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[1.]Paul YOHANNA, [2.]Charles Malachy Okechukwu NWAIWU

# COMPARATIVE RELIABILITY ESTIMATES OF COMPACTION CHARACTERISTICS OF SAMPLE RE-USE (SR) AND FRESH SAMPLE (FS) COMPACTION OF LATERITIC SOIL AS ROAD PAVEMENT MATERIAL

[1.]Department of Civil Engineering, University of Jos, Plateau State, NIGERIA
[2.]Department of Civil Engineering, Nnamdi Azikiwe Universtity Awka, Anambra State, NIGERIA

**Abstract:** A first-order reliability program (FORM) incorporated in FORTRAN program was employed to investigate the influence of sample re-use (SR) and fresh sample (FS) compaction of lateritic soil as pavement material compacted at the energy level of British Standard Light (BSL), and centred on regression equations established from laboratory results. The numerical properties of re-use (SR) and fresh sample (FS) compaction properties of lateritic soil were related with those from which the regression equations were formed. By means of regression equations for re-use and fresh sample compaction characteristics, for the related soil properties, reliability index (RI) were computed bearing in mind re-use and fresh sample compaction characteristics (Maximum Dry Density, MDD and Optimum Moisture Content, OMC) as dependent variables and the soil properties (gravel content, clay content, silt content, sand content and specific gravity) as independent variables. The results indicated that in the laboratory developed model, RI is dependent on variations in all the soil parameters. Generally, Observed trend showed that lower RI values for MDD sample re-use was recorded over the MDD fresh sample compaction. In the case of OMCs, higher RI values were observed for sample re-use compaction over fresh sample compaction. Although lower RI values for MDD sample re-use was recorded over MDD fresh sample compaction. However, OMCs of re-use sample compaction with higher RI must be strictly controlled in compacted lateritic soil as road pavement sub-base material. Stochastically, BSL compactive efforts did not produced tolerable safety index of 1.0 as recommended by the Nordic Committee on Building Regulation. Therefore higher energy level compacted using sample re-use compaction method is commended to model compaction properties of lateritic soil use as material for road sub-base of flexible pavement at Coefficient of Variation(COV) of 10-100 % range.

**Keywords:** compaction characteristics, fresh sample, lateritic soil, reliability/safety index, sample re-use, sub- base

## 1. INTRODUCTION

Lateritic soils are reddish tropically pedogenic surface deposits occurring in Australia, Asia, Africa and South America. The soils are essentially the outcome of tropical or sub-tropical weathering (Gidigasu, 1976). It has been reported by Sherman (1952) and Maignien (1966) that the two groups of this tropical soil were chemically identified by those in which iron oxide predominant (ferruginous laterite) and those in which alumina predominant (aluminous laterite). In tropical nations like Nigeria, Lateritic gravels as well as pisoliths exist which are noble for use as gravel roads as proposed by Osinubi and Bajeh (1994) and used extensively as pavement material for cheaper roads which carry small to intermediate traffic. Laterites are classified as problem soils and non-problem soils. The problematic one is characterized by swelling, depressions and lateral movement in the presence of underground water even when subjected to adequate wheel loads (Obeahon, 1993). When the soil is problematic in nature it requires some chemicals such as cement and lime to develop its essential geotechnical properties.

A reliability approximation of engineering structure is explained as the assurance on its capacity to accomplish its design aim for particular time duration (Dey and Kudmetha, 2013). Reliability approximations are founded on the probability concepts which gives the base for its measurement. The consistency of a system can be observed as the probability of its acceptable performance, agreeing to some routine functions, for a particular provision and exposed to extreme circumstances within a definite time interval (Dey and Kudmetha, 2013). Harrop-Willians, 1985; Benson and Daniel, 1994a, 1994b; Gui et al., 2000; Eberemu, 2008; Nwaiwu et al, 2009) reported that Reliability-based design has been in recycle to lessen the indecisions in geotechnical engineering when designing and in the construction process in terms of changes in soil nature and rock properties and other in situ situations.

Past researches (Nwaiwu et al, 2009; Sani et al, 2014, 2018; Yisa and Sani, 2014; Yohanna et al, 2015) used mathematical tools such as Probability theory to determine uncertainties in designs for engineering use and to measure their consequences on performance. These methods had been applied to solve structural strength problems and geotechnical engineering problems such as reliability estimate of strength and compaction properties. Such examination designates the performance and consistency of a geotechnical problems, and can be applied for risk-based choice making. To start a reliability examination, arbitrary fields of soil characteristics are normally generated to develop the requisite statistical parameters, e.g. mean and standard deviation. A technique of reliability study is then carefully chosen for calculating failure probability and reliability index (RI) (Dey and Kudmetha, 2013).

Even though many researches were carried out on the effect of sample re-use and fresh sample compaction of laterite soils(Gidigasu, 1970; Nelson and Sowers 1949; Yohanna et al., 2015), few literatures exist on the Reliability approximations of its compaction characteristics ( Etim et al., 2018; Oluremi et al., 2019).The aim of this research was to carry out a comparative reliability estimates on compaction characteristics of sample re-use (SR) and fresh sample (FS) compaction of lateritic soil. The objective was to determine the variability in reliability/safety index values base on laboratory-based model with respect to all the soil parameters.

