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Stratigraphic Influence on Geotechnical Properties of Subgrade Soils along the Irrua-Auchi Road, South Eastern Nigeria

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Abstract

Geotechnical investigation of the Irrua – Auchi road was carried out to determine the engineering properties of the subgrade soils and evaluate the pavement conditions with a view to establishing the causes of failures along portions of the road. This involved a study of the route geology, measurement of pavement deflection using the Benkelman beam device and in-situ dry density test of the subgrade soils using the nuclear gauge. Other tests included the routine geotechnical laboratory tests to determine index properties, compaction and CBR characteristics of the subgrade soils. Results indicated that the road traversed terrain underlain by the Ajali sandstone, the Imo shale and the Ameki Formations. The subgrade soils, composed mainly of fine grained materials classified as A-4 to A-2-4., were characterized by plasticity index of 4 -19%, MDD of 1.83 – 1.92 Mg/m^3, 48- hour soaked CBR of 0.86 to 1.12 to show the fairly similar geotechnical properties of the soils. The segment of the road underlain by the Ajali derived soils was characterized by average relative compaction of 0.96 and average deflection of 0.26 mm and is classified as stable. The segments underlain by the Ameki and the Imo shale derived soils were characterized by average relative compaction of 0.89 and 0.88 and average pavement deflections of 0.39 mm and 0.61 mm respectively and are accordingly classified as less stable and least stable. Conclusively, in this study, the pavement deflections revealed pattern that reflect the influence of soil structures derived from stratification of the underlying geologic units.

Keywords: key words, Subgrade soils, Engineering properties, Pavement deflection, Route geology

1. Introduction

Evaluation of highway pavement performance generally takes into consideration factors that include: geotechnical properties of the subgrade soils, design factors, construction material selection, construction methods, maintenance and usage factors Other pertinent factors such as geology and geomorphology of the terrain traversed by the roads are often regarded as insignificant. Subgrade soils occur as either residual soils formed by in-situ weathering of rocks or as transported soils formed by transportation cum deposition of fragments of pre-existing rocks. The texture, structure and mineralogical composition of the parent rocks have pronounced effects on the geotechnical properties of their derived soils (Gidigasu, 1976; Meshida, 1980; Meshida, 1987 and Ajayi 1987).

Several studies have highlighted the influence of geologic environments on highway pavement performance. Teme et al. (1987) observed that in the Basement Complex terrain of Southwestern Nigeria, roads constructed over igneous rocks terrains tend to be more durable than those constructed over metamorphic rocks terrains. Akpan (2006), also reported higher pavement failure rate over locations underlain by shale or marl derived subgrade soils along the Calabar – Itu highway than locations underlain by weathered basement or sandy unit subgrade soils. Similarly, Osadebe et al. (2010), concluded that residual soils derived from granitic rock terrain along the Kano-Kazaure highway have very good geotechnical properties; those derived from schistose and quartzite rocks have intermediate properties, while transported loose silty fine sand of the Chad Formation soils have poor geotechnical properties. Mineralogical composition of parent rocks also influences road failure as shown by Meshida (2006) that the causes of pavement failure along section of Ife-Ilesha highway was due to occurrence of schist- derived residual micaceous soils that contain abundant talc and hydromica, which have resulted in low field compaction

The effects of concealed near-surface geologic features on road performance have been demonstrated with the aid of remote sensing and geophysical methods. Several studies in the Basement Complex of Southwestern Nigeria (Oladapo et al., 2008; Akintorinwa et al., 2010 and Akintorinwa et al., 2011) involving, remote sensing, electrical and electromagnetic methods have been used to revealed that several failed road segments were due to the underlying fractures, buried river channels, rock contacts and sink holes.

Geomorphological factors also have strong influence on engineering properties of subgrade soils and performance of highways. Abam et al. (2000) studied hydrologic effect on road performance and concluded that the poor road performance of PortHarcout - Warri - Patani road is due to the alignment of the route across the main surface and subsurface water flow direction of the area. Similarly, Arumala and Akpokodje (1987), investigated the geotechnical properties of soils and pavement performance in the Niger Delta and concluded that, the most severe surface deformations, pavement cracking and failures occur in the seasonally flooded fresh / salt water swamps because of the high water table, poor drainage and the very fine-grained silty clays / clays used as sub grade materials.

This work studied the engineering properties of the sub grade soils along the Irrua - Auchi road and investigated the possible influence of geology and geomorphology on their geotechnical properties with a view to determining the significance of these parameters on the highway performance

2. Methodology

2.1 Study Route

The Irrua-Auchi highway lies within Edo State, Nigeria. It is a section of the Warri-Benin-Abuja highway that links the Southeastern part of the country to Abuja, the nation's capital territory (Figure 1). The road traverses a terrain lying within the humid tropical rain forest and the mixed savannah regions of the country; it is characterized by long wet season of about eight months with monthly average rainfall of 170 mm, followed by short dry season of about four months. The annual rainfall along the route ranges from 940 mm and 1900 mm, while the annual potential evapo-transpiration is estimated to be 188 mm.The mean annual temperature is 31ºC (Akintola, 1986).

The drainage pattern along the route is mainly dendritic and is characterized by many big perennial rivers such as Egono river that generally have wide floodplains. The relief along the road route is fairly high with elevations varying from 122 m and 425 m at southern and northern ends. The middle 15 km section has a relatively flat terrain with an average elevation of 90 m. The route has a flat to rolling topography with shallow water table in some segments.

2.2 Geological setting

Based on regional geological maps of Southeastern Nigeria, Edo State occurs within the region underlain by the sedimentary rocks of the Anambra and the Niger Delta basins which constitute part of the Southern Nigeria sedimentary basins. The origin of the Southern Nigeria sedimentary basins are closely linked to the break-up of the South America and African continents in the early Cretaceous (Murat, 1972). Three major cycles of sedimentation, the Lower Cretaceous to Santonian (oldest); Campanian to Paleocene and the Paleocene/Early Eocene to Recent (youngest) cycles have been established in these basins.

The Anambra Basin is a Cretaceous basin covering an area of about 40,000 sq. km with sediment thickness of about 12 km. The basin was developed during the second cycle of regional deposition (Campanian to Paleocene) after the Santonian folding and uplift of the Abakaliki region and dislocation of the depocenter into Anambra Platform and Afikpo region. Stratigraphic sequence of the basin consists of the Santonian to Early Paleocene Nkporo shale as the oldest unit. The overlying strata include: Mamu Formation, Ajali Sandstone, Imo Shale and Ameki Formation (Reyment, 1965; Murat, 1972; Agagu et al., 1985). Meanwhile, in a recent work, Nwajide (2005) showed that the Anambra Basin is a stacked basin sandwiched between the southern Benue Tough below and the Niger Delta Basin above; with Awgu Formation as the oldest unit and Nsukka Formation as the youngest unit (Table 1).

The Niger Delta Basin is confined to the area covered by a thick sequence of rocks belonging to the youngest (Tertiary) sedimentary cycle. The stratigraphy of the basin is subdivided into surface and subsurface formations. The surface formations from the oldest units are: the Imo Shales; the Ameki Formation; the Ogwashi-Asaba Formation and the Benin Formation. The subsurface units from the oldest are the Akata, Agbada and Benin Formations (Reyment, 1965; Short and Stauble,1967 and Avbovbo, 1978).

