface in July, could hardly be traced in November.

Due to the pecular characteristics of Regur soils, differentiating them from other clayey soils, the normal methods of stabilization for clayey soils were unsuited and new techniques were required. Unfortunately, practically no experimentation has been conducted on roads over these soils. It appears desirable to develop scientific research in this field in order that a large part of wasted time and materials through the adoption of random methods of treatment may be avoided. In the absence of scientific research, a description of the methods found successful is presented with what is hoped to be, a plausible theoretical explanation.

As already pointed out, Regur soils have a high bearing capacity when dry, but lose this almost entirely when saturated. When water comes in contact with the soil, it percolates downward by both gravity and capillarity. Hence, if a thick layer of impervious material be laid over the soil and well consolidated, wetting by atmospheric moisture will be eliminated and only the moisture entering by capillary action laterally and vertically will have to be dealt with.

Moisture entering laterally can largely be eliminated if the road is taken in embankment and water is prevented from stagnating on either side by efficient drainage. This leaves the water entering by capillary action from below, which is very difficult completely to eliminate. The quantity of this moisture will, however, be necessarily small as it will have to travel a long distance upwards against the gravity. Moreover, the water table in Regur soil area is generally low.

STONE BASE NOT RECOMMENDED:

Several engineers believe that a base of stones spread over Regur soil distributed the load over a wide area and decreased the pressure to safe bearing capacities of the soil. Stone soling (base) is costly, especially when the materials have to be transported great distances. Secondly, as in the case of sand, a stone base is not impervious and the Regur soil below may become saturated by water entering from the surface. When this happens, the bearing capacity of the soil decreases sharply and distribution over a safe area is not practical. Further, the Regur soil works upward through the base and, by lubricating, causes the stone to sink individually. Unless the material forming the base is homogenous, the usual formula for the determination of the surface, based on the distribution by the base over the specified area, cannot be applied.

In order to make the base homogenous, it must be built with an interlocking principle. This leads to excessive cost and in many cases the stone may not be fit for such construction. It was found that a six inch macadam coat on a well constructed ten inch base gave the same bearing capacity on the subbase as a twelve inch macadam surface. Hence, to give the same area of distribution, well-constructed Telford base requires a sixty per cent greater depth than that required for a macadam surface. This excess might be considerably more with the quality of Telford base commonly adopted.

To avoid the risk of failure with Telford type base, it is common practice to lay a moorum coat of three to four inches thick below the Telford base to prevent the Regur soil working up. An additional coat of moorum, three to four inches thick, is employed over the base to fill the voids between the stones and thus make the coat relatively impervious, and to provide a cushion for the road metal. Even with this treatment it is doubtful if the entire depth of base, including top and bottom moorum coats, can be considered homogenous; and whether the normal assumption of distribution of load is correct. It is reported that a good deal of success is attained by employing this method, but it is not clear whether the success is due principally to the moorum soil or the Telford type base. The method is, however, very costly. As engineers the consideration should be both economical and practical.

BASE COURSE RECOMMENDED:

Black Cotton Soils (Regur), of the table lands, generally overlies moorum; the thickness of the soil varying from a few inches to several feet. Immediately below the top stratum of Regur soil, the moorum may not be granular, since the decomposition of the underlying rock may result in a large clay fraction. One to three feet below the Regur stratum is normally found a good moorum which is a granular structure with the clay fraction sufficient for binder. This will form, when well consolidated, a fairly impervious mass. If the granular moorum soil is excavated and placed in nine to twelve inch lifts over the Regur soil, well consolidated, it provides an impervious layer with a high load bearing capacity over which the road metal is placed. This treatment protects the Regur soil from the moisture by percolating surface water or hygroscopic moisture. The moorum soil lift protects the underlying Regur soil by intercepting any moisture and retaining it. The resulting load bearing capacity of the Regur soil is not appreciably reduced even under adverse conditions. If well consolidated, the moorum lift is capable of distributing the load over the Regur soil in accordance with the usual formula, and the thickness of the surface coat and Telford base may be computed with reference to a concentrated load on the surface.

When the Regur soil is plastic, the moorum soil may be spread in lifts of three to four inches, thoroughly mixed and consolidated by rolling. This condition enables the Regur soil to incorporate into the moorum soil. Following consolidation a nine to twelve inch lift of moorum soil may be spread, moistened, and consolidated to provide an impervious layer. In computing the thickness of the base, the lower third of the moorum lift should be disregarded in allowance for incorporation with the Regur soil.

Special treatments of Regur soil have been practiced in extreme cases, by removing and replacing the Regur soils by moorum soils, to depths of approximately fifteen feet. With these extreme treatments no difficulty can be expected in excavation, resulting from springs or ground water.

DRAINAGE:

In Deltaic areas the formation of Regur soils are deposited as aeolian soils with no underlying moorum soils. In such formations laterite soil, or laterite moorum, has been found to provide a good base course. In these areas, laterite moorum may be costly due to long haul distances.