## 2. THEORITICAL BACKGROUND

### — Safety Factor

The safety factor of an engineering system is defined as a measure of the ultimate strength of a member or system to the working stress or the maximum permissible stress when put into use. Higher safety factor increases the safety of a system and reduces the risk of failure. The basic method for evaluating the safety factor of an engineering system was founded on its allowable safety factor created on a precise observation of responses from related systems. A technique for measuring the safety factor employ by engineers is well-defined as the proportion of the assumed nominal values of size x and response y (Kotegoda and Rosso, 1997, Duncan, 2000), defined by the expression.

$$Z = \frac{x}{y} \tag{1}$$

The factors x and y cannot be evaluated with confidence, the variable (x) and the corresponding response (y) functions is measured as likelihood distribution. Hence, the safety factor represented by z = x/y for the arbitrary variables X and Y is also an arbitrary variable.

Z=X/Y is explained as the ratio of size X and demand Y for the system. Kottegoda and Rosso, (1997) explained probability Pr of a failure system as

$$P_r = P_r[\, Z < 1] - F_2\ (1) \tag{2}$$

And the corresponding probability of non-failure defined as

$$R = 1 - \ P_r[Z < 1] = 1 - F_2(1) \tag{3}$$

Once the combined probability for X and Y is obtained, the reliability index of the entire arrangement can be appraised by calculating the cdf of X/Y. Here a zero likelihood of failure (pr = 0) and a consistency of 100 percent (r =1) can be attained when the highest demand Ymax does not surpass the least capacity Xmin, Thus the two disseminations do not intersect (Oriola et al, 2012).

### — Reliability Index (RI)

Reliability index is defined as the measure of consistency of an engineering system. Higher values of reliability index indicates similarity in the results variables. This connote that the higher the reliability index, the more reliable, reproducible and consistent are the test results from one testing period to another. The Mathematical definition of Reliability index (RI) is

$$ß = \frac{\mu}{d} \tag{4}$$

Also defined as measure of competence of an engineering project explained as the sum of sigma units (sum of standard deviation dx) and the mean value of the safety margin.

$$E(s) = \mu \tag{5}$$

The corresponding critical value defined as.

$$S = 0 \tag{6}$$

The RI of a structure, expressed by ß is explained as the relationship between mean and the related standard deviation of the safety margin of the structure (Yisa and Sani, 2014).

### — First – Order Reliability Method (FORM)

The probabilistic and deterministic design varies in methods and applications. It is founded on complete discounting of the possibility of failure. Design complications comprise element of doubt; irregularity and uncertainty. Probabilistic design is worried with regard to the likelihood that the structure will recognize the functions apportioned to it (Afolayan and Abubakar, 2003).

Supposing r and t(s) are strength dimensions and the loading consequence(s) of a structure are random variables, the aim of reliability analysis is to guarantee that r is certainly not surpassed by s (Oriola et al, 2012). Therefore, r and s are generally functions of dissimilar variables. Therefore, in other to regulate the influence of the stated variables on the potentials of the system, a limit state equation in terms of the simple design parameters are required (Afolayan and Abubakar, 2003) defined as:

$$g(t) = g(x_1, x_2 \dots \dots .. x_n) = r - s \tag{7}$$

where $x_1$ for I = 1.2….n, signify the elementary design variables.
The system limit state function can also be defined as

$$G(t) = 0 \tag{8}$$

Reliability provides an avenue for estimating the joint impacts of likelihood and a technique of differentiating between conditions where worries are mainly great or little (Duncan, 2000).

## 3. MATERIALS AND METHODS

### — Statistical Procedure of Analysis

Results were achieved via laboratory experiments. The statistical features and the input data for developing the prediction models of the materials and compaction variables are revealed in Table 1 and 2 (a and b) respectively.

Table 1: Design factors use for the analysis

| S/No | Variables | Distribution type | Mean E(x) | Standard deviation S(x) | Coefficient of Variation COV (%) |
|---|---|---|---|---|---|
| 1 | Maximum dry density sample re-use($MDD_{SR}$) | Lognormal | 18.84 | 0.628 | 3.33 |
| 2 | Maximum dry density Fresh sample($MDD_{FS}$) | Lognormal | 18.19 | 0.45 | 2.47 |
| 3 | Optimum moisture content ($OMC_{SR}$) | Lognormal | 12.51 | 1.25 | 9.99 |
| 4 | Optimum moisture content ($OMC_{FS}$) | Lognormal | 12.92 | 1.3 | 10.06 |
| 5 | Gravel content | Normal | 30.01 | 19.53 | 65.08 |
| 6 | Sand content | Normal | 22.94 | 4.13 | 18.00 |
| 7 | Silt content | Normal | 10.95 | 2.69 | 24.57 |
| 8 | Clay content | Normal | 31.10 | 4.28 | 13.76 |
| 9 | Specific gravity | Normal | 2.60 | 0.007 | 0.27 |

Table 2a: Input data for developing the prediction model (Maximum dry densities)

| $MDD_{FS}$ | $MDD_{SR}$ | Gravel | Sand | Silt | Clay | Gs |
|---|---|---|---|---|---|---|
| 17.65 | 18.2 | 7 | 28 | 9.45 | 34.6 | 2.46 |
| 18.21 | 18.52 | 7 | 25 | 16.95 | 34.6 | 2.6 |
| 18.65 | 19.48 | 26 | 24.5 | 11.95 | 24.6 | 2.6 |
| 18.55 | 19.42 | 70 | 16.5 | 9.45 | 22.1 | 2.63 |
| 18.65 | 19.15 | 56 | 18 | 11.95 | 32.1 | 2.65 |
| 18.1 | 19.5 | 30.1 | 22.9 | 11.95 | 32.1 | 2.66 |
| 18.1 | 19.18 | 23 | 24.5 | 9.45 | 32.1 | 2.58 |
| 17.6 | 17.59 | 25 | 22 | 11.95 | 34.6 | 2.68 |
| 18.72 | 18.84 | 29 | 29 | 6.95 | 32.1 | 2.63 |
| 17.65 | 18.55 | 27 | 19 | 9.45 | 32.1 | 2.53 |