2.3 Geology of Route

The Irrua-Auchi road occurs within the Benin flank of the Anambra Basin and Northern margin of the Niger Delta Basin (Figure 2). Stratigrahy of the Benin flank of the Anambra basin consist of Lokoja Bassange Formation as the oldest unit, followed by the Mamu Formation and the Maastrichtian Ajali Sandstone

A study of the Regional geological maps of Southeastern Nigeria and regional map of the Anambra Basin (Nwajide, 2005) indicates that sedimentary deposits of the Ameki Group underlie the first ten kilometres, about one quarter, of the road from its reference point at Irrua (CH 0+000) to CH 11+000 after Ewu. Thereafter, the road up to Aviele at about chainage CH 30 +000, representing about half of the route, is directly underlain by the deposits of the Imo Shale. The Ajali sandstone, also called the False-bedded sandstone, underlie the remaining portion of the road segment up to Auchi (CH 31+000 – CH 36+000). These lithologic descriptions of these stratigraphic units are as follows:

2.3.1 The Ajali Sandstone:

The Ajali Sandstone also referred to as the False-Bedded Sandstone consists of mainly friable poorly sorted, whitish; fine to coarse-grained, non-fossiliferous sandstone. The sandstone is frequently cross-bedded and sometimes contains thin interbeds of mudstone and occasional plant impressions. Fossils remains are rare within this formation and only fragments of plants and worms tracks recorded from the unit were used to date it as

Maastrichtian.

2.3.2. The Imo Shale

The Imo Shale is made up of rock units consisting of a thick sequence of blue to dark grey shale with occasional bands of clay-ironstones and subordinates thin sandstone. Surface outcrops of Imo Formation occur in a belt extending from North of Umuahia to North of Benin City (Short & Staüble ,1967). It is richly fossiliferous with fossil assemblage that is typical of a near-shore marine environment and indicates a Paleocene age. Imo shale is succeeded by the Ameki Formation.

2.3.3. The Ameki Formation

The Ameki Formation is heterogeneous in nature as it is composed of sandstone, shale, limestone, marl, siltstone and subsidiary lignite .(Avobovbo and Ayoola, 1981, Ogbukagu and Akujieze, 1990). The sandstone component ranges in fine to coarse grained and sometimes gravelly or pebbly in texture. The Formation is thus divided into two lithologic units. The lower unit is composed of fine to coarse grained sandstones consisting of interbeds of calcareous shale and thin shelly limestone. The upper unit is made up of grey to green coarse grained cross-bedded sandstones with intercalations of sandy clay.(Avobovbo and Ayoola, 1981).The heterogeneous composition of this formation is indicative of stratification under shallow marine to continental environments (Ogbukagu and Akujieze, 1990).

2.4 Field and Laboratory tests

The field work involved visual assessment of the route to determine its level of deterioration and to locate test points at every kilometre along the route. Bulk samples were collected from trial pits made at each test point. In-situ dry density (IDD) of the pavement sub grade soils were carried out to estimate their field compaction, the test was carried out along the road shoulder with the aid of nuclear gauge. Pavement deflection measurements were also made using the Benkelman beam.

The laboratory tests included, the grain size distribution, Atterberg limits, compaction and Californian bearing ratio. The test were carried out using standard procedures (BS 1377, 1999 and Bowles, 1988).

3. Results and Discussions

3.1Pavement Condition

Visual assessment of the road showed that it exhibited distresses (Plate 1) that included, wash-out (CH. 9+000), ruts and depressions (CH.10+500), edge damage (CH. 11+050), pot holes (CH. 16+000), longitudinal and traverse cracks (CH. 19+000), crocodile cracks (CH. 20+000) and bleeding (CH. 27+000), amongst others.

3.2 Soil Types and Index Properties

The subgrade soils along the road were residual soils developed by in-situ weathering of the underlying sedimentary rocks. The index properties of the soils are summarized in Table 2. The results indicated that the subgrade soils along the road were essentially fine grained in nature and were mainly composed of clays, silts and silty sands with fine grained components (< 0.075 mm) generally ranging from about 27% to 55% . The Ameki Formation derived soils had relatively high natural moisture contents ranging from 9.6% to 18.2%, while corresponding values ranged from 3.8% to 13.8% for the Imo Shale derived soils and from 6% to 14.5% for the Ajali Sandstone derived soils.

The grain size curves indicated that the soils derived from the Ameki Formation were well sorted and composed mainly of silt and clay (Fig. 3); those from the Ajali Sandstone were poorly sorted and composed mainly of silt and sand (Fig. 4). On the other hand, the Imo shale underlain segment of the road were characterized by both well sorted and poorly sorted soils with sand contents that generally increased from less than 10% between CH. 12+000 and 17+000 (Fig. 5a.) to over 50% between CH. 18+000 and 30+000. (Fig. 5 b-d), thus reflecting the effects of occurrence of thin bands of sandstones within the shale.

Liquid limit, LL, for most of the soils generally ranged from 16% to 41% while the plasticity index, PI, generally varied from 4% to 19%. Average LL values of 28%, 26% and 25% were obtained for the soils derived from the Ameki Formation, the Imo Shale, and the Ajali sandstone respectively. Corresponding average PI values were 12.3%, 7.6% and 10%.The plots of the soils on the plasticity chart (Figure 6) indicated that the clayey components were inorganic in nature and were characterized by low to moderate plasticity..Based on the AASHTO system of classification, soils derived from the Ameki Formation fell mainly within the A-6 and A-2-4 group, while the Imo Shale derived soils fall mainly within the A-4 and A-2-4. The Ajali Sandstone derived soils were mainly within the A-4 group with minor A-2-4 and A-2-6 soils.

3.3Compaction and Strength Characteristics

Compaction, CBR, field compaction and pavement deflection tests results are summarized in Table 3. Results of the moisture density relationship of the soils indicated fairly uniform average MDD of 1.83, 1.92 and 1.90 Mg/m^3 for the Ameki, Imo Shale and Ajali derived soils respectively. Corresponding average optimum moisture content (OMC) values were 13.3, 14.2 and 13.1 % respectively. Average un- soaked CBR values of 6.5, 6.2 and 11.5 were respectively obtained for the soils derived from the Ameki Formation, the Imo Shale and the Ajali

Sandstone with corresponding average soaked CBR values of 0.86, 0.83 and 1.12 respectively to indicate the poor strength characteristics of the subgrade soils.

3.4 In-Situ Dry Density (IDD)

Unlike the laboratory compaction tests, the in-situ dry density (IDD) test results showed variations in the IDD values of the soils. The average IDD values were 1.67, 1.73 and 1.83 for Ameki, Imo Shale and Ajali sandstone derived subgrade soils respectively. Relative compaction (RC) of the soils, which is the ratio of IDD to the MDD, is very relevant in pavement evaluation. The RC values (Figure 7) generally varied from 0.83 to 1.0 with an average of 0.89 for the Ameki soils; 0.77 to 0.99 with an average of 0.88 for the Imo Shale soils and from 0.81 to 1.07 with an average of 0.96 for the Ajali sandstone soils. The average RC values for the Ameki and the Imo Shale soils of 0.89 and 0.88 respectively are below the minimum value of 1.0 recommended by the Nigerian Federal Ministry of Works of the soils, while 0.96 RC value for Ajali soils is above 0.95 minimum recommended by Garber and Hoel (2010).

