GEOTECHNICAL CHARACTERIZATION OF LATERITIC SOILS OF PARTS OF ANAMBRA STATE SOUTHEAST, NIGERIA AS BASE MATERIALS.

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Abstract
Twelve samples were collected from different locations in Anambra State for evaluation as base material for road construction. The samples were tested for specific gravity, particle size distribution, atteberg limit, linear shrinkage, compaction and california bearing capacity. The result of the specific gravity test ranges from 2.35Mg/m^3 - 2.63Mg/m^3 while the values of the particle size distribution test ranges from 13% and 36% making only sample S8 unsuitable for use as base material. The samples revealed the following range of values for atterberg limit properties: Liquid Limit 22% to 44%; Plastic Limit 10% to23%; Plasticity Index 12% to 24%; Linear Shrinkage 7% to 11%. AASHTO soil classification system identified S8 as A-7(poor), S9 and S12 as A-2-7 (good) while others are A-2-6(good) samples. M.D.D values obtained from compaction parameters range from 1.96 Mg/m^3 to 2.24 Mg/m^3 and O.M.C as 7.44% to 14.67% while the California Bearing Ratio (unsoaked) ranges from 76% to 113%. Based on the Nigerian Federal Ministry of Works and Housing specification (NFMWH), samples S1, S6 and S8 are only suitable for sub-base while samples S2, S3, S4, S5, S7, S9, S10, S11 and S12 are suitable for both sub- base and base- course. However, samples S1, S6 and S8 can be improved with stabilizers for use as base-course materials.
Keywords: Lateritic soils, Geotechnical properties, Base Materials, Anambra State, road construction, road failure

1. Introduction

Nigeria being one of the developing countries of the world is faced with the challenges of infrastructural development. These includes, but not limited to roads, bridges, buildings and dams. However, the persistent failure of these engineering structures has become a source of worry to all stake holders. One of the factors responsible for these failures as adjudged by professionals include lack of in depth knowledge of the geotechnical properties of soil which is a precondition for its use in civil engineering construction either as a construction material or foundation for super structures. In Nigeria, lateritic soils are of great interest to the construction Industries due to its natural abundance, availability and favorable engineering properties. They are useful materials for construction of foundation, roads, airfields, low-cost housing and compacted fill in earth embankments [1], [2], [3], [4].
Several researchers [5], [6], [7], defined lateritic soil as those soil that have undergone serious weathering and are rich in oxides of iron and aluminum or both. They are formed in tropical regions with annual rainfall between 750 and 3000 mm usually in area with a significant dry season on a variety of different types of rocks with high iron content [8]. Laterite, a product of tropical weathering is characterized by red, reddish brown or dark brown colour with or without nodules or concreting and generally (but not exclusively) found below hardened, ferruginous crust or hard pan [9].
These types of soils are easily noticed in highway and airfield pavement where they are used as sub-base materials, resulting in pavement swelling, depression and lateral movements in the presence of water

even under moderate wheel loads. They are characterized by high natural water contents and liquid limits, low natural densities and friable and/or crumble structure. Since the characteristics and durability of any construction material is a function of its efficiency in response to the load applied on it [10], this research is therefore aimed at determining the geotechnical characteristics of some lateritic soil in parts of Anambra state to minimize structural failures especially roads.

Lateritic soil is one of the most widely used naturally occurring materials in the construction industry. Its abundance, availability and favourable engineering properties account for its use as base materials for roads and fill materials for foundations and embankments. However, a pre-construction geotechnical evaluation of these lateritic soils is necessary to mitigate structural failures.

The study area is Located within the south-eastern zone of Nigeria. Anambra State, Nigeria occupies a landmass of over 4120 sq. km. It is situated on a low elevation on the eastern side of the River Niger and shares boundaries with Kogi, Enugu, Imo, Abia, and Delta states in the north, northeast, south, southeast and west respectively (Fig. 1).

The climatic condition of the study area shows an annual rainfall of about 2000-3000mm, average temperature range of about 25 – 27.5^{0C}, and mean annual sunshine hours of about 1750hours [11]. Relative humidity varies with season with an average value of about 75 – 95% and a mean annual atmospheric pressure of about 1101±1.2mbars

Two major seasons dominates this area – rainy season and dry season [12]. Rainy season ranges from March to October with its peak in July and September, and a short break in August. The dry season ranges from November to February with the influence of harmattan felt between the months of December and January. These seasonal changes with its attendant variation in temperature, runoff, humidity, atmospheric and pore pressure contribute to the rate of laterization.