Table 2b: Input data for developing the prediction model (Optimum moisture contents)

| $OMC_{FS}$ | $OMC_{SR}$ | Gravel | Sand | Silt | Clay | Gs |
|---|---|---|---|---|---|---|
| 13.4 | 13.5 | 7 | 28 | 9.45 | 34.6 | 2.46 |
| 13.4 | 13 | 7 | 25 | 16.95 | 34.6 | 2.6 |
| 13.75 | 13.2 | 26 | 24.5 | 11.95 | 24.6 | 2.6 |
| 13.3 | 10.9 | 70 | 16.5 | 9.45 | 22.1 | 2.63 |
| 10.5 | 12.2 | 56 | 18 | 11.95 | 32.1 | 2.65 |
| 12.3 | 13.55 | 30.1 | 22.9 | 11.95 | 32.1 | 2.66 |
| 13.7 | 10.55 | 23 | 24.5 | 9.45 | 32.1 | 2.58 |
| 12.5 | 14.4 | 25 | 22 | 11.95 | 34.6 | 2.68 |
| 11.3 | 12.25 | 29 | 29 | 6.95 | 32.1 | 2.63 |
| 15 | 11.5 | 27 | 19 | 9.45 | 32.1 | 2.53 |

### — Procedure for Numerical Analysis

The results used for this analysis were obtained from laboratory tests on compaction characteristics of sample re-use and fresh sample compaction and the parameters related with compaction characteristics were determined in the laboratory. Parameters determined comprised the followings; maximum dry density sample re-use compaction ($MDD_{SR}$ ), maximum dry density fresh sample compaction($MDD_{FS}$), Optimum moisture content sample re-use compaction($OMC_{SR}$), Optimum moisture content fresh sample compaction($OMC_{FS}$), Gravel content(Gr), sand content(Sa), silt content(Si), clay content(Cl) and Specific gravity(Gs). Fundamentally, maximum dry density sample re-use compaction ($MDD_{SR}$ ), maximum dry density fresh sample compaction($MDD_{FS}$), Optimum moisture content sample re-use compaction($OMC_{SR}$), Optimum moisture content fresh sample compaction($OMC_{FS}$) were assumed lognormal distribution (Eberemu, 2008; Nwaiwu et al., 2009; Sani et al, 2014; Yisa and Sani, 2014). Gravel content (Gr), sand content (Sa), silt content (Si), clay content (Cl) and specific gravity (Gs) were assigned a normal distribution. These results were used to run a regression model for predicting laboratory compaction characteristics for both sample re-use and fresh sample compaction. The statistical investigations were done using Mini-tab R15 software to obtain regression equations for maximum dry density sample re-use compaction ($MDD_{SR}$ ), maximum dry density fresh sample compaction($MDD_{FS}$),Optimum moisture content sample re-use compaction($OMC_{SR}$), Optimum moisture content fresh sample compaction($OMC_{FS}$), as shown in equation 9 to 12.

$$MDD_{SR} = 20.8 + 0.0216Gr + 0.075Sa + 0.061Si - 0.074Cl - 1.04Gs \quad (9)$$

$$MDD_{FS} = 15.1 + 0.034Gr + 0.133Sa + 0.0905Si - 0.0249Cl - 0.45Gs \quad (10)$$

$$OMC_{SR} = -7.6 - 0.0268Gr + 0.043Sa + 0.103Si + 0.023Cl + 6.9Gs \quad (11)$$

$$OMC_{FS} = 41.4 - 0.127Gr - 0.384Sa - 0.197Si - 0.257Cl - 2.21Gs \quad (12)$$

where $MDD_{SR}$ = Maximum dry density sample re-use compaction, $MDD_{FS}$ =Maximum dry density fresh sample compaction, $OMC_{SR}$ =Optimum moisture content sample re-use compaction, $OMC_{FS}$ = Optimum moisture content fresh sample compaction, Gr = Gravel content, Sa= Sand content, Si=Silt content, Cl= Clay content, Gs=specific gravity.

## 4. RESULTS AND DISCUSSION

### — Measured MDDs and projected MDDs for sample re-use (SR) and fresh sample (FS) compaction

Results from the conceptual model developed (see equation 9 and 10) shows a robust connection between the measures MDD values for sample re-use compaction found by laboratory test and the corresponding projected values from the model with correlation coefficient R=0.565 (see Figure1) and 0.4-4.4% Error (see Table 3) with second order polynomial association. In the case of fresh sample compaction, a correlation coefficient R=0.806(see Figure 2) and 0.24-1.69% Error was documented (see Table 3). Result shows the individual contribution of each of the self-regulating variables (gravel content, clay content, silt content, sand content, and specific gravity) which produced the vital facts used in coming up with the regression equation for calculating MDDs. The gravel content, sand and silt content have been proven to be further active in the projection of MDDs of the soil studied designated by their positive coefficients for both sample re-use and fresh sample compaction (see equations 9 and 10) with higher values for fresh sample compaction over re-use sample compaction test. Generally a correlation coefficient values (R) of 0.565 % for MDDs sample re-use compaction and 0.806% for MDDs fresh sample compaction was recorded. The lesser coefficient noted for sample re-use compaction could be due to continuous rise in gravel to gravel interaction, due to continuous compaction which affects the transfer of compaction energy down to the finer materials and the void spaces within the soil matrix (Garga & Madureira 1985, Omotosho, 2006).

