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Case Report

Geotechnical Properties of Subgrade Soil along Indus Highway Jamshoro –Sehwan Road Sindh Pakistan

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ABSTRACT

In Pakistan, the road sector meets about 90% of the country's land transportation needs, and so the top priority challenges are appropriate operation and maintenance, new construction, widening and rehabilitation of national highways (where traffic is usually very heavy). In particular, the north-south corridor that runs between Karachi, Lahore and Peshawar is a route of primary importance linking Karachi Port, which handles about 95% of Pakistan's entire foreign trade, to Punjab Province, where economic activities are the most animated, and requires urgent improvement. The Indus Highway (National Highway No. 55), reduces the travel distance between Karachi and Peshawar by 500 km as compared with the travel distance between the same two cities on National Highway No. 5 (N-5), which runs along the eastern bank of the Indus River, since some sections of the Indus Highway also helps make regional cities like Larkana (in northern Sindh Province where rice production thrives) and Dadu (in central Sindh Province) more mutually accessible access to public services and markets in large cities in southern Sindh Province such as Karachi and Hyderabad, and thereby contribute to social and economic development in the province's local communities.

The road construction and failure is a common practice throughout the country, there are number of reasons behind that, this is general complain and cry of road failures after some time specially in asphalt roads before their life spam. Just to know the geotechnical causes this study has been carried out along the Indus Highway upon Jamshoro-Sehwan section Sindh province Pakistan.

For this purpose five samples have been collected from suitable locations with stabilized various percentages of fine aggregates. For investigation of different laboratory tests have been conducted like M C,L L, PL, P I, Sieve analysis, shrinkage limit, sp. Gravity, compaction and C B R test.

Even after the use of stabilization material sand or rock fines, the geotech properties indicated the low results in comparison to the standard specifications, which has been marked the greater cause of road failure in that portions, the ratio has not been maintained properly.Despite the use of stabilisation material (rock fines) at different percentages, the poor geotechnical properties of the soils as marked by the low maximum dry density, high linear shrinkage, high liquid limit values, high amount of fines, low CBR values and lack of drainage in the study area are the main causes of the failure of the road portion.

Keywords: Sieve analysis; sub-grade soils; failed portions; Stabilisation; L L, PL

INTRODUCTION

Pakistan has borders with India, Iran, Afghanistan, and China. It has 796 thousand km2 in area, main industries are agriculture and cotton production. The country's domestic transportation network is spread around the north-south corridor that connects the major cities where people and industries are concentrated: Karachi, the southern city which has 90% of the country's trade; Peshawar and Lahore, the major northern cities; and Islamabad, the capital city. The main highway and railway routes lie along this north-south corridor. The network of national highways is supervised by National Highway Authority (NHA) totals 8,885 km1, approximately 60% of the country's road transportation. The center point of the road network is National Highway that runs along the eastern bank of the Indus River and connects Peshawar, Lahore, and Karachi. The Indus Highway (National Highway 55)

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is a main route which lies along the western bank of the Indus River and runs nearly the entire length of Pakistan from north to south. It augments National Highway in north-south bound traffic traveling medium to long distance. In recent past, however, the Indus Highway has been unable to manage with the increasing traffic volume and larger size of vehicles sufficiently due to the lack of road capacity and deterioration of the road surface. As a result, traffic has become excessively concentrated on National Highway , causing frequent traffic jams [1].