3.5 Pavement Deflection and Evaluation

Results of the Benkelman deflection test indicated that the route had a highly variable deflection values ranging from 0.12 mm to 1.46 mm. The deflection profile is as shown on Figure 8. Based on the pavement deflection values, the Irrua – Auchi road can be classified into three segments. The segment between CH 31+000 to CH 36+000 with average deflection value of 0.26 mm can be classified as stable; the segment between CH 0+000 to CH 10+000 characterized by an average deflection of 0.39 mm is classified as less stable. The segment between CH 11+000 to CH 30+000 characterized by an average deflection value of 0.61 mm as least stable. As shown in Figure 7, the stable segment is underlain by the Ajali Sandstone, the less stable segment by underlain by the Ameki Formation, while the least stable segment is underlain by the Imo Shale.

From the summarized of the subgrade geotechnical properties, pavement deflection and the road route geology is shown in figure 9. It is pertinent to note that similarities were observed in the index properties and moisture-density relationships of all the subgrade soils. Minor variations were observed in their CBR strength characteristics. The high variation in the pavement deflection may therefore be due to factors other than geotechnical properties.

Soil structure is very significant for soils derived from sedimentary rocks as the environments of deposition strongly influence the structures of the sediments and their derived soils. According to Das (2007), clay deposits formed in the sea are highly flocculent and generally have light weight as well as high void ratio. On other hand, most of the sediments formed from freshwater possess intermediate structure between dispersed and flocculent

Stability of the road may therefore be explained from the perspective of soils structure. The unstable natures of the Imo Shale segment may be deduced from the fact that stratification of the formation occurred in marine environment suggesting that the clays within the sediments have flocculent structure; their derived subgrade soils also have flocculent structures that are unstable under loading, hence the high pavement deflection. In contrast the relatively stable underlain by the Ajali Sandstone may be attributed to the continental depositional environment of the formation suggesting that the clays within the sediments have mainly dispersed structure that are relatively stable under loading, hence the low pavement deflection. The Ameki Formation was deposited under shallow marine to continental environments indicating that the clays within the sediments may have combination of dispersed and flocculent structures. Consequently, their derived subgrade soils may have combination of flocculent and dispersed structures that are moderately stable under loading, hence the moderate pavement deflection.

Hydrology is also an important factor in highway performance. The critical portion of the least stable segment of the road traverses floodplain of several perennial rives. Hence, the high deflection and several failed segments recorded within this portion may be attributed to the shallow water table of the area along with the effect of the soil structure.

4.0 Conclusion

Geotechnical investigation of the Irrua – Auchi road was carried out to determine the engineering properties of the subgrade soils and evaluate the pavement conditions with a view to establishing the causes of failures along portions of the road. The 36 km road is a section of the Warri-Benin-Abuja highway that links the oil producing Niger Delta Region of the country to Abuja, the nation's Federal Capital Territory.

The study involved fieldwork that encompassed measurements of in-situ dry density using nuclear gauge and determination of pavement deflections with the aid of Benkelman beam device. The laboratory tests included determination of the natural moisture content, grain size distribution, Atterberg limits, compaction and strength characteristics involving unsoaked and 48 hour soaked California Bearing Ratio (CBR) tests.

Geological data of the area indicated that sedimentary deposits of the Ajali Sandstone, the Imo Shale and the Ameki Formation underlie the road. Results of the index tests showed that the subgrade soils were fine grained inorganic residual soils characterize by low to medium plasticity and low to medium compressibility. The soils fall within the range of A-4 to A-2-6 groups on the AASHTO classification system. Results of the moisture density relationship indicated that the soils had fairly uniform average MDD of 1.83, 1.92 and 1.90 Mg/m^3 for the Ameki, Imo Shale and Ajali derived soils respectively with corresponding average OMC values of 13.3, 14.2 and 13.1% respectively. The average un-soaked CBR values of 6.5, 6.2 and 11.5 respectively obtained for the soils derived from the Ameki Formation, the Imo Shale and the Ajali Sandstone with corresponding average soaked CBR values of 0.86, and 1.12 respectively, indicated generally poor strength characteristics of the subgrade soils irrespective of their parent materials.

The field geotechnical tests indicated that the Imo Shale and the Ameki derived soils had low average relative compaction values of 0.89 that is below the minimum value recommended by the Nigerian Federal Ministry of Works, while the Ajali Sandstone soils have corresponding value of 0.96 that is up to the minimum recommended value of 0.95 (Garber and Hoel,2010). Also, the pavement average deflections were, 0.26 mm, 0.39 mm and 0.61 mm for the segments of the road underlain by the Ajali Sandstone, the Ameki Formation and the Imo Shale respectively to show pattern that reflects the influence of soil structures derived from stratification of the underlying parent geologic units. The segments underlain by the Ajali Sandstone, the Ameki Formation and the Imo Shale are classified as stable, less stable and least stable respectively thus highlighting the significance of geology in pavement design and evaluation.

Conclusively, in this study, the pavement evaluation revealed that geotechnical field tests, which reflect the intrinsic geological properties of subgrade soils, may be more reliable as means of pavement evaluation in sedimentary rocks terrain than corresponding laboratory tests.

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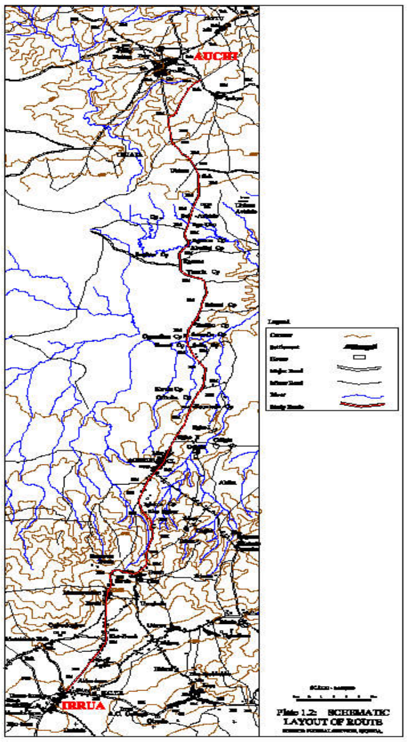

Figure 1: Route Location

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Table 1. Lithostratigraphic Units of the Anambra Basin (Nwajide, 2005)

Age	Basin	Stratigraphic Units						
Thanetian	Niger Delta	Imo Formation						
Danian								
Maastrichtian	Anambra Basin	Coal Measures	Nsukka Formation					
			Ajali Sandstone					
Campanian			Mamu Formation					
		Nkporo Fm	Nkporo Shale	Enugu Fm	Owelli Ss	Afikpo Ss	Otobi Ss	Lafia Ss
Senonian	Southern Benue Trough	Awgu Fm						