The practice of constructing road beds through cut sections of Regur soils would not be advisable. Special precautions must be taken, in such instances, to provide adequate edge drainage. Sand and gravel cushions are also recommended to prevent capillary and percolating water from entering the grade. The moorum layer or a sand cushion may then be placed in the usual way.

Regur soil areas are generally vast plains, where it is necessary to build all highways on fill sections to provide adequate drainage, it is necessary to build the road in embankment of at least a foot. If moorum soil is laid over the fill, capillary action will be minimized and the surface protected. If it is not too costly, it is good practice to enclose the Regur embankment with moorum soil. Though initial cost is high it will be more than offset by the reduced maintenance charges, since erosion on the berms and slopes will be minimized. The moorum protective soil need not be more than six inches thick.

PRACTICE IN THE UNITED STATES:

A method commonly employed to improve stability of clay soils is to increase the angle of internal friction by additions of large size granular material, while the cohesion may be preserved by water proofing the soil. To take advantage of the high cohesive strength of a clay soil, by the proper control of its moisture content, a bituminous surface treatment of heavy road oil was used on a section of road in Northwestern Minnesota. This area of Minnesota is very flat, the bed of an old glacial lake. Treatments of gravel to the surface was not successful, and for this reason the bituminous treatment method was given a trial in 1925. After treating the existing road with the road oil, it was found that the surface was more stable than under previous treatments, even for traffic volumes of seven hundred and five vehicles a day. This treatment pointed the way to a new field of research for treatment of heavy clays.

Dr. Hans F. Wintercorn,[10] one of the leading investigators, observed that stabilization of heavy clay was a function of the general character of the soil and its exchange cations. The exchange cations of high valency, large ionic radii, and low water affinity are desirable. It was also shown in the extensive studies by the Portland Cement Association, Endersby,[10] Becker, and Benson, that the successful treatment of heavy clay soils for soil cement construction required about sixteen and two tenths per cent of cement and for soil bitumen treatment about twelve and six tenths per cent of bitumen for meeting the prescribed specifications. The high percentages of cement and bitumen were not considered to be economical and, hence, these treatments have not been generally used by Highway Departments.

Further experiments with heavy clay soils, were carried out to determine the effect of the addition of a small amount of cement. In these tests it was found that the addition of small amounts of cement to these soils caused a marked improvement of the plasticity index,[10] the volume change, and shrinkage properties; thus causing these soils to function satisfactorily as subgrades capable of supporting pavements over them.

The most recent experimental work involving the stabilization of clay soils, by the addition of lime, is that reported by the Texas Highway Department. The addition of small amounts of lime was found to be surprisingly effective in the treatment of the highly plastic subgrade soils. This treatment increased the stability and water repelling properties of the soil sufficiently to permit its use as a base for the higher type pavements. The strength in the confined and unconfined compression test, the shrinkage and swelling properties, and the plastic properties were greatly improved. The result of lime upon clay soils is not of short life, and the following general conclusions were indicated by them:[10]

1. Soil-lime stabilization has definite application in highway construction for improvement of certain subgrade and flexible base materials.
2. Many natural soils are suited to lime stabilization. The identical materials proposed for use should be subjected to preliminary physical tests.
3. Good proportioning and mixing of constituents are advantageous.
4. The compacting moisture should be at, or slightly below, optimum moisture content for the given compactive effort employed.
5. A high degree of compaction greatly improved the stability of soil lime mixtures.
6. Suitable curing procedures of the soil-lime mixtures are also important to develop high strengths.
7. Application of bituminous wearing surface is desirable.

DARK CLAY SOILS OF WARM REGIONS:

Deep dark clays characterized by much shrinkage and swelling with changes in moisture have been described from many parts of the world. They are developed mainly in clayey calcareous sediments or residum from certain basic rocks, mainly basalt, gneiss and argellaceous limestone. Generally, they are high in calcium and have surface horizons either calcareous or neutral to only slightly acid, but strongly acid forms occur in some areas with more than forty inches of rainfall. (Generally found from warm temperature to tropical regions but also in cool regions.) They are found on every continent but largely in regions with well defined rainy and dry seasons and rainfall of less than fifty inches. The most extensive areas seemingly are in Africa, India, the Southern United States, Australia, South America, Philippines, Mexico, Cuba, and various islands in the Pacific. They are known as RENDZINA in the United States, REGUR or BLACK COTTON SOIL in India, BLACK EARTH in Australia and South America, TIRS in Morocco [6].

For our purpose four samples were chosen. Two samples were from Indian Regur soil and two were from Rendzina series of the United States. Regur samples are from two different states of India, one is from Bombay state and the other is from Nagpur of central province. The soil samples of the United States are Houston Black Clay of Texas and Merced Clay from California.

The general characteristics of these soils, their geographic setting, climatic conditions and the parent materials, are discussed first. The second part contains an experimental comparison carried out according to American Association of State Highway Officials standards.

