International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 12 ǁ December 2022 ǁ PP. 268-275

Re-Appraisal of the Excavation Method of a Typical Okobo Coal Mine At Ankpa, Kogi State, Nigeria

[1] Anikoh, Godwin A., Jethro[1], Michael A. [1] Onsachi Joseph M.
[1]*Kogi State Polytechnic, Lokoja, Nigeria*
Department of Mineral and Petroleum Resources Engineering, School of Engineering, Itakpe Campus.

Abstract
The research work is on re-appraised of the excavation method of Zuma 828 coal limited located within Okobo and Enjema in Enjema District of Ankpa Local Government Area in the south eastern part of Kogi State, Nigeria. The research was conducted using the field data and rock samples collected from Okobo coal field. Scanline method was used to determine the discontinuity parameter such as the discontinuity spacing index (I_f). In-situ and laboratory test were conducted on the rock sample (coal).Schmidt hammer was used to carry out in-situ testing of the rock on the field and samples were collected for laboratory tests such as bulk density, moisture content, point load, uniaxial compressive strength(UCS), and tensile strength were determined. The discontinuity spacing index (I_f) was evaluated from the major joint sets identified and the determination of the volumetric joint count (J_v). The discontinuity spacing index (I_f) was determined to be between 0.105mm to 0.178mm and volumetric joint count (J_v) was determined to be between 19.09mm and 11.21mm. The bulk density and unit weight as determined ranged from 1.28 g/cm^3 to 1.55 g/cm^{3}and 12.56 kN/m^3 to 15.21 kN/m^3 while moisture content ranged from 8.30% to 13.36%. The result of the average uniaxial compressive strength, point load strength, and tensile strength were 16.44 MPa, 0.14 MPa, and 0.21 MPa respectively. The rock strength was also analysed using RocLab from rocscience with the evaluated intact uniaxial compressive strength, estimated geological strength index, material constant, disturbance factor of the rock and the intact modulus as input parameters. Excavation assessments revealed that "Easy Ripping" is a possible method of excavating at Okobo coal deposits. Therefore, the only feasible excavation method for Okobo coaldeposit is "Easy Ripping" (with the use of Ripper dozers).

***Keywords**: Okobo coal mine, Scanline, discontinuity, moisture content, tensile strength. .*

Date of Submission: 04-12-2022 Date of acceptance: 15-12-2022

I. INTRODUCTION

Viability of a mining project rests upon the appropriate selection of rock excavation system right from the planning stage. This choice must be based on the understanding of the characteristics of rock mass,required product characteristics (mainly, size and grade) and selection of suitable equipment (especially, the excavating machine)(Dey, 1999). A machine is the product of human ingenuity and can be modified to suit a specific requirement (Eskikaya and Tuncdemir, 2007).However, rock mass is a natural component in the earth's crust and is thus immutable. It is imperative, therefore, to understand the rock to be excavated prior to selection of the machine. Excavability is a measure of how easy it is to remove earth materials and is used to determine appropriate excavation methods. It is a function of the geotechnical properties of the material (strength or density), and mass characteristics, in particular mechanical discontinuities. The excavability of rock is of paramount importance in the reappraisal of an excavation method selected as the most suitable and cost-effective method, not only in a mine but also in the construction of tunnels, subways, high ways and dams. A number of different methods has been proposed to evaluate the excavability of rocks based on their geotechnical properties such as $I_{s(50),}$ discontinuity spacing, (Weaver, 1975).Scoble and Muftuoglu, 1984; it has been reported that the type of equipment and the method of working also affect the excavability of rocks. (Pettifer and Fookies, 1994) The stronger the material, the more difficult it is to penetrate, breaks and consequently removes. However, mechanical weaknesses, in particular discontinuities are exploited to aid excavation. So a very strong rock may be readily excavability if it has closely spaced discontinuities while a moderately strong rock with widely spaced discontinuities may require greater effort to excavate.

1.1 LOCATION OF THE STUDY AREA

The study area (Zuma 828 coal limited) covers an area approximately 13.6 sq. km and lies within Okobo and Enjema in Enjema District of Ankpa Local Government Area in the south eastern part of Kogi State, Nigeria, lying within the Lower Coal Measures of Mamu Formation which is comprised of alternating sandstones, shales, sandy shales and mudstones, with coal seams or carbonaceous shales at various horizons. It is bordered in the east by Benue State and in the South by Enugu State.Okobo mine is located in an area which consists of lowlands and hills and the two slope face which was mapped has the following co-ordinates:

Table 1 Co-ordinates of the slope face taken from Okobo coal field

SLOPE FACE	ELEVATIONS	CO-ORDINATES
Face 1	306m	latitude N07^{0} 30.510^{11} Longitude E007^{0} 42.655^{11}
Face 2	302m	latitude N07^{0} 30.518^{11} Longitude E007^{0} 42.655^{11}

The mine is linked with a major road from Ankpa main town; the minor road that leads to Enjema community is tarred. While the other road that leads to the coal mine in Okobo is untarred.