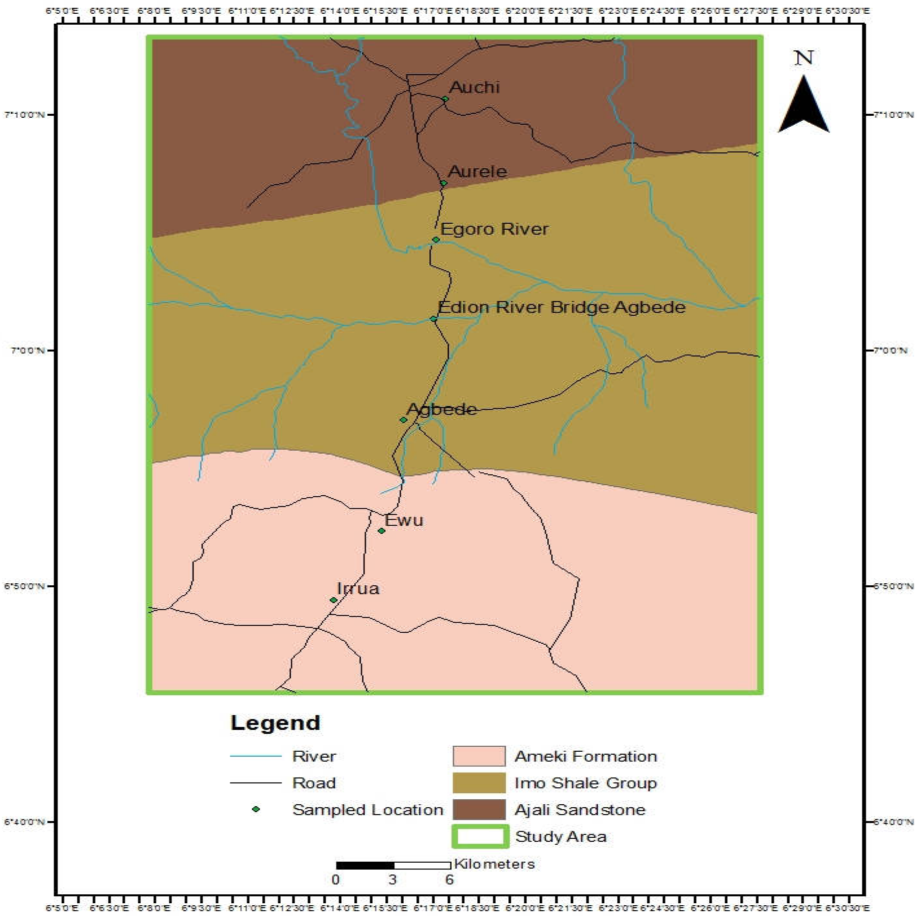
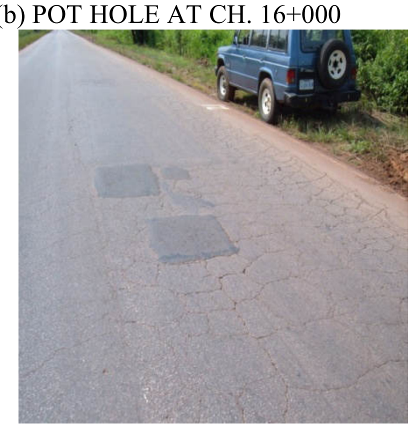


Figure 2: Geology of Route

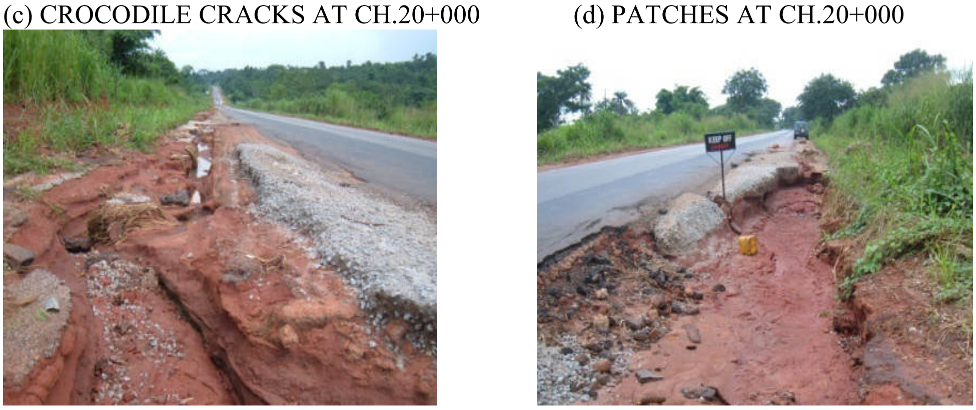
(a) BLEEDING AT CH.27+000

(b) POT HOLE AT CH. 16+000

(c) CROCODILE CRACKS AT CH.20+000



(d) PATCHES AT CH.20+000



(e) EDGEWASH OUT CH. 9+000

Plate 2 : Pavement conditions at some Locations on Irrua - Auchi road

Table 2. Soil Index Properties

Sanple No	Chainage	NMC %	% Pass.. No. 40	% Pass.. No. 200	Liqud Limit L L%	Plastic Limit PL%	Plasticity Index PI %	AASHTO CLASS.	Soil Description	Stratigraphy
1	0+000	10.3	78.8	55.1	41	22	19	A-7-6	Clayey soil	Ameki Formation
2	1+000	18.5	76.2	47.2	35	19	16	A-6	Clayey soil	
3	2+000	12	75.2	42.2	25	12	13	A-6	Clayey soil	
4	3+000	14.1	76.2	43.1	35	17	18	A-6	Clayey soil	
5	4+000	9.6	70.2	33.9	24	15	9	A-2-4	Silty sand	
6	5+000	11.6	73.5	34	23	13	10	A-2-4	Silty sand	
7	6+000	15	73.3	30	18	12	6	A-2-4	Silty sand	
8	7+000	14	79.7	28.8	19	13	6	A-2-4	Silty sand	
9	8+000	10.1	77.7	45.5	29	15	14	A-6	Clayey soil	
10	9+000	13.8	70.6	43.1	27	15	12	A-6	Clayey soil	
11	10+000	14	72.9	34.2	21	13	8	A-2-4	Silty sand	
12	11+000	12.5	72.4	10.8	14	14	0	A-3	Fine sand	
13	12+000	15	71.4	31.4	21	13	8	A-2-4	Silty sand	Imo Shale
14	13+000	12.2	68.6	31.1	16	12	4	A-2-4	Silty sand	
15	14+000	10	73.6	31.3	18	14	4	A-2-4	Silty sand	
16	\15+000	7.2	74.3	35.9	20	15	5	A-4	Silty soil	
17	16+000	12.3	63.3	19.1	23	17	6	A-2-4	Silty sand	
18	17+000	7.8	52.5	33.5	26	17	9	A-2-4	Silty sand	
19	18+000	10.7	49.6	35.1	25	16	9	A-2-4	Silty sand	
20	19+000	7.2	44.7	36.6	34	20	14	A-6	Clayey soil	
21	20+000	12	55.2	36.5	29	19	10	A-4	Silty soil	
22	21+000	6.8	49.4	38	18	15	3	A-4	Silty soil	
23	22+000	8.5	71.5	37.3	19	14	5	A-4	Silty soil	
24	23+000	7.3	55.8	40	24	16	8	A-4	Silty soil	
25	24+000	14.5	62.8	42.4	22	14	8	A-4	Silty soil	
26	25+000	8.6	54.7	42.4	30	20	10	A-4	Silty soil	
27	26+000	15.5	38	30.8	36	24	12	A-6	Clayey soil	
28	27+000	3.8	42.1	34.9	36	21	15	A-2-6	Silty sand	
29	28+000	14.3	40.5	30.2	29	17	12	A-2-6	Silty sand	
30	29+000	8.1	49.5	31.2	24	15	9	A-2-4	Silty sand	
31	30+000	11.1	93.4	52.5	16	12	4	A-4	Silty soil	