MERCED CLAY:

The Merced[9] soils are dark-colored, heavy-textured, poorly drained soils developed on alluvium of mixed but mostly granitic rock origin. These soils normally have a high water table and under natural conditions were often flooded and covered by water for considerable periods. Climate is semiarid to arid mesothermal with hot and dry summers and cool, moist winters. Mean annual precipitation ranges from five to fifteen inches, and mean temperature is about 63 F. Growing season averages about two hundred and fifty days.

The Merced soils are associated, in some places closely and intricately, with the more highly organic and friable Temple soils and with the less dark Rossi soils that have shallower surface soils and stronger concentrations of soluable salts. Where the three soils are associated, the Merced commonly lies at slightly higher elevations than the Temple and at slightly lower elevations than the Rossi. The Merced soils are somewhat similar to the Chino soils but have more compact and distinct subsoils. They also resemble the Stockton soils but lack the semiconsolidated substrata characteristic of the Stockton soils and differ as to parent material.

SOIL PROFILE:

			Range in thickness
1.	0-16"	Dark-gray slightly calcareous moderately alkaline clay. During the dry summer it cracks deeply and forms large blocks typical of adobe structure; secondary cracking near the surface produces a fine to medium strong blocky structure. Black and sticky when wet and very hard when dry. Grades into:	12-25"
2.	16-30"	Gray (near dark-gray) compact weekly blocky calcareous moderately alkaline heavy clay surface of aggregates in place shine when moist. Lime occurs segregated in small white specks. Distinct transition to:	12-20"
3.	30-50"	Olive-gray compact massive calcareous moderately alkaline clay. Lime occurs mainly segregated in soft light-colored masses and in small hard nodules. Distinct transition to:	
4.	50"-	Light olive-gray strongly motted massive slightly calcareous moderately alkaline stratified alluvium, mainly heavy-textured but with strata of sandy loam and sandy clay loam, distinctly less lime than in horizon above.	Several feet.

RANGE IN CHARACTERISTICS:

The surface soils range in color from dark grey to nearly black and normally are of clay loam or clay texture.

In some places they contain very little or no lime, particularly in the uppermost few inches, whereas, in other places they are slightly calcereous. The upper subsoils may be similar to or slightly lighter in color than the surface soils, but characteristically, they are more compact and contain distinct white specks of segregated lime. The large primary cracks of the dry surface soils extend into the upper subsoils. The lower subsoils usually have an olive cast, particularly when moist, and are moderately to highly calcareous, in places being very weakly cemented with lime. They are usually moderately alkaline in reaction but in places may be strongly alkaline. Underlying material is variable depending mainly on degree of stratification; it is usually distinctly less calcareous than the soil above and is commonly more friable and permeable. Slight or weak accumulations of soluble salts occur in the soils in many places, and in a few places moderate accumulations occur.

<u>TOPOGRAPHY</u>:

Nearly level, with irregular lower ridges and shallow depressions. Small sloughs common.

<u>DISTRIBUTION</u>:

Mainly along trough of the San Joaquin Valley, California. The land is comparatively low and gently sloping or undulating to flat. In places, expecially on low flats, the surface is bare and crusted with salts while in some of the higher areas of sandy soils the land is highly developed.

DRAINAGE:

Under natural conditions the soils were subject to overflow, and at times were under water for considerable periods. In many places the soils are now protected by levees for control of stream flow. Surface run-off and permeability slow; usually affected by higher water table, particularly during winter and spring.

HOUSTON BLACK CLAY:

Range in Characteristics:

This soil lies in Prairie country; however, they are not true Prairie soils but rather Rendzinas.[12] They have the dark color and high content of organic matter that characterize Prairie soils, but are calcareous throughout. The development of a normal Prairie soil profile has been retarded by the calcareous nature of the parent material and by erosion, which has proceeded nearly as fast as leaching, thus removing surface soil before it has had a chance to become greatly leached. The surface soils are mostly of brown or black clay -- sticky when wet but on drying break into fine grains giving a mellow crumbly consistency. Subsoils are brown and yellow clays, heavy but allowing ready penetration of water, air, and plant roots. On smooth-lying areas the soil is quite deep but on the steeper slopes it is thin, owing probably to a combination of erosion and lack of penetration of moisture.

GEOGRAPHIC SETTING?

Houston soils occupy large areas of undulating to rolling Prairies in central and northeastern Texas and central-southern Oklahoma. They comprise most of the Blackland Prairie and Grand Prairie. The elevation ranges from 400 to 800 feet above sea level.

CLIMATE:

Warm temperature and humid. Summers long and hot; winters short and mild, with a mean temperature of 40 and 50 degrees F. Average annual precipitation, largely rain, is 30 to 40 inches. Frost-free season two hundred and twenty to two hundred and sixty days.

PARENTAL MATERIALS:

Limestone in the Grand Prairie (western part) and marls and chalk in the Blackland Prairie (eastern part). In Oklahoma some of these soils are from sandstone and shale.