Highway construction and communication is very important for the infrastructure development of any country like Pakistan as a developing nation for transportation of goods and services, all four provinces of Pakistan are connected through a road network to final destination of Karachi sea port which is the capital of Sindh province Pakistan which is also the commercial hub of national and international trade [2]. Roads are the cheaper and afforadable source of communication between urban cities and rural villages largely dependent upon agricultural economy which needs easy access to markets for their product selling, while railway, air and water transport are not largely available for goods transport, roads are indispensable in the transportation of people, goods and services from one place to another. Roads have been generally as small rural roads, highways and motorways etc.another subclass is intercity municipal roads. There are two main types of pavements based on design considerations i.e. flexible pavement and rigid pavement. Variance between flexible and rigid pavements is based on the structure in which the loads are distributed to the subgrade. Flexible pavement can be described as the one consisting of a mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade. Water bound macadam roads and stabilized soil roads with or without asphaltic toppings are famous examples of flexible pavements. A rigid pavement is build from cement concrete or reinforced concrete slabs. Grouted concrete roads are in the type of semi-rigid pavements. The design of rigid pavement is based upon providing a structural cement concrete slab of sufficient strength to resists the loads from traffic. The rigid pavement has rigidness and high modulus of elasticity to distribute the load over a relatively wide area of soil. Urban roads are wide paved roads found within cities and towns [3]. The inter-state and inter-city highways are those that connect two or more States together. The third category of roads is the rural roads which are mainly earth roads. These roads connect farms and villages with inter-city roads. The road serves as inter-links between towns, states and countries and therefore is known as the common means of transportation [4].

Due to heavy transportation and weathering or climation conditions like rains, floods there are some damages and cracks known as road failure which causes the depression pop-outs and removal of bituminous from surface carpet layer exposing the sub-base or even sub-grade, this is geotechnical termed as road failure which badly affects the road transportation and causes accidents with loss of life and economy.

The National Highway Authority Pakistan is responsible for construction and maintenance of national highways and motorways for all four provinces of Pakistan and there are provincial ministries established in every province naming the ministry of communication and works for construction and maintenance of rural and municipal roads. There are different like pitting, rutting and waviness patterns failed segments of major highways across the country usually. A number of causing factors have been identified, such as misuse of highways, lack of maintenance culture, poor construction practices and geotechnical factors [5].

A number of Engineering properties have been identified as the major factors influencing the failure of many roads within and outside the country. Despite the technological improvement in the country, the cause of pavement failures has remained a serious concern in almost all the major highways in Sindh province. A pavement is the durable surface material laid down on an area intended to sustain vehicular or foot traffic, such as road or walkway. The terms base and sub- base are sometimes used interchangeably to refer to the sub-surface layers of a pavement, sub-base is the layer of aggregate material laid on the sub-grade on which the base course layer is laid. It may be neglected when there will be only foot traffic on the pavement, but it is necessary for surfaces used by vehicles. The base and sub-base layers at the study area were exposed by the different grades of pitting along the road [6]. Road failures are almost invariably linked directly to the underlying soil (sub-grade soil) which usually bears the load carried by the road. The term “sub-grade” as used in Civil Engineering refers to the in-situ material upon which the pavement structure is placed. It may be the material reworked in-situ or even the imported material from another source such as a cut. Sub-grades are also considered layers in the pavement design, with their thickness, assumed to be infinite and their material characteristics assumed to be unchanged or unmodified. The sub-grade serves as the foundation for the highway pavement and distributes the load from the upper layers to the soil underneath [7]. A satisfactory sub- grade is able to resist the effect of both traffic and weather. Under heavy traffic loads, sub- grade soils may deform and contribute to distress in the overlying pavement structure manifesting as failure. It is therefore very important to adequately prepare this layer if the road is to last.