Figure 1. The Location Map of Kogi state showing the study Area
(Source: Kogi State survey 1998)

II. Materials and Methods

Materials

The study area is situated around Okobo and Enjema in Enjema District of Ankpa Local Government Area in the south eastern part of Kogi State, Nigeria (Fig 1) .It is located about 16km east of Ankpa town in Kogi State approximately 200km North of Enugu.

2.1 Methods

Sample Collection and Preparation

The work was carried out using the field data and coal sample collected from phase one and two of the study area. This was done using sledge hammer. The samples were labelled and put in a sample bag. Field data were also collected through a scanline survey which was used for the determination of the discontinuity parameters. In doing this, a 50m tape was stretched across the slope face at the convenient height corresponding to where the coal has many discontinuities. Any discontinuity that cut across the tape was mapped (i.e. their respective spacing and orientation was determined and recorded) A total number of 150 and 250 discontinuities were mapped for Okobo deposits respectively which are in accordance to ISRM (1981). The rock samples collected were taken to Federal University of Technology Akure, Ondo State and were used to determine their physical and mechanical properties.

2.2 Assessment of Rock Excavability

The excavability of rock depends on the geotechnical properties of the material, on the method of working, and on the type and size of excavation equipment used. The main excavation methods are blasting, ripping and digging. Each system considers a different set of geotechnical parameters. The graph suggested by (Franklin, and Broch, 1971)considered only two parameters: fracture (joint) spacing index, I_f, and point load strength index, $I_{s(50)}$. A successful classification system should be easy to use (quantifiable data, easy to determine, user friendly) and should also give information about currently available equipment (Tsiambaos and Saroglou, 2010). The oldest graphical indirect rippability assessment method is that of (Franklin, and Broch, 1971).I It considers two parameters: the fracture spacing, I_f, and strength values of intact rock. Franklin's method has been re-evaluated and modified by many researchers.(Shehu and Saliu, 2014).Hadjigeorgiou and Scoble (1990) also considered point load strength, weathering, discontinuity spacing and discontinuity orientation in their assessment of excavabilityThe excavability chart considers the types of excavation equipment and requires engineering geological parameters such as the discontinuity spacing index (I_f) and point load strength index ($I_{s(50)}$). These parameters are relatively easy to obtain through field and laboratory studies using equations (1) and (2).

$$I_f = n/J_v \quad (1)$$

Where n = Number of major joint sets identified, and J_v= Volumetric Joint Count.

$$I_{s(50)} = P/D_e^2 \quad (2)$$

Where P is the failure load and $D_e$is the equivalent diameter.

2.3Determination of Density/Unit Weight

The equipments used to determine the density of the coal sample were; Measuring cylinder, Oven to dry the core samples at 105^0C, desiccators, Calliper (with accuracy of 0.1mm), digital Balance with accuracy of 0.01 g, Sample container (not-corrodible) with airtight lid, sledge hammer.The objective of the test is to measure the density and estimate the unit weight of the rock samples. Buoyancy technique for irregular rock samples was adopted and the procedures follow the standard suggested by ISRM (1981) and conform to ASTM (1994).

The measuring cylinder of 500 ml capacity was filled with water and recorded as V_1 (cm^3) and the weight of the prepared samples obtained from the study area was measured using electric meter and recorded. The samples were inserted in the water in the cylinder and the increase in volume were recorded as V_2 (cm^3). The change in volume was calculated as ($V_2 – V_1$) cm^3. .

The density was determined using Equation (3).

$$\rho_b = \frac{M}{\Delta V} \quad (3)$$

Where ρ_b is the density of water in g/cm^3, M is the mass in g and ΔV is the change in volume in cm^3.

The unit weight was estimated from the determined density by using Equation

$$\gamma = \rho x g \quad (4)$$

Where γ is the unit weight in kN/m^3, ρ is the bulk density g/cm^3 and g is the acceleration due to gravity in m/s^2.