REGUR:

The name "REGUR" originated from the Telugu word "Nala Ragada" meaning sticky black earth. It is more commonly known as Black Cotton Soil.(1)

VARITY:

The soil may be broadly classified under two categories:

(1) Those formed in situ by decomposition of parental rocks like trap, granite, gneiss or limestone which by long continued weathering action had been converted into Black Cotton Soil, and

(2) Those formed elsewhere by similar process, transported by wind and rain from their original place of formation and deposited in low lying and flat areas and subjected to continued weathering action.

GEOGRAPHICAL DISTRIBUTION:

These soils cover an area of nearly 200,000 square miles, found throughout the southern half of the peninsula covering the Deccan Plateau. Roughly, these soils are found between 73 and 80 degrees longitude and 15 to 25 degrees latitude. The first type described above is generally found in tablelands such as the Central Province and the Deccan, and the second type in low lying plains and Deltaic areas.

GEOLOGICAL FORMATION RELATED TO THESE SOILS:

It seems that the material of the Deccan trap formed by the basaltic lava flowing over the plateau of Bombay Deccan has given rise to this group of soils and to its stalellite varieties; while the granitic and gneissic, generally acidic, bed rocks of the Peninsula give rise to a group of red soils and their varities. The boundaries of these two groups under the circumstances cannot be expected to be co-terminous with the limits of the geological bed rock and wide extent of black soil found over the surrounding granitic and basic gneiss. The formation of black soils from granite and gneiss has been attributed by Ramiah and Raghavandrachari to the rocks containing minerals of different chemical composition; e. g. soda-lime felspar.

CLIMATE:

The region in which the Regur soil occurs in India is characterised by mild winters and hot summers with good, but not regularly distributed rainfall. The rainfall is mostly received between June to September but is heavily affected by evaporation and by desiccating winds during draught periods.

TOPOGRAPHY:

These soils are generally found on flat and undulating plateau of the Bombay Deccan but they are also occurring in the river valley. On uplands and on the slopes, the soils are light colored and shallow, the depth of twenty to forty feet are found where the topography is level and in the river valleys.

SOIL CHARACTERISTICS:

In view of the extensive area covered by them, the soils of the region cannot be identical all over the area, but the most important variation is in regard to their depth, although they possess certain morphological, physical and chemical characteristics which are common in both deep and shallow soils. The surface soil is of typical black color, but a greyish black color and very dark brown is also found in certain places. The subsoil, especially deeper soils, show a brownish to brownish red color and which generally begins at a depth of two to three feet from the surface. The structure is cloddy but occasionally crumb structure or aggregates with natural cleavages are also seen. The subsoil structure in the deeper phases is in some cases laminar with slanting cleavages and in very deep soils, the structure is of lantil form as described by Krishana and Perumal.[8] Similar structure has been found in a recent study of soil profile up to a depth of twenty-one feet. This type of structure seems, however, to be developed only in deep soils and in lowest horizon.

The soils are of heavy texture and the clay content varies between forty and sixty per cent. These are saturated with calcium and have considerable amounts of free carbonates in the form of nodules (known as kankars) throughout the mass. A feature of Regur soils of Indis is that they contain small black shining shot-like objects as commonly found in buckshot soil of Australia. Deeper soils have sometimes a zone of accumulation of salt and high saturation with sodium base. Such formation is known as "Chopan" in certain places. A high exchange capacity (40 to 60 m.e. per 100 gms. of soil) of the soil in spite of low organic matter content is a characteristic of these soils and calcium predominates in the exchange complex but not where magnesium is found to dominate or is equal to exchangeable calcium, similar to what has been reported for some typical Chernozem soils and in some Australian Black Earth.

Although the colloidal complex of the average Regur is saturated with bi-valent cations, the change from dry to wet state causes great swelling of the colloids in contrast to the general observation of Chernozem soils in which the change from dry to wet state causes little swelling of Chernozem despite the montmorillonite nature of its colloids which have an expanding lattice structure and are, therefore, amenable to swelling.

The exchange capacity per gram of the oven dry clay fraction comes to 1 milliequivalent in Regur as against 0.4 milliequivalent for the mineral clay fraction and 2.0 milliequivalent for the organic fraction, respectively, of Chernozem.

Generally, there is little movement of R_2O_3 in lower depths due to high pH and the presence of alkaline earth bases. In Regur the contents of Fe_2O_3 is practically the same as that of Al_2O_3 and varies between nine and twelve per cent. The ratio of SiO_2/R_2O_3 of the clay fraction in Regur is nearly three and that of SiO_2/Al_2O_3 is about four. Chemical, optical, ex-ray and dehydration studies carried out of the clay fraction of Regur show that the dominant clay mineral in Regur has been the montmorillonite group but the presence of a small amount of illite has also been noted.[5]

The black soils of India have essentially alkaline reaction as the pH varies between 7.2 and 8.7. Another feature of these soils is their low content of nitrogen and phosphorus. Nitrogen is generally between three and six hundredths percent while P_2O_5 is about twelve hundredths percent, but the biological activity such as ammonification and nitrification are very vigorous.

Hosking[7] made a comparative study of Black Cotton Soil and Australian Black Earth, which extends from subtropical to tropical latitudes.