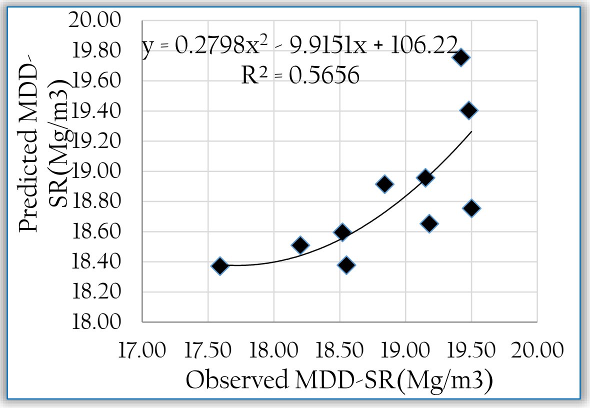

Figure 1: Plot of measured MDD values against projected MDD values for sample re-use (SR) compaction

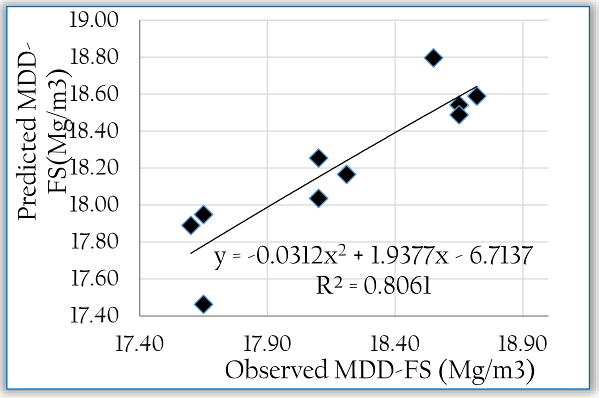

Figure 2: Plot of measured MDD values against projected MDD values for fresh sample (FS) compaction

Table 3: Measured MDD values and projected MDD values from the models for sample re-use (SR) and fresh sample (FS) compaction.

| Maximum dry density(MDD) for Sample reuse (SR) compaction | | | | | Maximum dry density(MDD) for Fresh Sample(FS)compaction | | | |
|---|---|---|---|---|---|---|---|---|
| Sample No | Observed MDD | Predicted MDD | Absolute Error | % Error | Observed MDD | Predicted MDD | Absolute Error | % Error |
| 1 | 18.20 | 18.51 | 0.31 | 1.70 | 17.65 | 17.95 | 0.30 | 1.69 |
| 2 | 18.52 | 18.60 | 0.08 | 0.41 | 18.21 | 18.17 | 0.04 | 0.24 |
| 3 | 19.48 | 19.40 | 0.08 | 0.39 | 18.65 | 18.54 | 0.11 | 0.58 |
| 4 | 19.42 | 19.76 | 0.34 | 1.73 | 18.55 | 18.80 | 0.25 | 1.33 |
| 5 | 19.15 | 18.96 | 0.19 | 1.01 | 18.65 | 18.49 | 0.16 | 0.87 |
| 6 | 19.50 | 18.75 | 0.75 | 3.82 | 18.1 | 18.25 | 0.15 | 0.85 |
| 7 | 19.18 | 18.65 | 0.53 | 2.75 | 18.1 | 18.04 | 0.06 | 0.36 |
| 8 | 17.59 | 18.37 | 0.78 | 4.44 | 17.6 | 17.89 | 0.29 | 1.65 |
| 9 | 18.84 | 18.91 | 0.07 | 0.40 | 18.72 | 18.59 | 0.13 | 0.70 |
| 10 | 18.55 | 18.38 | 0.17 | 0.93 | 17.65 | 17.46 | 0.19 | 1.06 |

More over the large residual error of maximum 4.4% (see Table 3) recorded for MDDs sample re-use could be responsible for the lack of fit of the variables to the MDDs sample re-use compaction. This connote that the model developed for MDDs sample re-use compaction did not fit the data set well when compared to MDDs fresh sample compaction which recorded lower residual error of 1.69% maximum (see Table 3). The engineering implication of the recorded results shows that better relationship exist between the MDDs fresh sample compaction and the independent variables considered and more adequately describe their functional relationship between the experimental factors(independent variables) and the MDDs fresh sample compaction. Thus modelling of MDDs for any engineering application such as embankment, dam or pavement purposes using this variables can best be done with fresh sample compaction method.