Topographically, Anambra state falls into two main landform regions: a highland region of moderate elevation that covers much of the state south of the Anambra River, and low plains to the west, north, and east of the highlands. The highland region is a low asymmetrical ridge or cuesta in the northern portion of the Awka Orlu Uplands, which trend roughly southeast to North West, in line with the geological formations that underlie it. It is highest in the southeast, about 410m above mean sea-level, and gradually decreases in height to only 33m in the northwest on the banks of the Anambra River and the Niger River.

Geologically, Anambra State lies in the Anambra Basin which has about 6,000 m of sedimentary rocks comprising the Nkporo Shale, the Mamu Formation, the Ajali Sandstone and the Nsukka Formation as the main deposits (Table: 1). On the surface, the dominant sedimentary rocks are the Nanka Sand which is a lateral equivalent of Ameki Formation [13]. For the purpose of this research samples were collected from three geologic formations namely: Nanka Sand consists of a distinct unit of sands, shale-siltstone and finely laminated shale. The sand subunits comprises of uncemented, medium to coarse grained and pebbly quartz sand, with thickness varying from 50 to 90m [14] ; Imo Formation, characterized by thick layers of shale/mudstone units and thin lenses sands. The shale unit is generally dark grey, silty, micaceous, and contains woody tissues while the mudstone is pebbly in certain horizon; and Ogwashi-Asaba Formation, also referred to as the lignite series is characterizes by a sequence of coarse-grained sandstone, light coloured clays and carbonaceous shale within which are intercalations of lignite seams of continental origin ([15](Fig. 1).

Fig. 1. Geologic Map of Anambra State showing sample locations

Table 1: Stratigraphy of Anambra Basin (Modified after [16])

GEOLOGICAL TIMELINES	FORMATION	
Upper Oligocene to Miocene	Ogwuashi - Asaba Formation	
Ecocene	Ameki formation	
Paleocene	Imo shale	
Maastrichtian to Palaeocene	Nsukka formation	ANAMBRA BASIN PROPER
Upper Maastrichtian	Ajali formation	
Lower to Middle Maastrichtian	Mamu formation	
Lower Capanian to early Maastrichtian	Nkporo/ Enugu Shale	
Santonian	Awgu shale	
Turonian to Cenomanian	Eze - Aku formation	
Cenomanian	Odukpani formation	
Albian Aptian	Asu river group	
Precambrian	Crystalline Basement Complex Rocks	PROTO - ANAMBRA BASIN

2. Materials and Methods

The method used in this research consists of both field and laboratory procedures. A total of twelve samples were collected from (12) different borrow pit within the state (Table 2) for the purpose of this study. The disturbed soil samples were collected using using shovel at an average depth of 4m depending on topography and overburden. The samples were subsequently stored in a polythene bags in order to maintain its natural moisture content and were taken to Anambra State Materials Testing Laboratory, Awka, Nigeria for relevant geotechnical analysis after labelling. A Global Positioning System (GPS) was used to record the co- ordinates of sample locations for easy references.

TABLE 2: DETAILS OF SAMPLES COLLECTED

SAMPLE NUNBER	DEPTH(m)	LOCATION	CO-ORDINATES	
			LATITUDE	LONGITUDE
S1	2.0	ISINGWU, ORSUMOGHU BP	5°52'29.32"N	6°55'37.03"E
S2	1.0	AGULU	6°6'45.41"N	7°4'9.56"E
S3	1.5	AGULU	6°7'8.32"N	7°4'5.41"E
S4	3.0	UMUATUOLU, UMUERI BP	6°17'51.23"N	6°51'59.97"E
S5	4.0	IKEM, NANDO	6°21'11.78"N	6°55'2.70"E
S6	1.8	UGWU NDI UKA,AGULERI	6°19'58.08"N	6°52'49.87"E
S7	1.5	OBA-UMUOJI RD	6°5'38.49"N	6°51'17.19"E
S8	2.0	ENUGU-UMUONYIA-ACHINA BP	5°58'1.52"N	7°8'27.68"E
S9	3.0	EZIRA-UMUOMAKU-UMUONYIA RD	5°59'19.21"N	7°13'10.18"E
S10	2.7	ARMY SITE, NAWFIA BP	6°12'4.16"N	7°0'42.56"E
S11	3	NEAR CCC, AGULERI BP	6°20'5.38"N	6°53'7.89"E
S12	1.8	AZU-OGBUNIKE BP	6°10'36.69"N	6°52'59.06"E