In discussing the data on the composition of Regur and the black soils of India, Hosking[7] points out that the figures for the organic matter content of Regur reported by the earlier investigators are extremely exaggerated. His analysis seldom shows much more than one percent of organic matter in Regur, whereas, Australian black soils have an organic matter content ranging from two to five percent, with many as low as one percent and some as high as ten percent. It is suggested that the difference in the organic matter content of the soils in the two regions is due to the higher temperature in India and the cultivation of the Regur over a period of centuries.

HOSKING[7] ANALYSIS OF REGUR

Locality	Horizon	Depth in.	Reaction pH.	$CaCO_3$ %	P_2O_5 %	K_2O %	Mn_3O_4 %	Organic Matter %
Bombay Broach Dist.	A	0-6	8.1	0.09	.105	.649	.155	.7
	AB	6-12	8.4	0.05	.102	.656	.159	.6
	B	12-24	8.4	0.11	.095	.635	.159	.6
Central Province Negpur	A	0-8	8.0	1.55	.093	.612	.218	1.4
	B	24-48	8.0	2.22	.072	.673	.173	1.4
	BC	48-	8.2	11.6	.083	.656	.155	.5
Bombay Dharwar	A	0-6	8.8	0.05	.035	.458	.05	1.0
	AB	11-17	8.9	0.06	.033	.456	.053	1.0
	B	26-32	9.2	0.82	.027	.457	.051	.9

EXPERIMENTAL WORK:

The following experiments are carried out for the purpose of comparison of these soils.

1. Specific Gravity.
2. Mechanical Analysis of Soil.

3. Atterberg limits, Plastic limit, Liquid limit, Plasticity index, Shrinkage limit, Shrinkage ratio, etc.

SPECIFIC GRAVITY:

The method used was A.A.S.H.O. Designation: T 100-38. Specific gravity is defined as the ratio of the weight of a given volume of a substance to the weight of an equal volume of some other substance taken as the standard. The specific gravity of solids is usually referred to water at 4 degrees centigrade. The absolute specific gravity of soil is the weight per unit volume of only the solid material in it (exclusive of the voids or pores) relative to water at 4 degrees centigrade.[3]

In this case pure kerosene was used instead of water as kerosene possesses properties similar to water at standard.

MECHANICAL ANALYSIS OF SOIL:

The method used was A.A.S.H.O. Designation: T 87 and T 88. A.S.T.M. D. 421, D. 422.

One of the first properties which should be determined is the particle size distribution of the soil. After the size distribution has been determined, the soil can be classified on the basis of texture. Such classification separates soil into groups having certain physical properties. The grain size of particles retained on no. 200 sieve may be determined by sieve analysis. The sizes of soil particles passing a no. 200 sieve are determined by hydrometer analysis.

The hydrometer method of grain size analysis is based on the fact that particles of equal specific gravity settle at a rate that is proportional to the size of the particle. (Stokes Law).

SCOPE:

The mechanical analysis can be used by the highway engineer for the determination of the following:[15]

1. The particle size distribution of soil.
2. The texture classification.
3. The suitability of soil for blending with other soil gradings to obtain ideal soil mixtures for stabilization.
4. An index to soil drainage and frost heave material.
5. A qualitative separation of binder soils after their colloidal activity has been established.
6. The approximate plasticity index of clay and sand combinations after the plasticity of the clay has been evaluated.
7. As an aid in the determination of the soils groups as classified by the U. S. Public Roads Administration.
8. An index to soil erosion as measured by the clay ratio.

ATTERBERG LIMITS:

After a cohesive soil has been remolded, its consistency can be changed at will by increasing or decreasing the water content.[14] Thus, for instance, if the water content of clay slurry is gradually reduced by a slow desiccation, the clay passes from a liquid state, finally into a solid state. The water contents at which different clays pass from one of these states into another are very different. Therefore, the water contents at these transitions can be used for identification and comparison of different clays. However, the transition from one state to another does not occur abruptly as soon as some critical water content is reached. It occurs gradually over a fairly wide range in the value of the water content. For this reason every attempt to establish criteria for the boundaries between the limits of the consistency involves some arbitrary elements. The method that has proved most suitable for engineering purposes was derived from agronomy. It is known as Atterberg's Method, and the water contents that correspond to the boundaries between the state of consistency are called the Atterberg Limits.

PLASTIC LIMIT:

The method used was A.A.S.H.O. Designation: T 90.

The plastic limit defines the boundary between the solid and plastic state. This constant is further defined as the lowest moisture content, expressed as a percentage by weight of oven dry soil, at which the soil can be rolled into threads 1/8 inch in diameter without the threads breaking to pieces.

Soil which cannot be rolled into threads at any moisture content is considered non-plastic.

The plastic limit is the moisture content at which the cohesive soils pass from the semi-solid to the plastic state. It also equals the moisture content at which the coefficient of permeability of homogenous clays becomes practically equal to zero.[15]

LIQUID LIMIT:

The method used was A.A.S.H.O. Designation: T 89 - 42.