2.4 Determination of Moisture Content

The equipment and materials used are; Crucible, Spatula, Tongs, Balance (sensitive to 0.0001g), Desiccator, Prepared coal sample.

(a) Heat the empty crucible and cover in oven maintained at a temperature of 105 °C. After one hour, remove the crucible from the oven and cool in a desiccator for 15- 20 minutes.

(b) Using tongs, record the empty crucible weight.

(c) Using a spatula, transfer approximately 1g of the rock sample to the crucible and mass to the nearest 0.0001g and record mass as (W_1). Subtract the crucible from the mass (W_1) and record as mass (W_3).

(d) Secure the crucible in a desiccator and transfer into a pre-heated oven at 104-110 ^{o}C.

(e) Heat for one hour without the lid on the crucible.

(f) Place the cover on the crucible and transfer into the desiccator for 15 – 20 minutes to cool. Re-mass the crucible to the nearest 0.0001g and record the weight in grams as (W_2).
(g) Open the crucible and examine for complete combustion. If coal is still visible, return the step (d) and repeat.
The moisture content calculation was carried out by using equation (5) and table (5) shows the percentage of moisture in the analyzed samples ranging from 8.30% to 13.36% with the average moisture content estimated to be 11.68%.

$$\%\ \text{moisture, uncorrected} = \frac{W_1 - W_2}{W_3} \times 100 \quad (5)$$

Where W_1= mass of crucible and sample in gram.
W_2= mass of crucible.
W_3= mass of sample in gram.

2.5Uniaxial Compressive Strength (UCS)
The uniaxial compressive strength was determined by adopting the Mathematical model developed by Akram and Bakar in 2007 which relatedpoint load strength index and uniaxial compressive strength for un-cored rocksample was adopted. The model is as shown in Equation (6).

$$\sigma_c = 22.792 I_{s(50)} + 13.295 \quad (6)$$

2.6 Point Load Strength
The test is intended to determine point load strength of the rock samples.The irregular rock sample was prepared using sledge hammer; a sample width was measured with the aid veneer calliperand was placed between the platen point in a way to allow at least 0.5m diameter and the distance between the platens was measured and recorded.The lower platen was raised into firm contact with the specimen using the pump and the maximum load achieved was recorded. The pressures released valve was opened and manually forced the lower platen down to allow the next specimen to be tested.
The calculation was carried out by using uncorrected point load test method.

$$I_s = P/{D_e}^2 \quad (7)$$

Where P is the failure load and D_e is the equivalent diameter.

$${D_e}^2 = \frac{4A}{\pi} \quad (8)$$

$$A = DH \quad (9)$$

where D is the distance between load contact points in mm and H is the width of the specimen in mm.

$$F = \left(\frac{D_e}{50}\right)^{0.45} \quad (10)$$

F is the correction factor.

$$I_{S(50)} = F I_S \quad (11)$$

where $I_{S(50)}$ is the corrected point load strength index.

2.7Tensile Strength
Rocks are complex material and there is no single factor to relate uniaxial compressive with tensile strength like other strength parameters such as shear strength etc. ISRM (1989) relationship between the point load strength ($I_{s(50)}$) and tensile strength (T_o) as shown in Equation below was used in estimating the tensile strength.

$$T_o = 1.5 I_{s(50)} \quad (12)$$

The Equation above is adopted in this study to determine the tensile strength.

III. Results and Discussions

Results

Tables 1a and b are the results of the Schmidt hardness test values which were observed on the field.

Table 1a: Descending Values of Schmidt Rebound Hardness.

	S/N	Okobo Coal
Upper 50% Values Averaged	1	18
	2	18
	3	15
	4	15
	5	14
	6	14
	7	10
	8	10
	9	10
	10	10
Lower 50% values Discarded	11	10
	12	10
	13	10
	14	10
	15	10
	16	10
	17	10
	18	10
	19	10
	20	10

Table 1b:Upper 50% Values of Schmidt Rebound Hardness Averaged

S/N	Okobo
1	18
2	18
3	15
4	15
5	14
6	14
7	10
8	10
9	10
10	10
Average	**13.4**

Table 2: Determined Parameters for Excavatability Assessment

	N	J_v	I_f	Is (Mpa)	*GSI*
Okobo Face I	2	19.09	0.105	0.14	30
Okobo Face II	2	11.21	0.178	0.14	30

Table 3: Selected Excavation Methods

S/N	Methods	Selected Method
1	Excavatability Chart	Easy Ripping
2	Tsiambaos and Saroglou Chart	Ripper