2.1 Laboratory Test

The laboratory analysis was carried out according to the British standard of soil testing for civil engineering purposes (BS 1377: Part 1-9, 1990) (Plate 1). The laboratory test was aimed at determining the suitability of the lateritic soils for use as construction materials using the AASHTO and FMW standard methods in relation to the general specification for roads and bridges. Specific gravity which is the measure of the density of a soil relative to that of water was estimated using pyconometer. Specific gravity is closely related to the mineralogy and/or the chemical composition of the soil [1] [17] and the higher the specific gravity, the higher the degree of laterization [18]. Sieving analysis for the determination of the soil particle size distribution was carried out by mechanical method using an automatic shakers and a set of sieves while the clay content in terms of liquid limit, plastic limit, plasticity index and shrinkage potential in order to estimate plasticity, strength and settlement characteristics of the soil sample was determined by the atterberg limit test using casgrande apparatus. California bearing ratio (CBR) test was also carried out to evaluate the mechanical strength of the samples. Only unsoaked method of CBR was conducted to characterize the lateritic soil for use as a base course material. A portion of the air-dried sample was mixes with 5% of its weight of water. This was put in C.B.R mould in 5 layers with each layer compacted with 55 blows using a 4.5kg rammer. The compacted soil and the mould was weighed and placed under an automated CBR machine with proving ring factor of 0.0215KN/m^3. Load was recorded at penetration interval of 0.25mm.

The result of specific gravity obtained from the samples range from 2.35Mg/m^3 to 2.64Mg/m^3. Specific gravity is proportional to laterization. The percentage of material passing through sieve no 200BS ranges from 13% -36% as shown in Table 3 and Fig. 2. According to [19], all samples tested excerpt S8 can be deduced as suitable for use as base materials as the percentage by weight finer of sieve 200BS is less than 35%. However, sample S8 has a percentage fines passing of 36% which may reduce the strength of compacted laterites [20], [21].

Table 3: SUMMARY RESULT OF GEOTECHNICAL ANALYSIS.

SAMPLES	COMPACTION		C.B.R (%)	G.S (Mg/m^3)	ATTERBERG LIMIT (%)				SIEVE ANALYSIS (%)			CLASSIFICATION	AASHTO RATING
	M.D.D (Mg/m^3)	O.M.C (%)			L.L	P.L	P.I	L.S	GRAVEL	SAND	FINES		
S1	2.03	12.16	78	2.60	27	13	14	8	-	74	26	A-2-6	GOOD
S2	2.24	10.39	103	2.61	29	14	15	8	-	77	23	A-2-6	GOOD
S3	2.24	10.39	96	2.61	30	15	15	9	-	78	22	A-2-6	GOOD
S4	2.21	7.44	85	2.62	22	10	12	7	9	68	23	A-2-6	GOOD
S5	2.18	9.63	112	2.63	33	14	19	9	9	68	23	A-2-6	GOOD
S6	2.05	11.55	76	2.63	38	20	18	9	-	80	20	A-2-6	GOOD
S7	2.10	10.86	91	2.61	35	18	17	8	-	66	34	A-2-6	GOOD
S8	2.02	13.01	79	2.60	42	20	22	9	-	64	36	A-7-5	POOR
S9	2.08	13.62	96	2.35	44	20	24	10	18	62	20	A-2-7	GOOD
S10	2.08	11.55	99	2.64	37	21	16	10	13	67	20	A-2-6	GOOD
S11	2.05	8.04	113	2.63	29	16	13	8	-	87	13	A-2-6	GOOD
S12	1.96	14.67	83	2.60	43	23	20	11	8	65	27	A-2-7	GOOD