The liquid limit is defined as that moisture content, expressed as a percentage of weight of the oven-dry soil, at which the soil will just begin to flow when jarred slightly. It is further defined as the boundary between the plastic and liquid state of the soil.

There are two methods for finding the liquid limit of a soil. (1) Mechical and (2) hand method. For our purpose mechanical method is used. The apparatus is shown in Figure 1. Before starting the experiment, the height to which the cup is lifted shall be adjusted, by means of a gage attached to the grooving tool, so that the point on the cup which comes in contact with the base is exactly 1 cm. (0.3937 in.) above the base. The adjustment plate shall then be secured.

The moisture content corresponding to the intersection of the flow curve with the 25 shocks ordinate shall be taken as the liquid limit of the soil.

(27a)

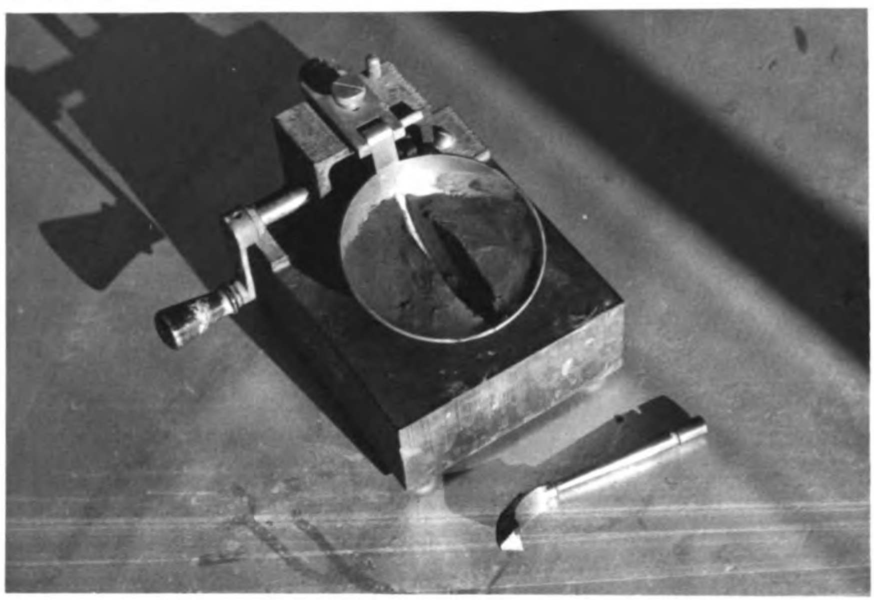

FIG. 1.

The liquid limit can be used as an index to distinguish between cohesive soils. All soils with less than thirty liquid limit can be classed as granular. The average clay soils may have liquid limits up to 100; above 100 the soil contains a large amount of colloidal material similar to bentonite or peat.

Liquid limits for sands vary from 10 to 35. The lower limits indicate beach sand or rounded sand grains, and the higher limits indicate a high degree of surface roughness and angularity. Liquid limits for silts and loam usually from 20 to 40; for clays the liquid is above 35.[15]

PLASTICITY INDEX:

The method used was A.A.S.H.O. Designation: T 91.

Plasticity index is defined as the difference between the plastic limit and the liquid limit. It is the range of moisture content through which the soil is plastic. When the plastic limit is equal to or greater than the liquid limit, the plasticity index is reported as zero. When the plastic limit cannot be determined, the plasticity index may be designated by the letters NP (non-plastic) to indicate that the soil is entirely lacking in plasticity.

The plasticity index is used primarily in the selection of binder material and as a control in stabilizing operations.

SHRINKAGE LIMIT:

The method used was A.A.S.H.O. Designation: T 92.

The shrinkage limit is defined as the maximum calculated water content, expressed as a percentage of weight of oven dried soil at which a reduction in water content will not cause a decrease in volume of the soil mass, but at which an increase in moisture will cause an increase in volume of the soil mass.[4]

The shrinkage limit is a means of describing the pore space present in a soil after it has been compacted by shrinkage to the maximum density obtainable (at a given moisture content). It is a well defined point of the moisture content scale, marking the change from solid to semi-solid state.

SHRINKAGE RATIO:

The method used was A.A.S.H.O. Designation: T 92.

The shrinkage ratio is the ratio of the volume change to moisture loss and is equal to the bulk specific gravity of the dried soil. The shrinkage ratio is used in calculating volume changes.

The volume change for any soil above the shrinkage limit can be computed approximately for various soil consistencies occurring in the field such as the shrinkage of soil mixtures used in mud-jacking, fill shrinkage, etc. Stabilized mixtures can be designed so that shrinkage after compaction can be held to a minimum which in turn reduces the rate of absorption of rain water. Soils which are difficult to mix and compact by field methods can be detected by high shrinkage and high soil colloids.[15] Figure 2 shows the comparison of the shrinkage characteristics of the four soil samples.