Table 4: Bulk Density/Unit Weight Samples

S/N	V_1 (cm^3)	V_2(cm^3)	ΔV (cm^3)	Mass (g)	ρ(g/cm^3)	γ (kN/m^3)
1	400	418	18	23.95	1.33	13.05
2	400	415	15	19.21	1.28	12.56
3	400	416	16	24.80	1.55	15.21
4	400	412	12	17.25	1.44	14.13
5	400	419	19	27.39	1.44	14.13

Table 5: Moisture content of rock Samples

S/N	W_1 (g)	W_2(g)	ΔW (g)	M (%)
1	22.66	19.99	2.67	13.36
2	43.87	39.61	4.26	10.80
3	29.27	25.99	3.28	12.62
4	22.66	19.99	2.67	13.36
5	48.53	44.81	3.72	8.30
Average				**11.69**

Table 6: Point Load Strength Index of rock Samples

H(mm)	D(mm)	P(kN)	A(mm^2)	De^2(mm^2)	Is(MPa)	F	$I_{s(50)}$(MPa)
58	20	0.22	1160	1476.96	0.15	0.89	0.13
60	38	0.35	2280	2902.99	0.12	1.03	0.12
50	37	0.34	1850	2355.49	0.14	0.99	0.14
63	35	0.30	2205	2807.49	0.11	1.03	0.11
40	40	0.41	1600	2037.18	0.20	0.95	0.19
Average							**0.14**

Table 7: Tensile Strength of rock Samples

S/N	$I_{s(50)}$(MPa)	UCS (MPa)	To(MPa)
1	0.13	16.26	0.20
2	0.12	16.03	0.18
3	0.14	16.49	0.21
4	0.11	15.80	0.17
5	0.19	17.63	0.29
Average	**0.14**	**16.44**	**0.21**