Table 2. Soil Index Properties Continued

Sanple No	Chainage	NMC %	% Pass.. No. 40	% Pass.. No. 200	Liqud Limit L L%	Plastic Limit PL%	Plasticity Index PI %	AASHTO CLASS.	Soil Description	Stratigraphy
32	31+000	6	79	45.3	26	17	9	A-4	Silty soil	Ajali Sandstone
33	32+000	14.5	49.3	37.1	25	15	10	A-4	Silty soil	
34	33+000	5.9	72.3	58.5	23	14	9	A-4	Silty soil	
35	34+000	14.2	53.2	44	32	17	15	A-6	Clayey soil	
36	35+000	14.6	56	27.9	26	17	9	A-2-4	Silty sand	
37	36+000	9.9	80.1	29.3	29	16	13	A-2-6	Silty sand	

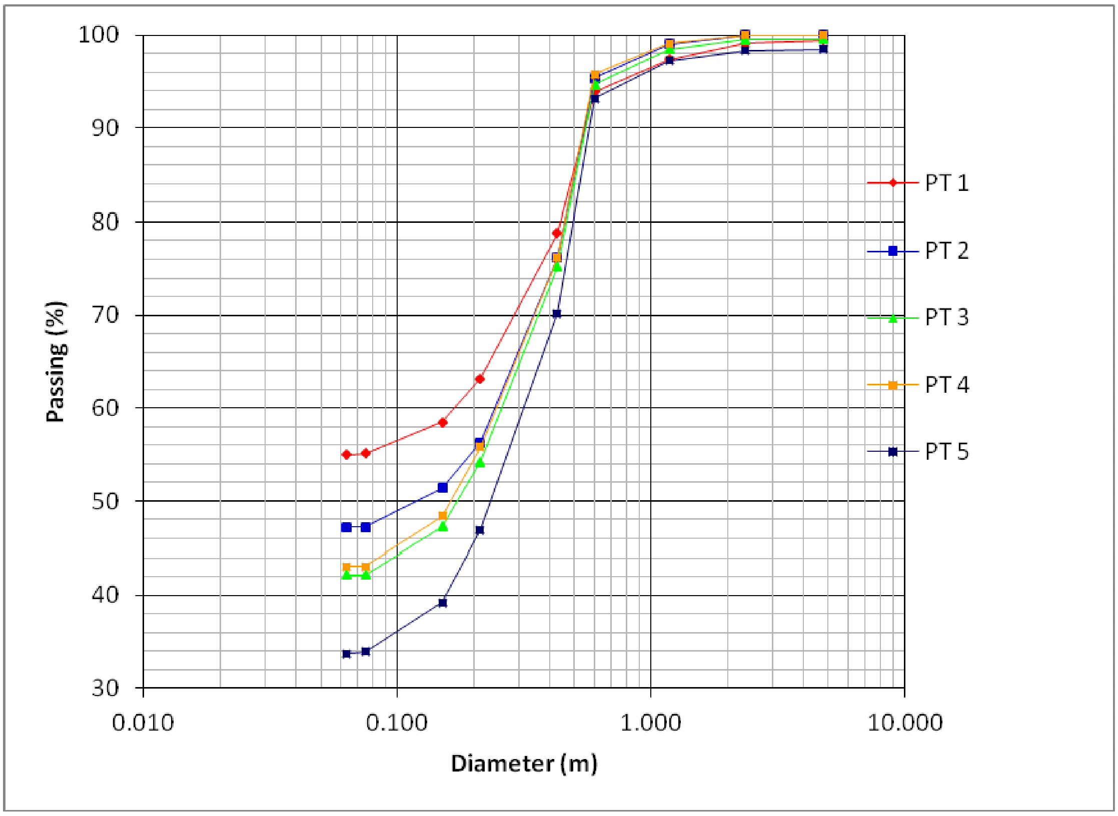


Fig.3. Grading Curves for Ameki Formation derived soils.