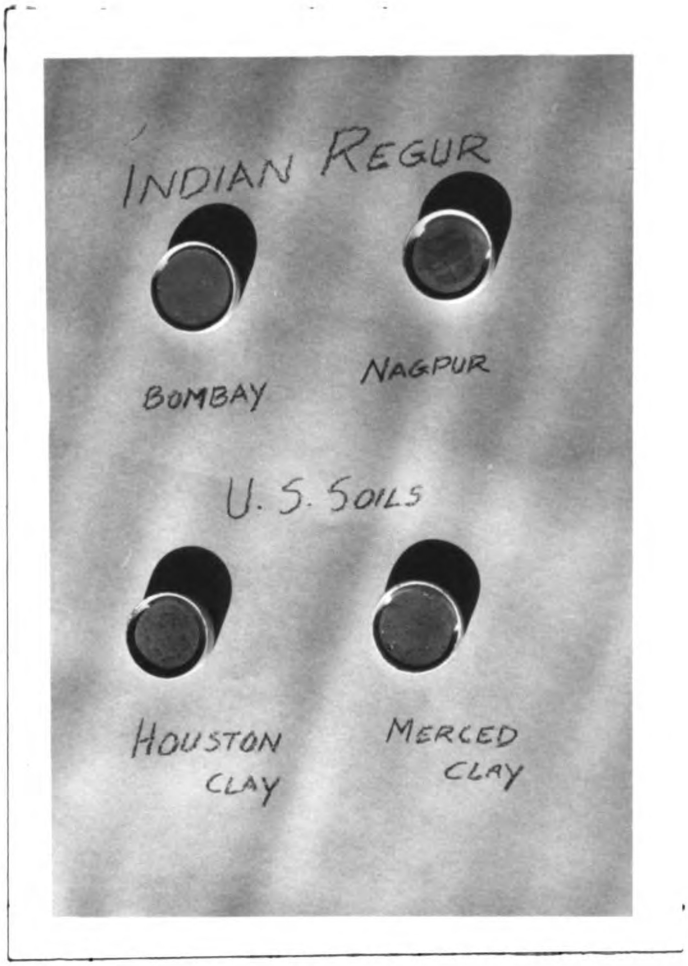

FIG. 2.

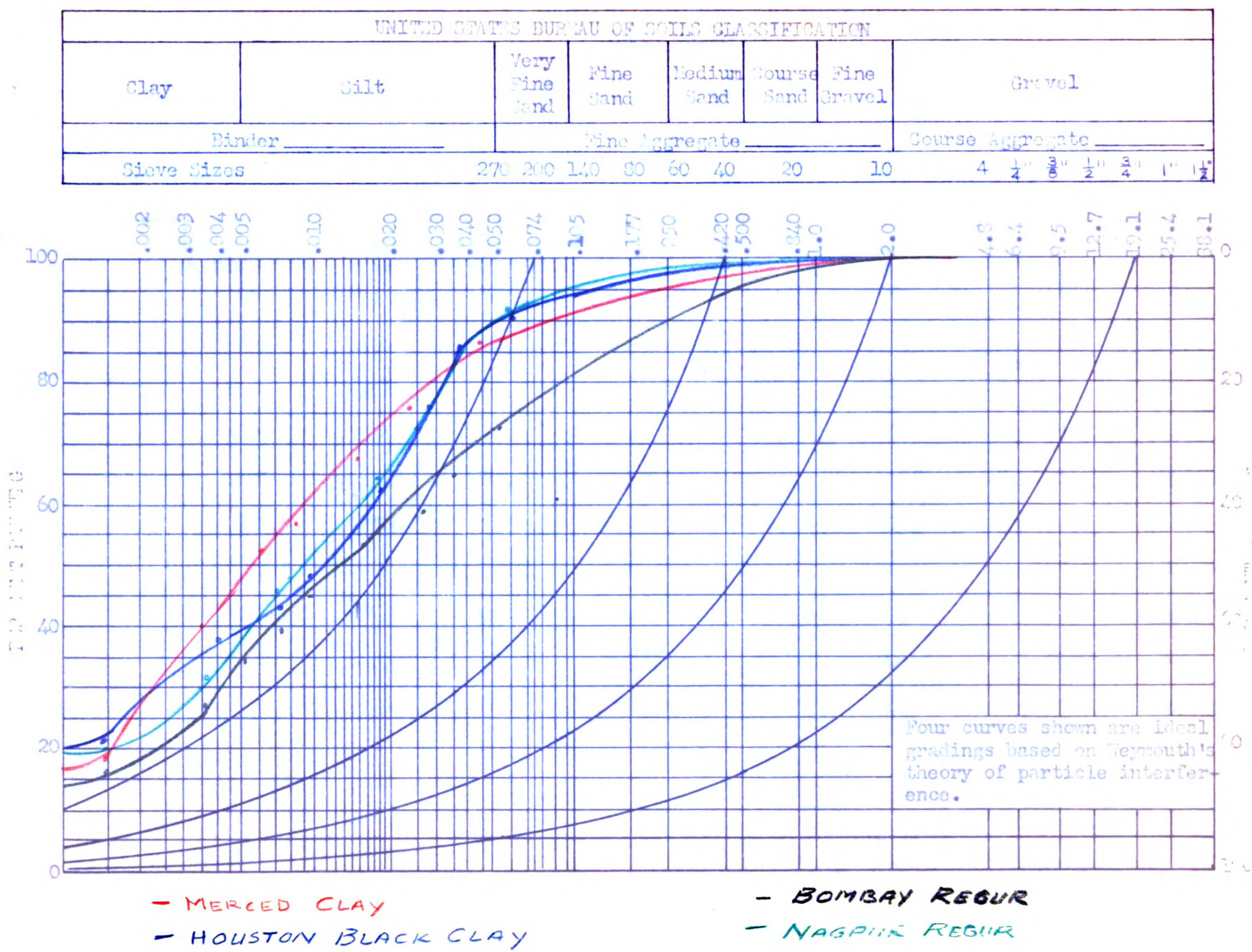
UNITED STATES BUREAU OF SOILS CLASSIFICATION
Clay
Silt
Very Fine Sand
Fine Sand
Medium Sand
Course Sand
Fine Gravel
Gravel
Binder
Fine Aggregate
Course Aggregate
Sieve Sizes 270 200 140 80 60 40 20 10 4 1/4" 3/8" 1/2" 3/4" 1" 1 1/2"
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
100 80 60 40 20 0
0 20 40 60 80 100
Four curves shown are ideal gradings based on Weymouth's theory of particle interference.
– MERCED CLAY
– HOUSTON BLACK CLAY
– BOMBAY REGUR
– NAGPUR REGUR