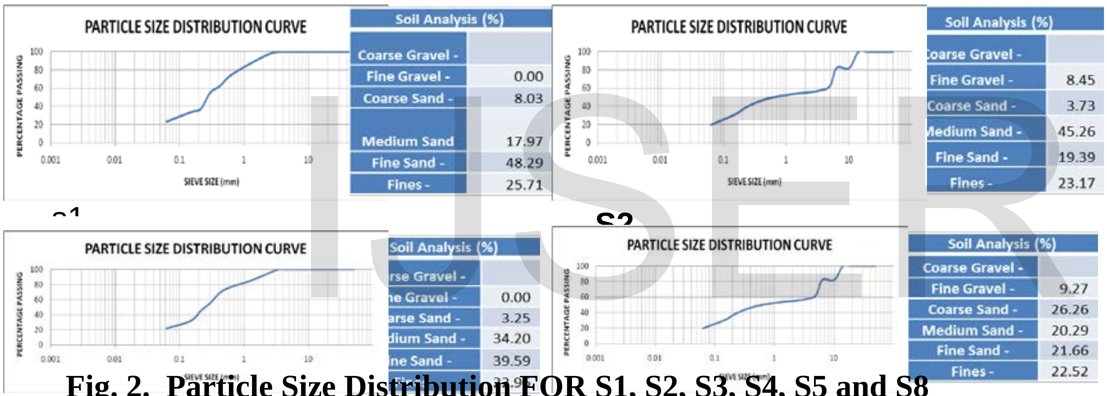
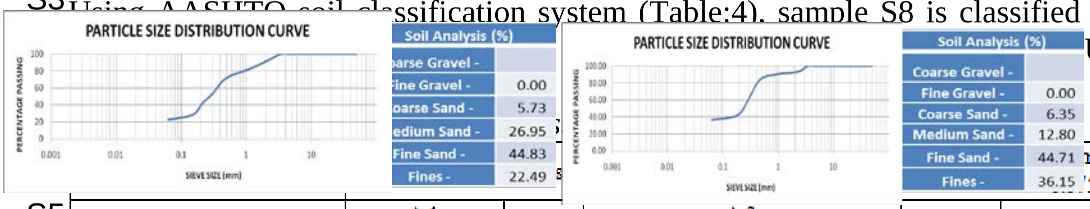


Fig. 2. Particle Size Distribution FOR S1, S2, S3, S4, S5 and S8

Using AASHTO soil classification system (Table:4), sample S8 is classified as A-7(poor), S9 and ... USCS, almost all the ...



... more than 35% passing ... 75 mm)

Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis % passing 2.00 mm (No10) 0.425 mm (No40) 0.725 mm (No200)	50max 30max 15max	50max 25max	51min 10max	35max	35max	35max	35max	36min	36min	36min	36min
Characteristics of fraction passing Liquid limit Plastic Index	6max		N.P	40max 10max	41min 10max	40max 11min	41min 11min	40max 10max	41min 10max	40max 11min	40min 11min
Usual types of significant Constituent material	Stone fragment Gravel and sand		Fine Sand	Silty or clayey Gravel and sand				Silty soils		Clayey soils	
General rating	Excellent to Good							Fair to poor			

The atterberg limit result shows that the samples tested have liquid limit ranging from (22% to 44%); plasticity index (12% to 24) and linear shrinkage (7% to 11%) table 3. The liquid limit values indicate the absence of expandable clay. Liquid limit less than 30% indicates low plasticity, between 35% and 50% indicates intermediate plasticity while 50% and 70% shows high plasticity. Liquid limit range of

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70% and 90% indicates extremely high plasticity [22]. On this basis, all samples tested have low to medium plasticity. According to the Federal Ministry of works standard for roads and bridges (1997) which specified a liquid limit of < 35%; plasticity index < 12% and linear shrinkage <8% for sub-base and base-course materials, only sample S4 falls within the standard for sub-base and base-course materials.

The result of the compaction of the samples revealed that the optimum moisture content range from 7.44% to 14.67% and maximum dry density of 1.93 Mg/m^3 to 2.24 Mg/m^3 as seen in table 4. Figure 3 shows the graphical behavior of these soils during compaction. The expected range when using a standard proctor test is shown in table 5 according to [23].