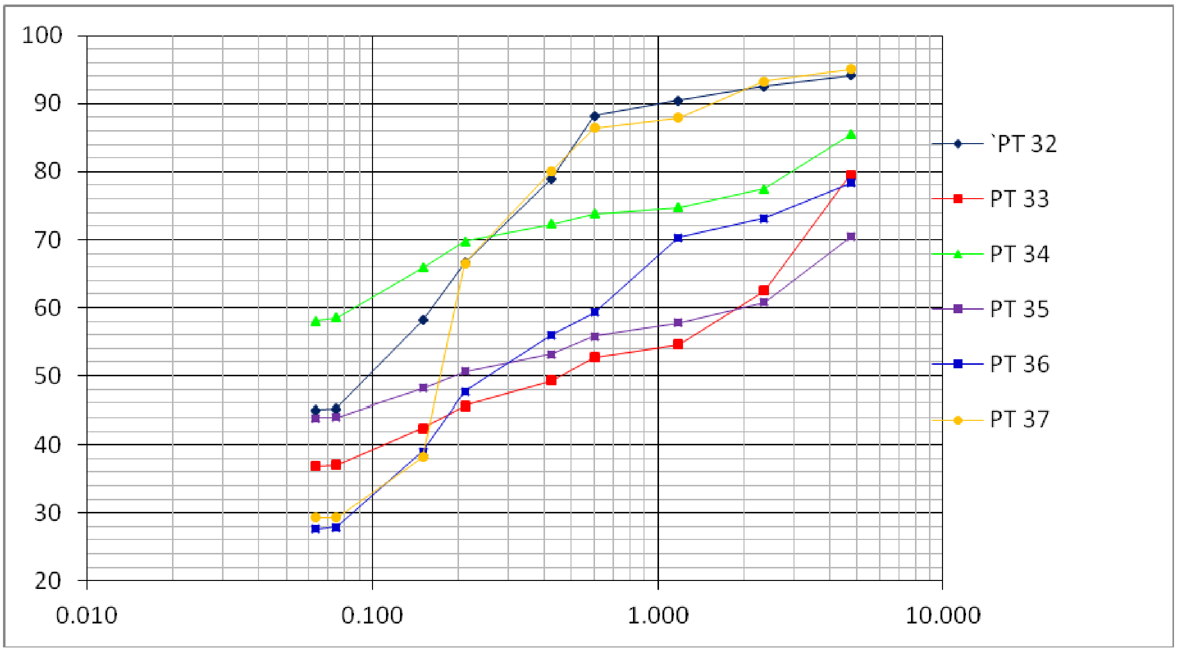


Figure 4. Grading Curves for Ajali sandstone derived soils

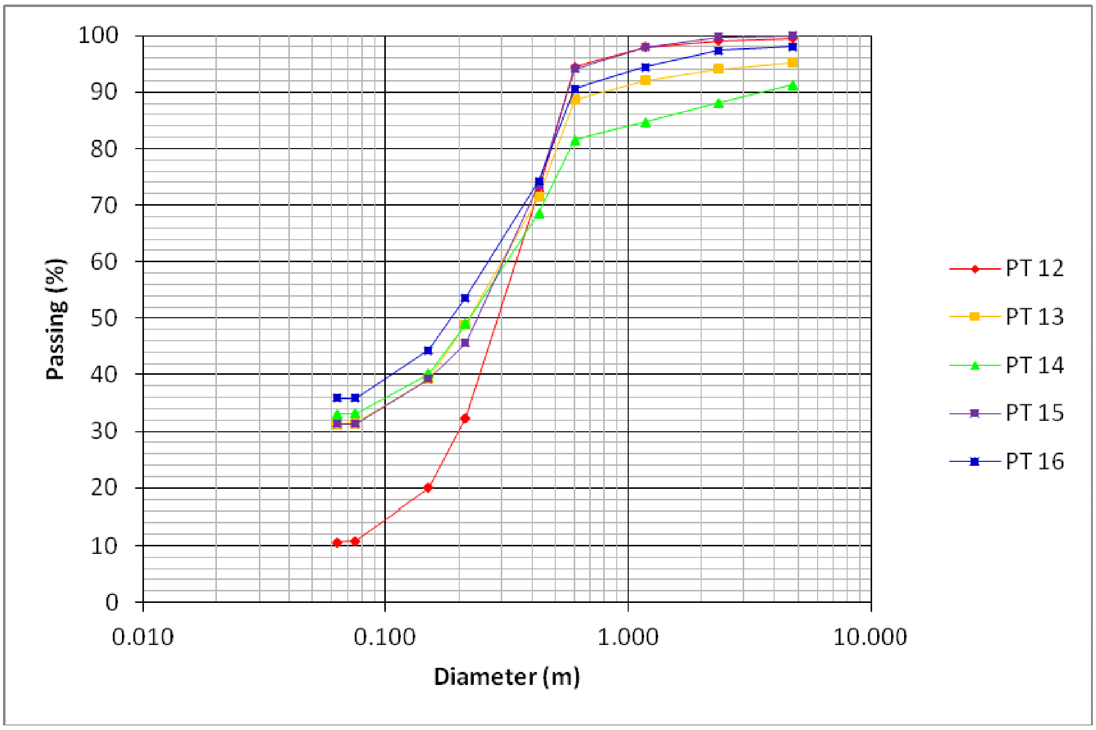


Figure 5a. Grading Curves for Imo shale derived soils (CH. 12+000 -17+000)

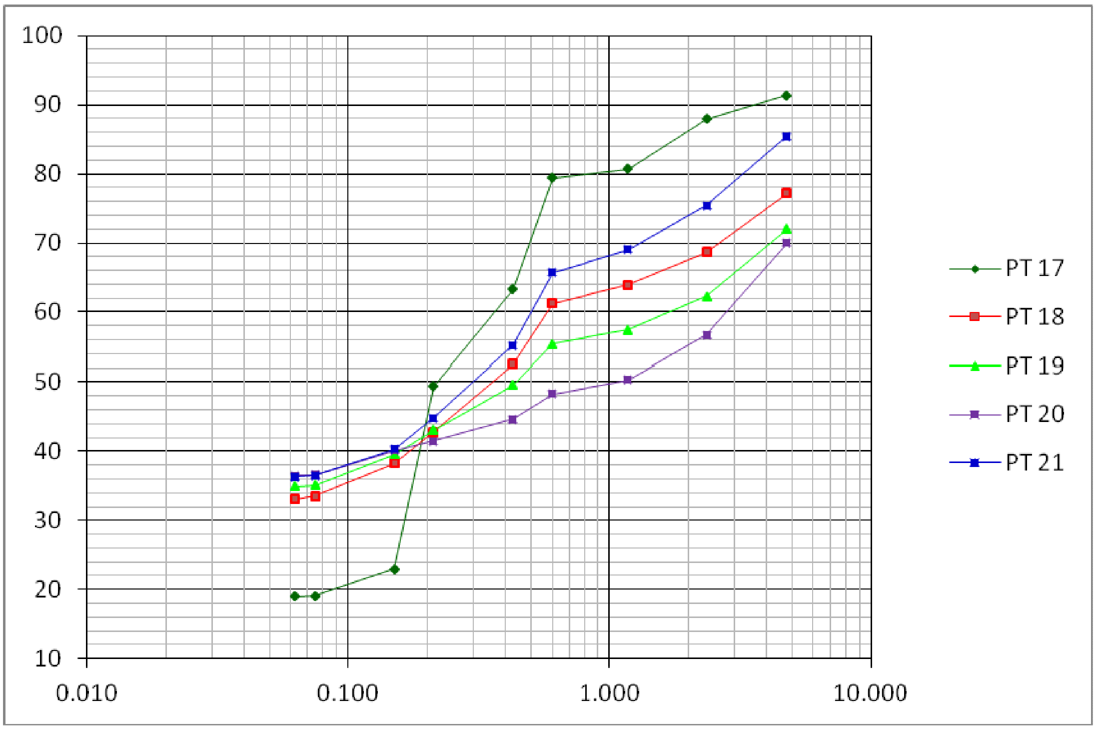


Figure 5b. Grading Curves for Imo shale derived soils (CH. 18+000 – 21+000)

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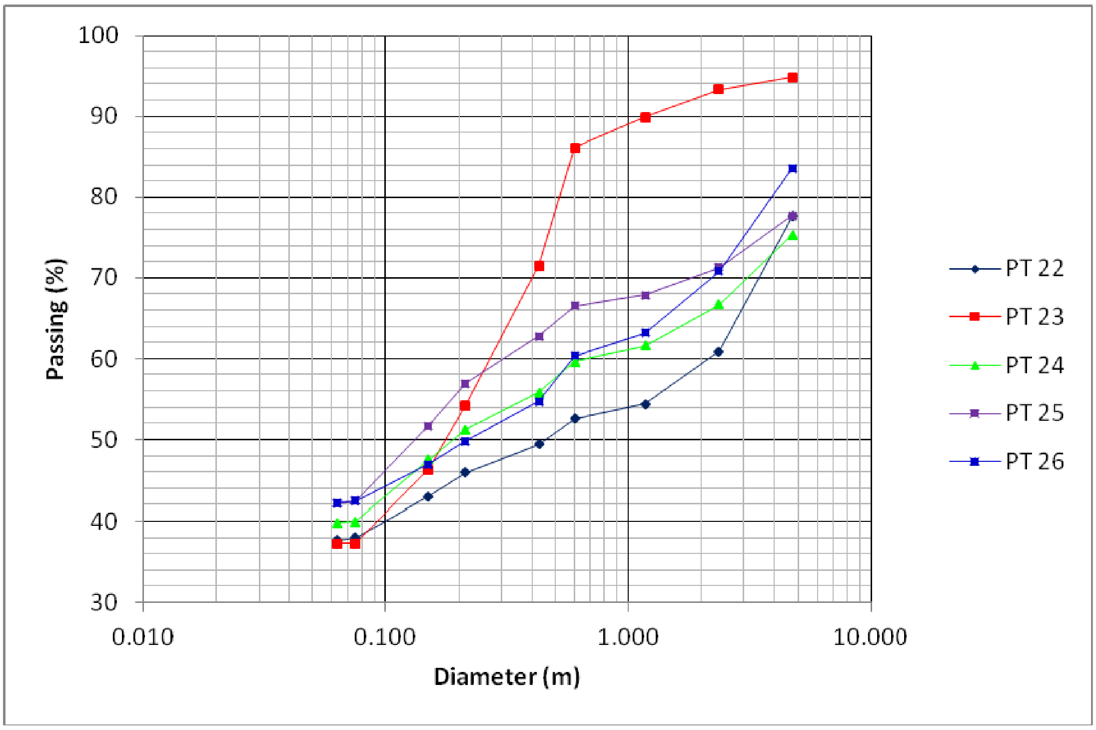