Table No. 1

COMPARISON OF SPECIFIC GRAVITY AND PERCENTAGE OF GRAIN SIZE DISTRIBUTION.

Soil Sample	Merced Clay		Houston Black Clay		Nagpur Regur		Bombay Regur	
Specific Gravity	2.74		2.31		2.46		2.65	
Time in Minutes	Per cent Soil in Suspension (P)	Grain Dia. mm.	Per cent Soil in Suspension (P)	Grain Dia. mm.	Per cent Soil in Suspension (P)	Grain Dia. mm.	Per cent Soil in Suspension (P)	Grain Dia. mm.
1/2	87.0	.0446	89.5	.055	91.0	.0525	72.9	.0503
1	81.2	.0317	85.2	.0385	81.0	.0375	64.9	.036
2	75.5	.0228	76.6	.0282	72.5	.0268	59.0	.0255
5	67.5	.0142	63.7	.0183	62.0	.0176	53.0	.0166
15	56.7	.00865	55.0	.0107	49.4	.0102	45.0	.0096
30	52.0	.0062	48.6	.00755	41.0	.00716	38.0	.00687
60	46.0	.00445	42.2	.00548	33.6	.00505	34.0	.00495
120	39.2	.00314	37.8	.00387	30.7	.00365	27.0	.0035
24 hrs.	17.6	.00093	20.6	.00113	16.8	.00107	15.0	.001025

Table No. 2.

Comparision of Atterberg Limits:

Soil Sample	Plastic Limit	Liquid Limit	Plasticity Index	Shrinkage Limit	Shrinkage Ratio
Merced Clay	34.5%	49.5%	15.0	13.1	1.8
Houston Black Clay	39.0%	60.0%	21.0	15.1	1.88
Nagpur Regur	39.5%	57.5%	18.0	14.7	1.85
Bombay Regur	20.5%	33.0%	12.5	11.7	1.96

CONCLUSION:

The specific gravity of Merced clay and Houston Black clay is two and seventy four hundredths and two and thirty one hundredths, respectively, and that of Bombay Regur and Nagpur Regur have two and sixty five hundredths and two and forty six hundredths, respectively. The higher value of specific gravity indicates that those samples have more silt, sand and calcareous material. This also can be seen from the Mechanical Analysis graph. The high specific gravity samples are not as well graded as the low specific gravity samples indicate.

From grain size analysis experiments it was found that United States samples have the same amount of clay percentage but the gradation is different and also the same with the Indian soil samples. This is due to the climatic conditions. Both Merced clay and Bombay Regur are from the costal area and hence, contain more silt, sand and calcareous material. While Houston Black clay and Nagpur Regur are from interior parts of the country and contain more clay and better gradation.

The Atterberg limit test results conclude the same. The high plastic limit and liquid limit with high plasticity index indicates the soil samples contain more clay and colloidal particles with resulting low specific gravity. These conclusions agree with the specific gravity result of the mechanical Analysis. The low plastic limit and liquid limit, with low plasticity index, indicates lower percentages of clay and colloidal particles than the other two samples.

The high shrinkage limit of Houston Black clay and Nagpur Regur demonstrate that there are more contained voids and, hence, the conclusion of more clay and colloids. The low shrinkage limit of Merced clay and Bombay Regur indicate lower voids and, hence, more silt, sand and calcareous material. While the shrinkage ratio of all the samples are practically the same, it indicates the similarity of characteristics of these soils are the same and their formation similar.

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