The causes of roads failure in Jamshoro-Sehwan section have been attributed to several factors such as poor construction materials, poor design and specification, road usage, poor drainage, geological and geotechnical factors [8,9]. Geological factors are usually not considered as precipitators of road failure even though the highway pavement is founded on the geology. The proper design of highway requires adequate knowledge of subsurface conditions beneath the highway route. Previous studies have revealed that the integrity of the highway pavement can be undermined by the existence of geological features and/or engineering characteristics of the underlying geologic/geoelectric sequences [10,11]. Field observations and laboratory experiments revealed results that road failures can arise from inadequate knowledge of the geotechnical characteristics and behavior of residual soils on which the roads are constructed and non-recognition of the influence of geology and geomorphology during the design and construction phases. It is crucial to develop a sub- grade with a California Bearing Ratio (CBR) value of at least 10. Anonymous reported that if a sub-grade has a CBR value less than 10, the sub-base material will deflect under traffic loadings in the same manner as the sub-grade and cause pavement deterioration. The stability and durability of pavement depends on the traffic load or intensity and the strength of pavement layers. Pavement failure is certain to occur if the pavement is not perfectly designed with the present traffic condition being considered. If it is designed without considering incremental traffic in the near future, the pavement life will be successively reduced. A flexible pavement surface reflects the entire behaviour of the sub grade layer, it thereby, emphasises more attention on making the soil sub-grade of superior soil properties. In previous research, road failure occurred due to the following reasons: Inadequacies in pavement structural design, poor sub-grade soil properties insufficient pavement drainage and effect of seasonal fluctuations of temperature over base course aggregates and poor visco-elastic properties of asphalt binder. Adewoye et al. observed that the flexible highway failures along the Oyo-Ogbomoso road, which manifested as waviness/corrugation rutting and potholes were due to environmental factors such as poor drainage, lack of maintenance and misuse of the highway pavement. It was also noted that runoff due to precipitation, largely found its way into the pavement structure damaging them in the process. A road is usually divided into different parts namely: pavement, base, sub-base and sub-grade. Sub-grade is the soil foundation which directly receives the traffic loads from the pavement and a satisfactory subgrade resists the effects of both traffic load and weather.

The aim of this research is to examine the effect of rock fines on the geotechnical properties of sub-grade soil materials along failed portions of Jamshoro – Sehwan section road, south- western Sindh province Pakistan in order to reassess their direct productive application as soil materials or the need for incorporating the stabilization method to enhance their properties for flexible road construction.

METHODOLOGY

The study area

Jamshoro, is the place of largest University residential campus in the country, situated about 18 kilometers from Hyderabad on the right bank of River Indus, was a rather barren hilly terrain until 1955 when it was selected for the establishment of Sindh University Campus. The place was selected to be a University township away from the humdrum of Hyderabad city which was short of space to meet the ambitious expansion programs of the University.

Excitingly, Jamshoro is actually the gate-way to the Indus Valley, now world famous for its civilization and rich cultural heritage. The world famous Ranikot Fort is located 40 km. to the north of the Sindh University campus, in the northward continuation of the same hilly terrian which become Laki Ranges, merging with the Khirthars northwards, and Amri, an important archeological site, lies about 15 km. further north. Sehwan, a well known township lies 25 km. to the north of Amri. Mancher Lake the largest fresh water lake in the region, is situated to the west north west of Sehwan. Travelling about 150 km. north through the Indus plains brings one to the site of Moen-jo-Daro, the most important archeological site of the Valley (Figure 1).

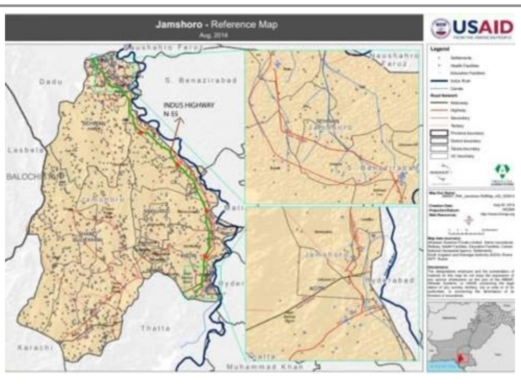

Figure 1: Jamshoro-reference map..

Jamshoro :Latitude: 26.4279Longitude: 67.863State: Sindh, 05Country: Pakistan, PKContinent: AsiaTimezone: +05:00

Sehwan :Latitude: 25.4394Longitude: 68.2903State: Sindh, 05Country: Pakistan, PKContinent: AsiaTimezone: +05:00

For the purpose of this research study the different engineering tests were conducted on subgrade soils, tests were performed to understand the nature of soil that the highway was constructed on. In this research article, the basic tests required for the construction of roads and highways are brieflylisted. Commonly conducted tests are: Soil classification, particle size distribution, moisture content determination, specific gravity, liquid limit and plastic limit tests. Moisture content, grain size analysis and specific gravity tests.