- **Comparison between measured OMCs and projected OMCs for sample re-use (SR) and fresh sample (FS) compaction**

Results from the conceptual model developed (see equation 11 and 12) shows a strong relationship between the measures OMCs values for sample re-use compaction obtained by laboratory test and the projected values from the model(R=0.428 )(see Figure 3) and 0.35-17.07% Error (see Table 4) with polynomial association. In the case of fresh sample, R=0.932(see Figure 4) and 0.01-3.96% Error was recorded (see Table 4). Result shows the individual role of each of the self-governing variables (gravel content, clay content, silt content, sand content and specific gravity). The sand content, silt content, clay content and specific gravity have been revealed to be active in the estimate of OMCs of the soil designated by their positive coefficients for sample re-use compaction only (see equation 11) with higher values for fresh sample compaction over re-use sample compaction test. Generally the correlation coefficient values (R) of 0.428 % for OMCs sample re-use compaction and 0.932% for OMCs fresh sample compaction shows that the soil parameters are more correlated to the OMCs fresh sample compaction than sample re-use compaction. The large residual error of maximum 17.07% (see Table 4) recorded for OMCs sample re-use could be responsible for the lack of fit of the variables to the OMCs sample re-use compaction. This suggest that the model developed for OMCs sample re-use compaction did not fit the data set well when compared to OMCs fresh sample compaction which recorded lower residual error of 3.96% maximum(see Table 4).

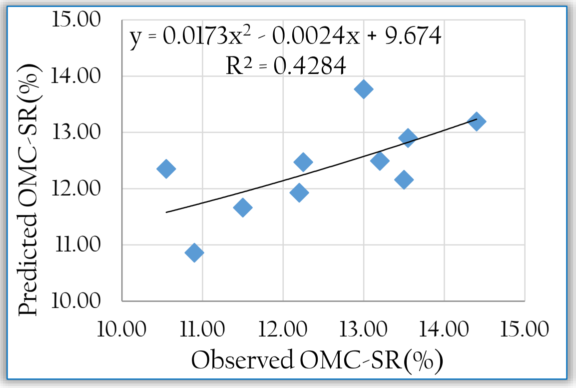

Figure 3: Plot of measured OMC values against projected OMC values for sample re-use (SR) compaction

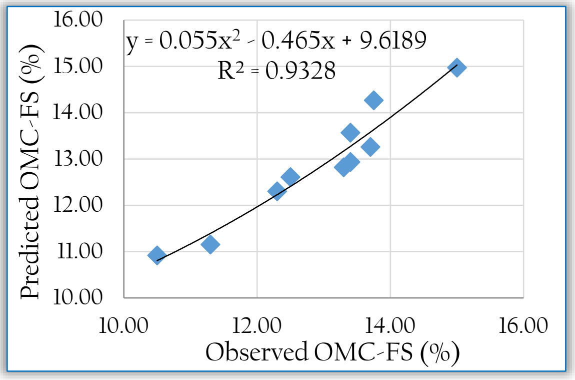

Figure 4: Plot of measured OMC values against projected OMC values for fresh sample (FS) compaction

Table 4: Measured OMC values and projected OMC values from the model for sample re-use (SR) and fresh sample (FS) compaction

| Optimum moisture content (OMC) for Sample reuse (SR) compaction | | | | | Optimum moisture content (OMC) for Fresh Sample(FS)compaction | | | |
|---|---|---|---|---|---|---|---|---|
| Sample No | Observed MDD | Predicted MDD | Absolute Error | % Error | Observed MDD | Predicted MDD | Absolute Error | % Error |
| 1 | 13.50 | 12.16 | 1.34 | 9.93 | 13.40 | 13.57 | 0.17 | 1.26 |
| 2 | 13.00 | 13.77 | 0.77 | 5.92 | 13.40 | 12.93 | 0.47 | 3.48 |
| 3 | 13.20 | 12.49 | 0.71 | 5.35 | 13.75 | 14.27 | 0.52 | 3.76 |
| 4 | 10.90 | 10.86 | 0.04 | 0.35 | 13.30 | 12.82 | 0.48 | 3.61 |
| 5 | 12.20 | 11.93 | 0.27 | 2.23 | 10.50 | 10.92 | 0.42 | 3.96 |
| 6 | 13.55 | 12.90 | 0.65 | 4.79 | 12.30 | 12.30 | 0.00 | 0.01 |
| 7 | 10.55 | 12.35 | 1.80 | 17.07 | 13.70 | 13.26 | 0.44 | 3.23 |
| 8 | 14.40 | 13.19 | 1.21 | 8.37 | 12.50 | 12.61 | 0.11 | 0.86 |
| 9 | 12.25 | 12.47 | 0.22 | 1.80 | 11.30 | 11.15 | 0.15 | 1.33 |
| 10 | 11.50 | 11.66 | 0.16 | 1.41 | 15.00 | 14.97 | 0.03 | 0.18 |

The engineering suggestion of the recorded results shows that better association exist between the OMCs fresh sample compaction and the independent variables considered and more satisfactorily define the functional relationship between the experimental factors (independent variables) and the OMCs fresh sample compaction. Thus modelling of OMCs for any engineering application such as embankment, dam or pavement purposes using this variables can best be done with fresh sample compaction method.

## — Comparative Reliability Estimate on Compaction Characteristics for sample re-use (SR) and fresh sample (FS) compaction.

### ≡ Impact of MDD and OMC on Reliability Index for sample re-use (SR) and fresh sample (FS) compaction.

The deviation of Reliability index (RI) for MDDs and OMCs sample re-use and fresh sample compaction with coefficient of variation is revealed in Figure 5. The RI for MDDs sample re-use and fresh sample compaction increased with rise in coefficient of variation. Though it was still negative in both case, higher RI values were noted for MDDs fresh sample compaction over re-use sample compaction. RI varied considerably for MDDs sample re-use compaction than fresh sample compaction, which is an indication that variability of MDDs sample re-use compaction has extreme impact on the RI for road pavement sub-base materials. The values ranged from -2.16 to -0.678 and -0.515 to -0.803 for MDDs sample re-use and fresh sample compaction respectively. The wider range of RI values for sample re-use over fresh sample compaction is an indication of the magnitude of effect of these variables on the MDD of the soil. Practical field compaction density can be achieved with wide range of methods or design variables due to wide range of RI values recorded in sample re-use method over fresh sample method of compaction.