Figure5c. Grading Curves for Imo shale derived soils (Ch. 22 - 26)

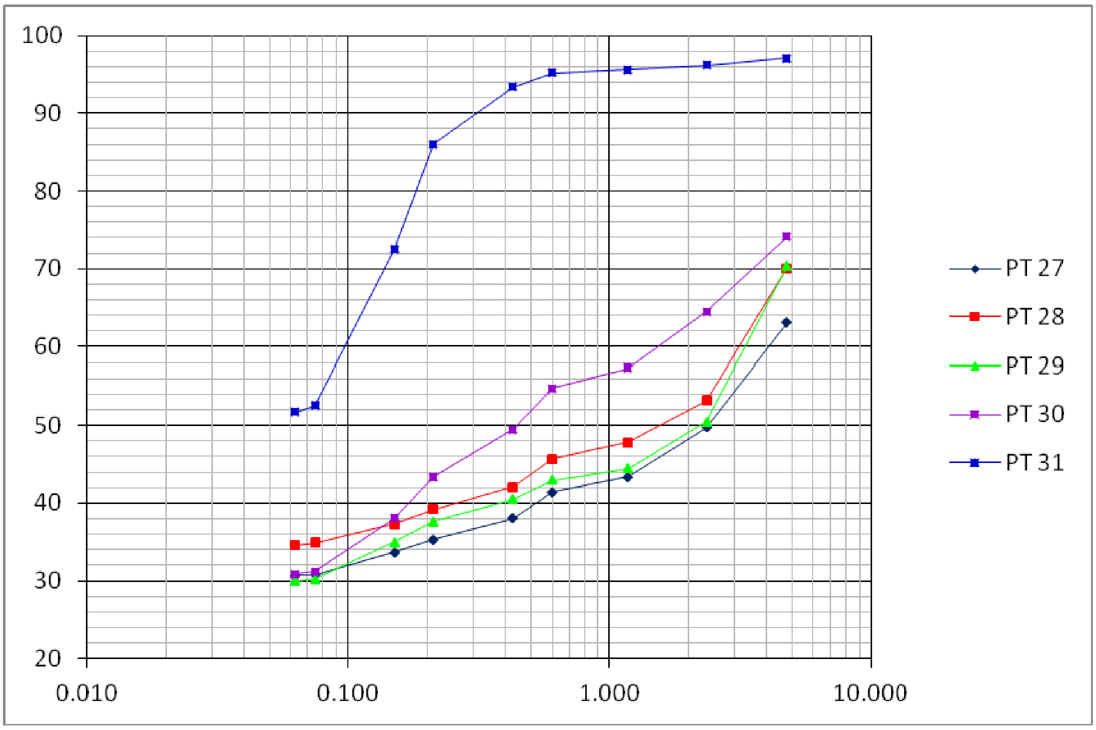

Figure5d. Grading Curves for Imo shale derived soils (Ch. 27+000 - 30+000)

Table 3. Summary of Compaction, CBR and Pavement Deflection Tests Results

Sanple No	Chainage	MDD	OMC	IDD	Relative Compaction (%)	CBR UNSK. %	CBR SK. %	Pavement Deflection (mm)	Pavement Evaluation	Stratigraphy
1	0+000	1.63		1.56	0.95	4	0.36	0.43	Less Stable	Ameki Formation
2	1+000	1.85		1.549	0.84	8	0.83	0.18		
3	2+000	1.87		1.645	0.86	13	1.26	0.91		
4	3+000	1.85		1.654	0.89	4	0.36	0.49		
5	4+000	1.84		1.845	1	5	0.42	0.12		
6	5+000	1.87		1.769	0.95	4	0.39	0.18		
7	6+000	1.89		1.605	0.83	6	0.60	0.43		
8	7+000	1.91		1.629	0.85	13	1.38	0.49		
9	8+000	1.98		1.825	0.92	8	0.81	0.37		
10	9+000	1.94		1.641	0.85	4	0.43	0.24		
11	10+000	1.88		1.625	0.86	5	0.47	0.49		
12	11+000	1.84		1.53	0.81	31	3.12	0.37	Least Stable	Imo Shale
13	12+000	2.01		1.646	0.82	5	0.51	0.91		
14	13+000	2.00		1.759	0.88	8	0.83	0.64		
15	14+000	2.02		1.626	0.8	5	0.52	0.70		
16	\15+000	1.95		1.74	0.89	6	0.59	0.18		
17	16+000	1.96		1.508	0.77	12	1.14	0.82		
18	17+000	1.91		1.806	0.95	5	0.64	0.18		
19	18+000	1.99		1.901	0.96	5	0.47	0.76		
20	19+000	1.97		1.838	0.93	6	0.66	0.29		
21	20+000	1.94		1.619	0.83	10	1.19	1.46		
22	21+000	1.95		1.833	0.94	8	0.79	0.59		
23	22+000	2.04		1.819	0.89	7	0.70	1.35		
24	23+000	1.86		1.805	0.95	8	0.77	0.53		
25	24+000	1.98		1.741	0.88	10	1.04	1.23		
26	25+000	2.01		1.995	0.99	7	0.72	0.29		
27	26+000	1.86		1.7	0.91	6	0.63	0.30		
28	27+000	1.86		1.544	0.81	4	0.42	0.12		
29	28+000	1.95		1.766	0.91	3	0.35	0.61		
30	29+000	1.94		1.838	0.94	8	0.77	0.37		
31	30+000	1.97		1.772	0.9	4	0.40	0.49		

Table 3. Summary of Compaction, CBR and Pavement Deflection Tests Results Continued

Sanple No	Chainage	MDD	OMC	IDD	Relative Compaction (%)	CBR UNSK. %	CBR SK. %	Pavement Deflection (mm)	Pavement Evaluation	Stratigraphy
32	31+000	1.94		2.08	1.07	6	0.63	0.24	Stable	Ajali Sandstone
33	32+000	1.95		1.57	0.81	4	0.44	0.24		
34	33+000	1.97		2.1	1.07	4	0.45	0.12		
35	34+000	1.86		1.761	0.95	23	2.33	0.49		
36	35+000	1.86		1.824	0.98	5	0.50	0.30		
37	36+000	1.93		1.716	0.89	27	2.84	0.18		