Field sampling

The method adopted in this project involves reconnaissance survey of the road to determine the failed sections. The samples of subgrade were collected at the edge of the shoulder of the road and dug out using digger and spade from depth 600 mm below the asphaltic surface. They were suitably packed into sacks and labelled in such a manner that each material can be identified distinctly. They were taken to the laboratory where the natural moisture content of the soils were determined immediately. The soil samples were then air-dried for about three weeks before carrying out Atterberg limit, grain size analysis, specific gravity, compaction and California Bearing Ratio, these were carried out in accordance with BS 1377 (4).(ASTM F2656-070).

Stabilization of soils

After the engineering tests and analysis of the soil samples were carried out, further detailed tests were conducted on the soil samples with varying percentages of rock fines as the stabilising agent. A rock fine collected from a stone crush company located at Petaro Crusher Plant was used. Due to the fine nature of the rock fines, no analysis was done on it. This was introduced directly to the soils in percentages of 2, 4, 6, 8 and 10% in order to characterize the effects of the rock fines on the engineering properties of the soil (Figure 2).

Figure 2: Pakistan national highway network map.

RESULTS

Natural moisture content

The natural moisture contents of the soils are 17%, 10%, 8% and 25% for locations 1, 2, 3 and 4 respectively. The natural moisture content is generally required to provide information on the moisture conditions of the soil in the field. Which provides useful method for classification of the cohesive soils. The strength, as well as the state of consistency of a soil, can be concluded by relating its moisture content to its index properties. All the samples have low moisture content in their natural states indicating that the soils have moderate percentage of clay. This reffers that there is no interaction of sub grade and sub base soils with water from numerous fractures in the basement rock which escalates the wet-ability of the soils. This condition is expected to greatly increase the shear strengths of soil and therefore no constant failure of the overlying pavements.

Grain size analysis

The results obtained for grain size analysis are shown in Figure 3. The % finer passing 425 µm sieve range between 32 and 50. These values show that the samples are not suitable as sub- grade materials because their values are higher than the standard specifications.

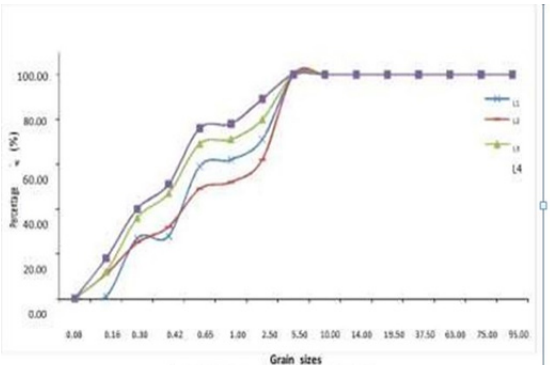

Figure 3: Graph showing grain size analysis.

Atterberg limits

The Atterberg limits are the basic measure of the water contents of a fine-grained soil: its shrinkage limit, plastic limit and liquid limit. Depending on the result of its water content, a soil may appear in one of four states: solid, semi-solid, plastic and liquid. The results of Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) are presented in Table 1. The liquid limit ranges from 0.0%-46%. Locations 3 and 4 did not flow and did not roll; hence having liquid and plastic limits values of 0.0% each. The liquid limits of locations 1 and 2 are all above 35% while their plastic limits are all below 30%. They fall below the acceptable requirements for soil sample that can be used as subgrade or fill during construction of highway in Pakistan. Therefore the failures may be due to infiltration of water into the subgrade layer. But for locations 3 and 4, which even after adding the different percentages of rock flour to serve as stabilization material still had no liquid nor plastic limit values are to be worked upon. They are non-plastic; hence they fall within the range of cohesion less soil, which will cause problem during compaction therefore resulting in road failure

Table 1: Summary of liquid limit, plastic limit, plasticity index and shrinkage limit.