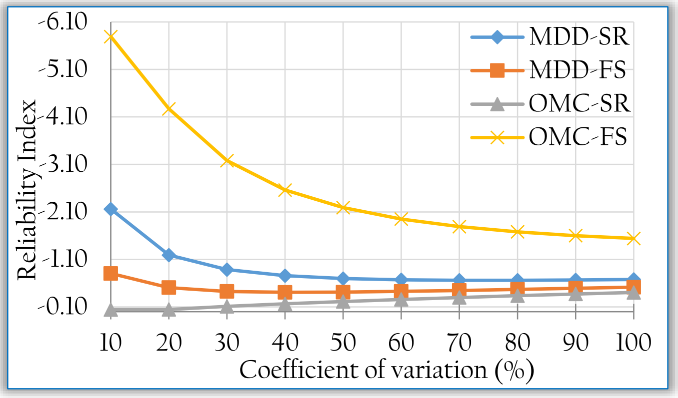

Figure 5: Reliability indices for sample re-use (SR) and fresh sample (FS) compaction of lateritic soil

In the case of OMC, significant difference in RI values was recorded for both sample re-use and fresh sample compaction. Higher safety index values were recorded for OMCs sample re-use compaction over fresh sample compaction and it is evident that OMCs sample re-use compaction have more significant effect on RI which is a sign that variability of OMCs sample re-use compaction has extreme impact on the RI for road pavement sub-base materials over fresh sample OMCs. The values ranged from -0.403 to -0.0437 and -5.79 to -1.54 for OMCs sample re-use and fresh sample compaction respectively. The engineering implication of the negative RI values is the lack of safety of the system. Positive safety index values connote a reliable safe system. However, the level of variation in the RI values within the range of coefficient of variation of 10-100% indicate the level of significance of the independent variable on the compaction properties (dependent variable).Results recorded with wider range of variation in RI values for sample re-use suggest a more reliable and more easily achieved compaction in the field. Moisture added to the soil during field compaction greatly influence the compaction density achieved in the field. Therefore, care should be taken to ensure that these variables are properly controlled in the field to arrive at desired compaction energy in the field for pavement, Dam or embankment applications.

### ≡ Impact of Gravel Content

The variations of gravel content on Reliability index (RI) with respect to sample re-use and fresh sample compaction is presented in Figure 6. The RI diverse considerably as the coefficient of variation increased from 10–100% for both sample re-use MDDs and fresh sample MDDs which signals that changes in gravel content has extreme impact on the RI for road pavement sub-base materials. Although negative safety index values were recorded in both cases, However higher RI values was observed for fresh sample compaction over sample re-use compaction. This implies gravel content has significant effect on MDDs sample re-use than fresh sample compaction. The values ranged from -5.53 to -4.42 and -2.07 to -1.25 for MDDs sample re-use and fresh sample compaction respectively.

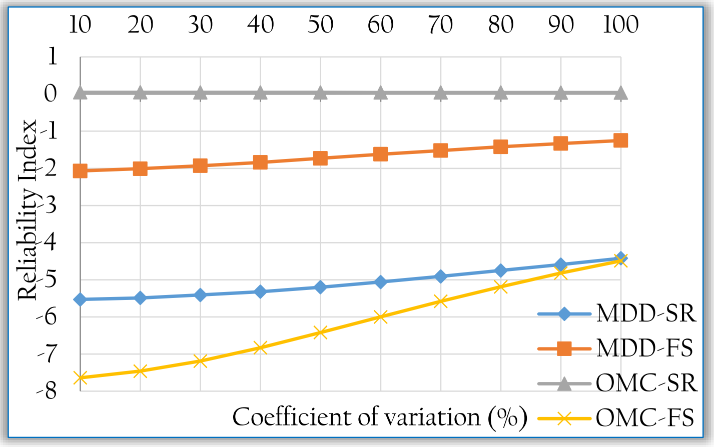

Figure 6: Reliability index for gravel content using sample re-use (SR) and fresh sample (FS) compaction of lateritic soil with coefficient of variation

In the case of OMCs, The RI values remained almost constant for sample re-use compaction and varied considerably for fresh sample compaction. The constancy in the RI values of sample re-use compaction is a suggestion that gravel content has no significant effect on the RI for road pavement sub-base materials. The values ranged from -0.0472 to -0.0407 and -7.64 to -4.49 for OMCs sample re-use and fresh sample compaction respectively.

### Impact of Sand Content

The effect of the dissimilarity in sand content on RI with respect to sample re-use and fresh sample compaction is presented in Figure 7. The RI varied considerably as the coefficient of variation increased from 10 – 100% for both sample re-use MDDs and fresh sample MDDs which is an signal that changes in sand content has extreme impact on the RI for road pavement sub-base materials .Although negative RI values were recorded in both cases, However higher RI values was observed for fresh sample compaction over sample re-use compaction. This implies that sand content has less significant effect on MDDs sample re-use than fresh sample compaction. This could be due to the packaging of the soil particles under the influence of higher energy application with sample re-use compaction .The values ranged from -5.18 to -2.4 and -1.76 to -0.5 for MDDs sample re-use and fresh sample compaction respectively.