Table 5: Compaction classification (Modified from [23])

Maximium Dry Density (Mg/m^3)	Optimium Moisture Content (%)	Classification
1.44-1.685	20-30	clay
1.60-1.845	15-25	Silty clay
1.75-2.165	8-15	Sandy clay

Comparing these with the values obtained from all the samples tested, it can be deduced that they all satisfied the compaction standard and can be classified as sandy clay.

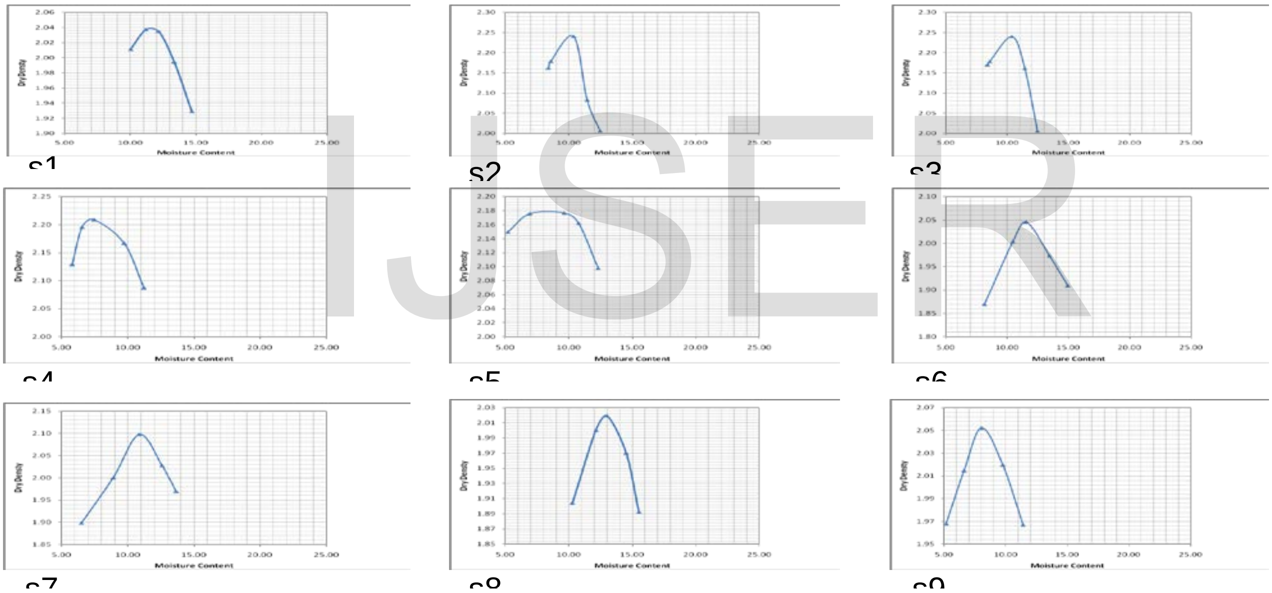

Fig. 3. Compaction graph of S1, S2, S3, S4, S5, S6, S7, S8 and S9

The unsoaked California bearing ratio (C.B.R) values of the samples tested ranges from 76% to 113% (Table 3 and Fig.--). From the Federal Ministry of works and housing, 1997 recommendation of >10 % for sub-grade; >30% for sub-base; >80% for base-course, it can be deduced that samples S1, S6 and S8 are not consistent with the specification for use as base-course materials. However, they are suitable for use as sub-grade and sub-base materials.