Sample	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
L1 0% rock flour	46.4	28.6	17.83
L1 2% rock flour	38.9	28.6	10.33
L1 4% rock flour	43.0	24.7	18.3
L1 6% rock flour	44.6	21.7	22.86
L1 8% rock flour	41.4	9.8	31.61
L1 10% rock flour	41.7	21.7	19.96
L2 0% rock flour	47.8	21.1	26.75
L2 2% rock flour	44.8	26.7	18.13
L2 4% rock flour	45.9	30.8	15.13
L2 6% rock flour	45.1	40	5.1
L2 8% rock flour	43.9	15	28.9
L2 10% rock flour	45.5	22.2	23.28
L3 0% rock flour	0.0	NP	NP
L3 2% rock flour	0.0	NP	NP
L3 4% rock flour	0.0	NP	NP
L3 6% rock flour	0.0	NP	NP
L3 8% rock flour	0.0	NP	NP
L3 10% rock flour	0.0	NP	NP
L4 0% rock flour	0.0	NP	NP
L4 2% rock flour	0.0	NP	NP
L4 4% rock flour	0.0	NP	NP
L4 6% rock flour	0.0	NP	NP
L4 8% rock flour	0.0	NP	NP
L4 10% rock flour	0.0	NP	NP

Specific gravity

The specific gravity is a very useful index in the identification and evaluation of laterite aggregates for pavement construction. An increase in specific gravity has been found to be associated with a decrease in void ratio [28]. The specific gravity values of the tested soils range from 2.6 to 2.7, the values for each sample are average of their determinations. Generally, the specific gravity of the samples fall within the reported specific gravity for lateritic soils (2.50 to 4.60) in accordance with the standards. The results obtained for the different locations are shown in Table 2.

Table 2: Results of specific gravity and grain size analysis.

Sample	Specific gravity	425 µm excess fines (%)
L1	2.73	38
L2	2.58	33
L3	2.62	47
L4	2.64	51

Compaction test

The result of the maximum dry densities (MDD) and optimum moisture content (OMC) for the subgrade samples are presented. The MDD and OMC ranged from 1496 kg/m3 to 1982 kg/m3 and 4.70 to 11.70% respectively. The instability of the locations must have been as a result of lack of drainage system which eventually resulted into road failure.

California Bearing Ratio (CBR) test

The result of California bearing ratio (CBR) test is presented in The CBR values for the samples range between 0 to 5%. These values are generally less than 10% recommended for highway sub-grade soils by National Highway Authority & the Federal Ministry of Works. The soils yielded fair to poor CBR values. Such low values are not likely to provide a stable compacted sub-grade material. This deficiency could be attributed to high amount of clay present in the soil, ingress of water with a poor drainage and poor laterisation of the soil used. Therefore, in terms of strength, the soils samples are not suitable as subgrade materials because their CBR values fall below:

CONCLUSION

From the field observations and various laboratory tests carried out on the soil samples collected from the failed sections of the road, the following conclusions were made:

Lack of provision of the drainage system on the highway leads to the reduction in the strength character of the soil as a result of ingress of water. The values of natural moisture contents of this failed road indicating that the load bearing capacity of the soils increase rapidly as the moisture content values are lower than the plastic limit values. The higher liquid limit values obtained for most of the soils may have contributed to the failure of those sections as liquid limit correlates to the compressibility of soils.

The linear shrinkage of most of the soils are greater than 8%, this indicates that there will likely be shrinkage problem; most of the samples have linear shrinkage values greater than 10%, hence will pose field compaction problem which might have also contributed to the failure of the sections of the road.

The maximum dry density values of the soil samples classify them as poor highway foundation materials. This poor compaction character can also result in the failure of the sections of the road pavement.

Despite the addition of the stabilisation material in different percentages of 0, 2, 4, 6, 8 and 10 to the soil samples, the CBR values obtained still fall below standard. This is likely to be caused by the poor laterisation of the soil used

Sequel to the above findings and conclusion, it is recommended that all the materials used for road construction should conform to specification. State and Local Government should have a maintenance agency to embark on routine, periodic and emergency maintenance; this will also prevent the road from deteriorating before their design life.

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