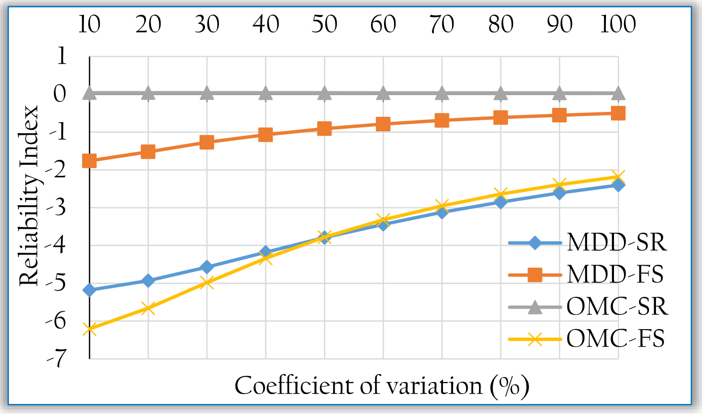

Figure 7: Reliability index for sand content using sample re-use (SR) and fresh sample (FS) compaction of lateritic soil with coefficient of variation

In the case of OMCs, The RI values remained almost constant for sample re-use compaction and varied considerably for fresh sample compaction. The constancy in the safety index values of sample re-use compaction is a suggestion that sand content has slight or no effect on the RI for road pavement sub-base materials compacted using sample re-use energy. The values ranged from 0.03675 to 0.044376 and -6.21 to -2.18 for OMCs sample re-use and fresh sample compaction respectively.

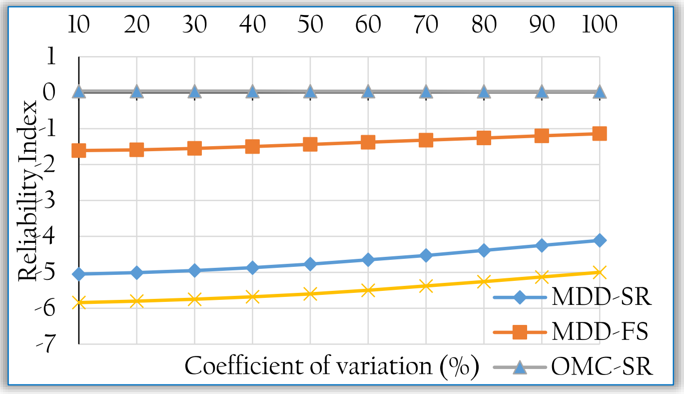

Figure 8: Reliability index for silt content using sample re-use (SR) and fresh sample (FS) compaction of lateritic soil with coefficient of variation

### Impact of Silt Content

The outcome of the variation of silt content on RI with respect to sample re-use and fresh sample MDDs is presented in Figure 8. The RI varied considerably for sample re-use compaction only and no major variation in the RI was observed for fresh sample compaction as the coefficient of variation rise from 10 – 100 % which is a suggestion that changeability of silt content has extreme impact on the RI for road pavement sub-base materials when sample re-use compaction technique is used. Negative RI values were noted in both cases. The values ranged from -5.05 to -4.11 and -1.61 to -1.14 for MDDs sample re-use and fresh sample compaction respectively.

In the case of OMCs, The RI values remained almost constant for both sample re-use compaction and fresh sample compaction. The constancy in the RI values is a suggestion that silt content has slight or no effect on the RI for road pavement sub-base materials. The values ranged from 0.0353 to 0.0448 and -5.84 to -5.0 for OMCs sample re-use and fresh sample compaction respectively.

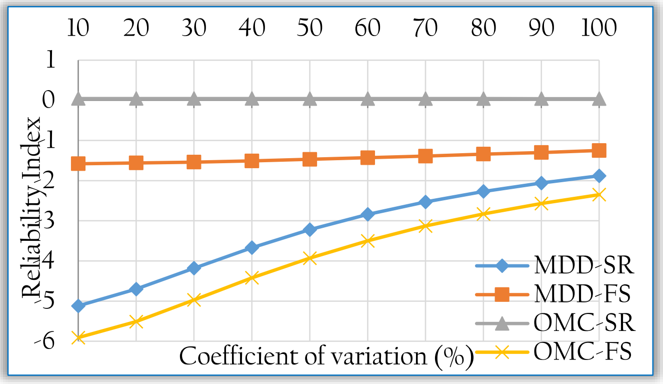

Figure 9: Reliability index for clay content using sample re-use (SR) and fresh sample (FS) compaction of lateritic soil with coefficient of variation

### Effect of Clay Content

The result of the variation in clay content on RI with respect to sample re-use and fresh sample MDDs is shown in Figure 9. The RI varied noticeably for sample re-use compaction only and no substantial difference in the RI was observed for fresh sample compaction as the coefficient of variation rise from 10 – 100 % which is a suggestion that inconsistency of clay content has severe impact on the RI for road pavement sub-base materials when sample re-use compaction technique was used. The values ranged from -5.12 to -1.88 and -1.58 to -1.25 for MDDs sample re-use and fresh sample compaction respectively.