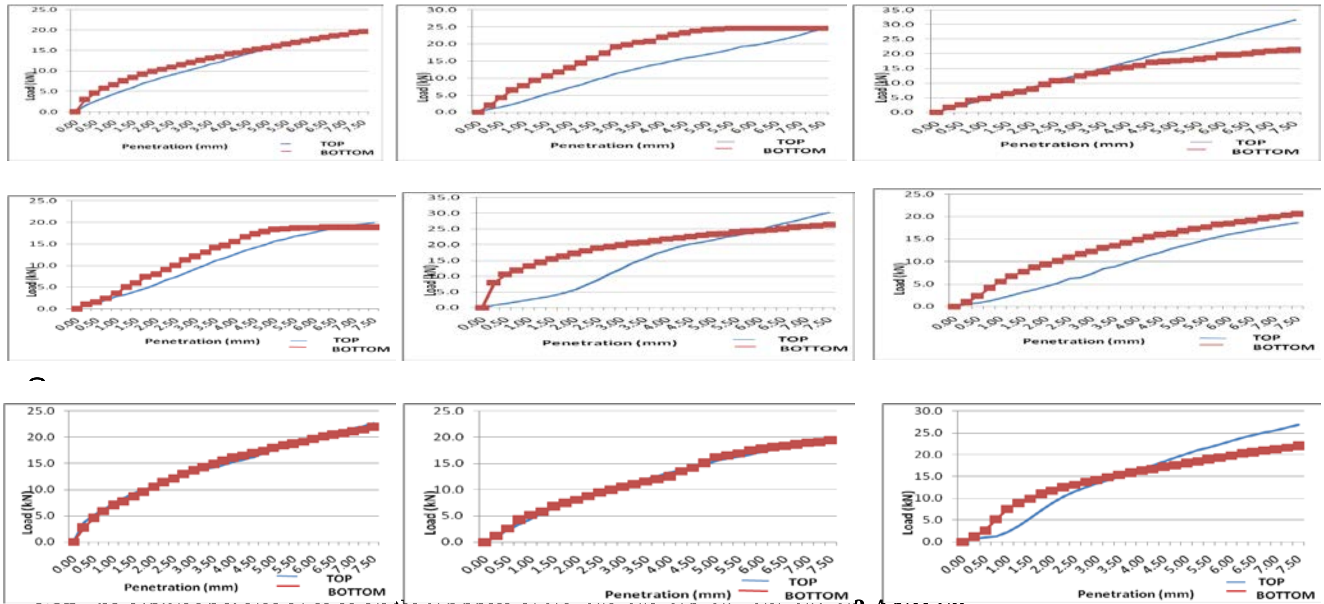

Fig. 4: UNSOAKED C.B.R FOR SAMPLE S1, S2, S3, S4, S5, S6, S7, S8 AND S9

4.0 Conclusion

The sieve analysis shows that all samples tested are well graded with samples S1,S2,S3,S4,S5,S6,S7,S9,S10,S11 and S12 having fines less than 35% passing 200BS sieve, while S8 has more than 35%. Using AASHTO soil classification system, sample S8 is classified as A-7(poor), S9 and S12 as A-2-7 (good) while the rest falls under A-2-6 (good). Almost all the samples are classified as sandy clay based on USCS. The specific gravity test on all the samples shows a satisfactory result with average of 2.59 Mg/m^3 which fall within the FMWH specification range. All samples tested have low to medium plasticity which is one good quality of laterites suitable for road construction. Only 25% of the total samples comprising S1, S6 and S8 are considered not suitable as base- course materials based on California Bearing Ratio test although they can be improved using stabilizers. However, all samples tested are suitable for both sub-grade and sub-base. Based on both AASHTO and FMWH specification, only sample S4 is suitable for use as base-course. It is therefore recommended that adequate testing of materials for suitability as construction material be carried out before and during construction to avoid structural failures. It also recommended that geochemical analysis be carried out on these samples to determine their Silica/Sesquioxide ratio to enhance further classification.

5.0 Acknowledgements

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6.0 Competing Interest

Authors have declared that no competing interest exists.

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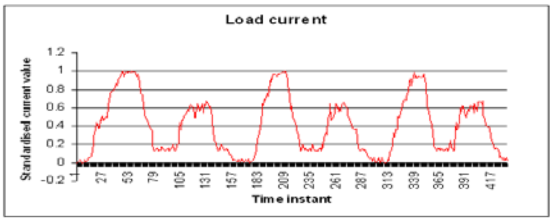

Figure 1: Testing data- load current (amperes)

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Table 1: Margin specifications

Margin	*A4 Paper*	*US Letter Paper*
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4. forth level: (a) Heading 4
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Number equations consecutively with equation numbers in parentheses flush with the right margin, as in (1). First use the equation editor to create the equation. Then select the "Equation" markup style. Press the tab key and write the equation number in parentheses.

$$E = \sum_{p=1}^{P} \sum_{k=1}^{K} (\delta_{pk}^{o})^2 \qquad (1)$$

5. Other recommendations

Equalize the length of your columns on the last page. If you are using *Word*, proceed as follows:
Insert/Break/Continuous.

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Author Profile

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