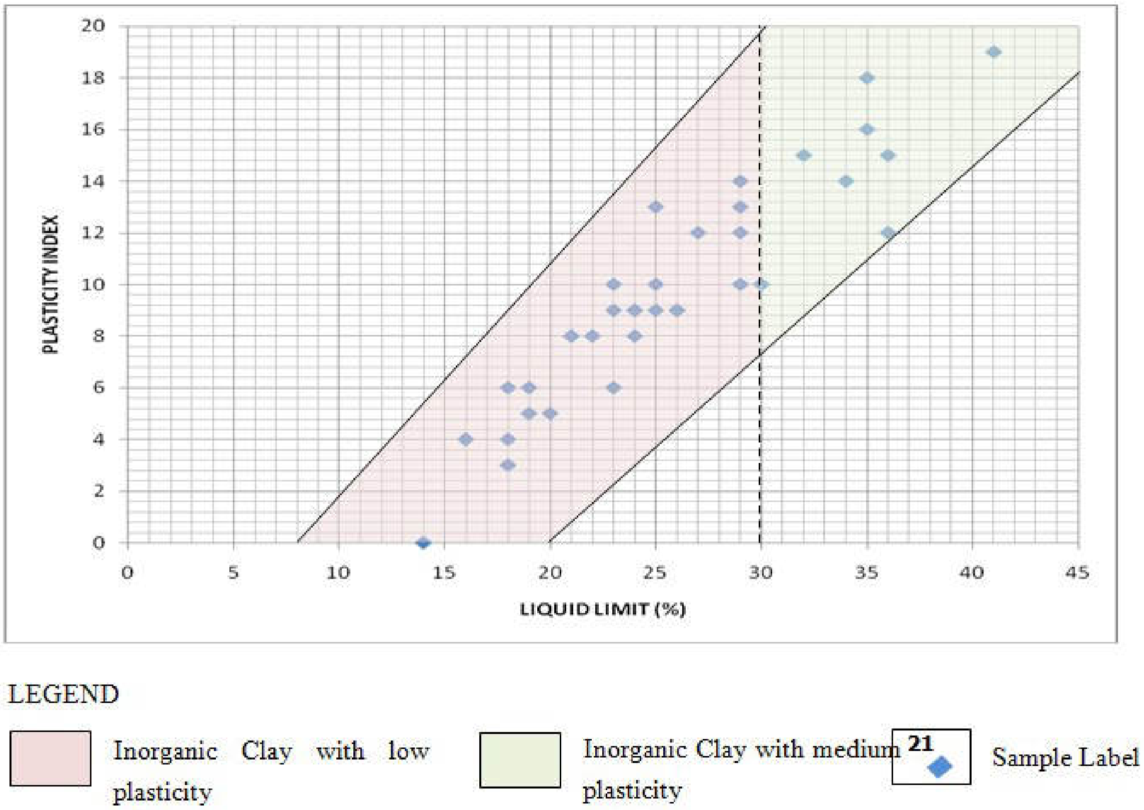

Figure 6: Casagrande Chart

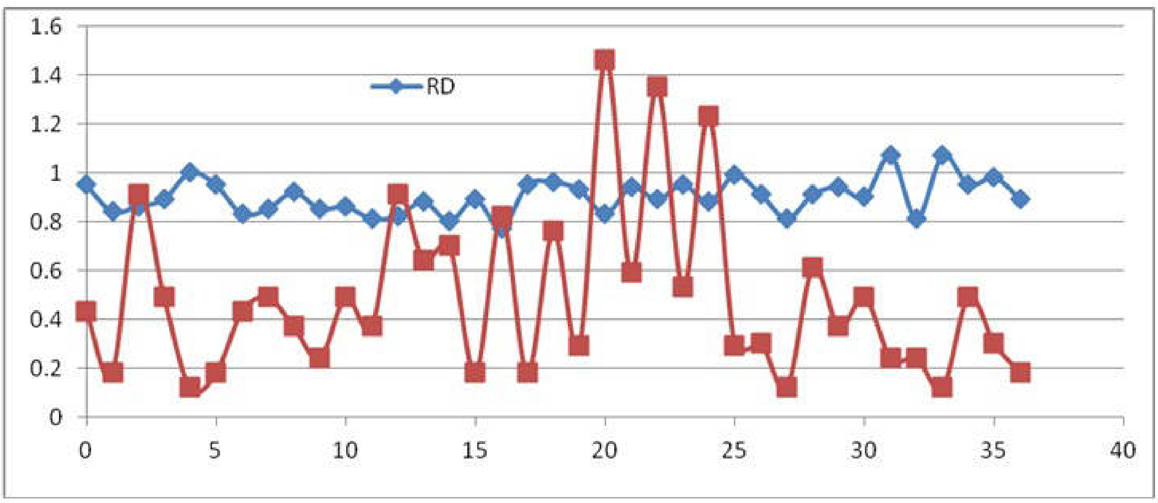

Figure 7. Plot of Relative Compaction and Pavement Deflection Values

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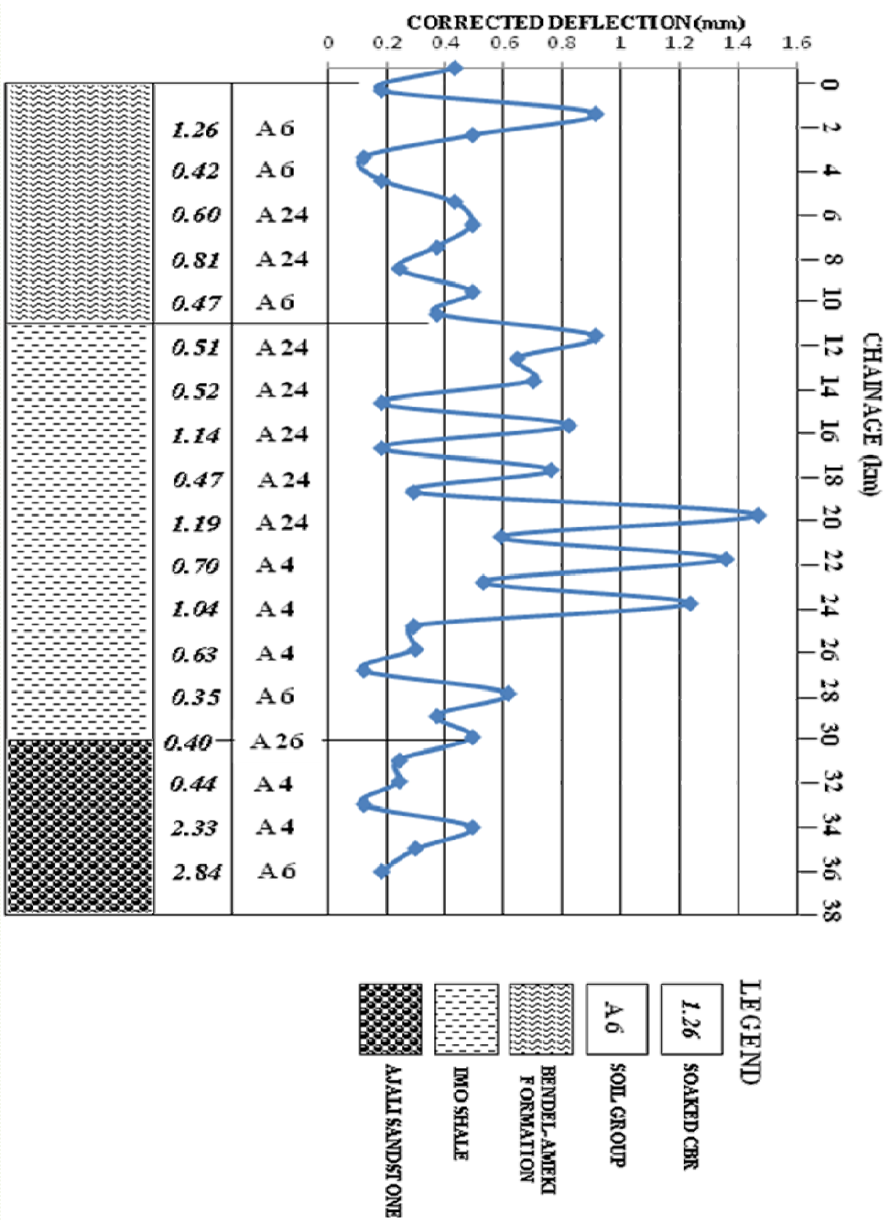

Figure 8. A summary of the subgrade geotechnical properties, pavement deflection and the road route geology