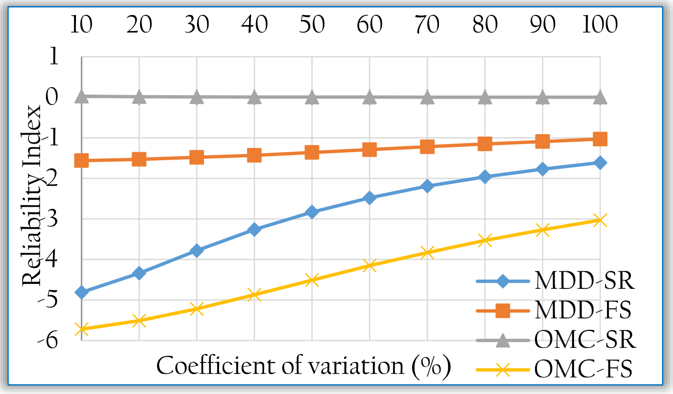

Figure 10: Variation of reliability index for specific gravity using sample re-use (SR) and fresh sample (FS) compaction of lateritic soil with coefficient of variation

In the case of OMCs, the RI values remained almost constant for sample re-use compaction and varied significantly for fresh sample compaction. The constancy in the RI values for sample re-use compaction is a suggestion that clay content has slight or no effect on the RI for road pavement sub-base materials when compacted using sample re-use techniques. The values ranged from 0.0397 to 0.0442 and -5.91 to -2.35 for OMCs sample re-use and fresh sample compaction respectively.

### Impact of Specific Gravity

The effect of the variation in specific gravity on RI with respect to sample re-use and fresh sample MDDs is shown in Figure 10. The RI varied considerably for sample re-use compaction only and no imperative difference in the RI was observed for fresh sample compaction as the coefficient of variation increased from 10 – 100%, which is a suggestion that changes in specific gravity has severe impact on the RI for road pavement sub-base materials, When sample re-use compaction technique was used. RI values ranged from -4.81 to -1.61 and -1.56 to -1.03 for MDDs sample re-use and fresh sample compaction respectively.

In the case of OMCs, The RI varied significantly for both sample re-use compaction and fresh sample compaction. The significant difference in the RI values is a suggestion that unevenness of specific gravity has severe impact on the RI for road pavement sub-base materials. The values ranged from 0.00357 to 0.0283 and -5.72 to -3.03 for OMCs sample re-use and fresh sample compaction respectively.

### Model Assessment for Compaction characteristics

RI achieved for compaction characteristics of the soil are revealed in Table 5 and 6. NKB Report (1978) stated a safety index value of 1.0 as the minimum value for serviceability limit state design of structural components. A comparison of NKB Report (1978) RI value of 1.0 and the recorded RI values are shown in Table 5 and 6. It clear that all the RI values fall below the recommended 1.0 required by NKB Report (1978).

Table 5: Stochastic model valuations of satisfactory safety index for sample re-use Compaction characteristics

| Variables factors | Beta Value | | Acceptable Range of COV (%) | |
|---|---|---|---|---|
| | MDD | OMC | MDD | OMC |
| BSL Compaction | -2.16 to -0.678 | -0.403 to -0.044 | NIL | NIL |
| Gravel Content | -5.53 to -4.42 | 0.0407 to 0.0472 | NIL | NIL |
| Sand Content | -5.18 to -2.4 | 0.0367 to 0.0443 | NIL | NIL |
| Silt Content | -5.05 to -4.11 | 0.0353 to 0.0448 | NIL | NIL |
| Clay Content | -5.12 to -1.88 | 0.0397 to 0.0442 | NIL | NIL |
| Specific Gravity | -4.81 to -1.61 | 0.0036 to 0.028 | NIL | NIL |

Table 6: Stochastic model valuation of satisfactory safety index for fresh sample Compaction characteristics

| Variables factors | Beta Value | | Acceptable Range of COV (%) | |
|---|---|---|---|---|
| | MDD | OMC | MDD | OMC |
| BSL Compaction | -0.80 to -0.52 | -5.79 to -1.54 | NIL | NIL |
| Gravel Content | -2.07 to -1.25 | -7.64 to -4.49 | NIL | NIL |
| Clay Content | -1.76 to -0.5 | -6.21 to -2.18 | NIL | NIL |
| Silt Content | -1.61 to -1.14 | -5.84 to -5.0 | NIL | NIL |
| Sand Content | -1.58 to -1.25 | -5.91 to -2.35 | NIL | NIL |
| Specific Gravity | -1.56 to -1.03 | -5.72 to -3.03 | NIL | NIL |

## 5. CONCLUSION

A FORTRAN program was employed to explore the influence of sample re-use (SR) and fresh sample (FS) compaction of lateritic soil as pavement material. Results obtained revealed that reliability index (RI) is subject to alterations in all the soil parameters. Observed trend showed that lower RI values for MDD sample re-use was recorded over the MDD fresh sample compaction. In the case of OMCs, higher RI values were observed for sample re-use compaction over fresh sample compaction. Although lower RI values for MDD sample re-use was recorded over MDD fresh sample compaction. However, OMCs of re-use sample compaction with higher safety index must be strictly controlled in compacted lateritic soil for use as pavement sub-base material. This implies that sample re-use as a method of soil compaction has more significant effect on the compaction characteristics of the lateritic for road pavement sub-base materials (MDDs and OMCs) than fresh sampling method of soil compaction. Stochastically, BSL compactive efforts did not record an acceptable RI value of 1.0 as endorsed by the Nordic Committee on Building Regulation. Thus, higher energy level compacted using sample re-use compaction method is recommended to model compaction characteristics of lateritic soil use as sub-base material in road pavement at the flexible choices of coefficient of variation of 10-100%. Finally, caution must be reserved in safeguarding the compactive efforts and adequate moisture content required to yield effective reliability index are imprudently supervised during field construction.

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