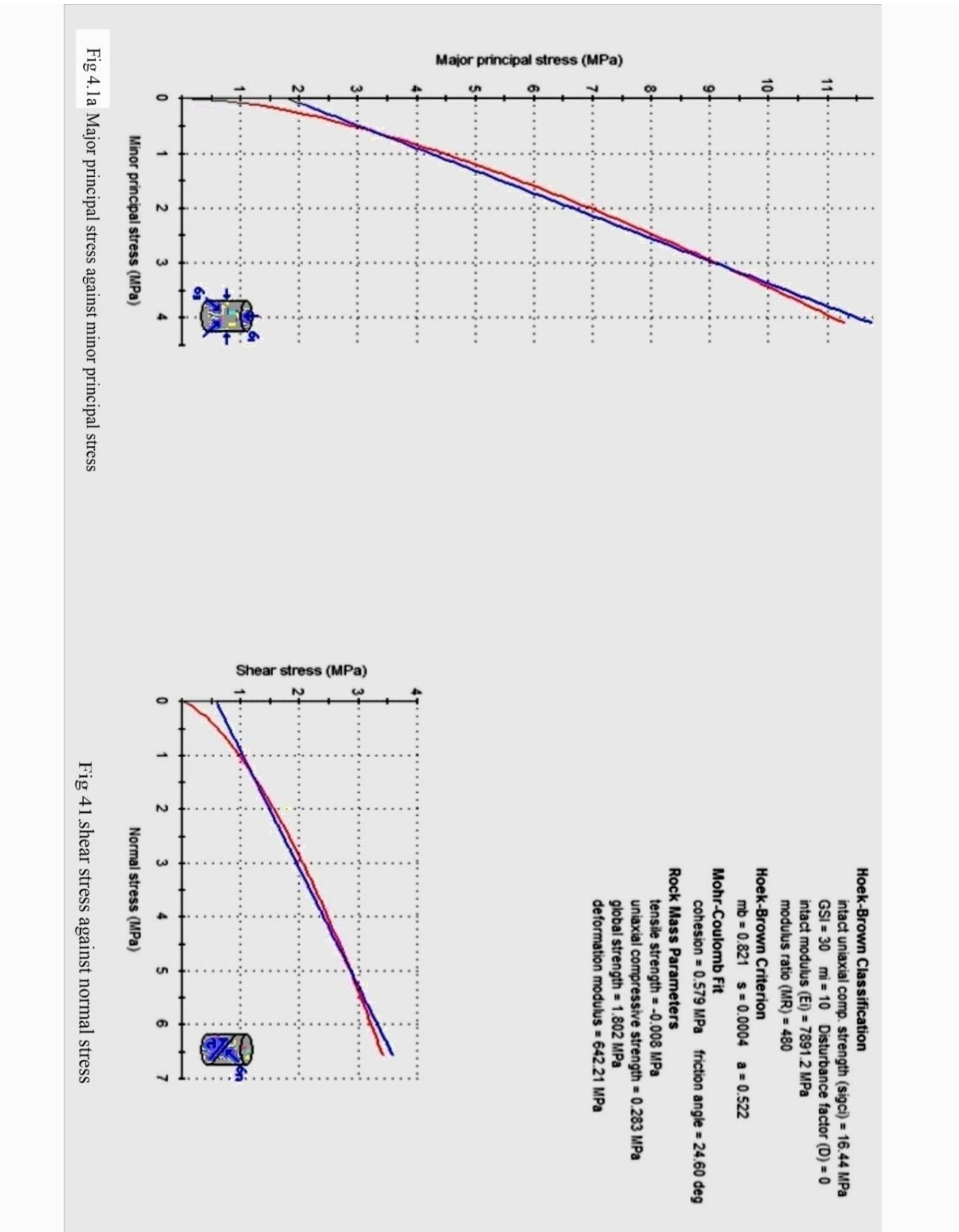

Figure4. 1a and b: Analysis of Okobo Coal Strength using RocLab

IV. Discussion

Table 1a and b shows the result that was obtained using Schmidt Impact Hammer of type L for the hardness determination, the rebound value of the Schmidt Hammer is used as an index value for the intact strength of rock material, and the standard method for the Schmidt Hammer test as described by ISRM (1981) and ASTM (1994) was followed. The measured test values were ordered in descending order. The lower 50% of the values were discarded and the average obtained of the upper 50% value to obtain the Schmidt Rebound Hardness (ISRM, 1981).

Table 2 shows the result of Mean discontinuity spacing which was measure separately for both face 1 and face 11 and the discontinuity spacing (I_f) which was calculated from Equation (S1) by ISRM (1981), and Table 3 Shows the Selected Excavation Methods for Okobo Coal Samples which was re-appraised putting into consideration the Geological Strength Index (*GSI*) and the determined point load index as proposed by Tsiambaos and Saroglou (2010) (Table2). The *GSI* was evaluated using RocLab application software, a software application which provide a simple implementation of Hoek-Brown failure criterion. Table 3 shows result of the bulk Density and Unit weight of Okobo coal with their values ranging from 1.28 g/cm^{3}to 1.44 g/cm^3 and 12.56 KN/m^3 to 15.21 KN/m^3, with average unit weight of 13.05km/m^3.

Table 4 shows the result of the moisture content. The values of the moisture content range from 8.30% to 13.36%. Table 5,6and 7 shows the result of point load, uniaxial compressive strength, and tensile strength. The values determined for the three parameters ranged from 0.11 Mpa to 0.19 Mpa, from 15.80 Mpa to 17.63 Mpa and from 0.17 Mpa to 0.29 Mpa respectively. The point load test result falls within the range of low strength according to the point load classification (Broch and Franklin, 1972), while the uniaxial compressive strength fall within the range of moderate strength according to the uniaxial compressive strength classification (Bell, 1992).

4.1Analysis of Okobo coal strength

Figure4.1a shows the Analysis of Okobo coal strength using Roclab with the evaluated intact uniaxial compressive strength determined to be 16.44Mpa , estimated geological strength index as 30, material constant as 10, disturbance factor of the rock as zero (0) and the intact modulus as 480 (input parameters).
Figure4.1b shows the plot of density of major principal stress, (Mpa) against the minor principal stress, (Mpa) while Figure 4.1b shows the plot of shear stress, (Mpa) against normal stress, (Mpa).

V. Conclusion

The study involved the assessment of rock excavability which was performed based on the work of Pettifer and Fookes (1994), it took into account the types of excavating equipment and geotechnical parameters, such as the discontinuity spacing index (I_f) and the point load strength index ($Is_{(50)}$), determined from the laboratory which are easily obtained through field and laboratory studies and these were used together with the excavability chart shown in Figure (1). The excavation assessments revealed that “Easy Ripping” is a possible method of excavating Okobo coal deposits. Therefore, the only feasible excavation method for Okobo coal deposit is “Easy Ripping” (with the use of Ripper dozers).

The work revealed that the Zuma 828 coal limited, (Okobo based coal mine) did a proper equipment selection for excavation of coal. The study also reveals that the result obtained from the analysis of the physical and mechanical properties of Okobo coal matches the equipment selection for its excavation.

References

[1]. **Akram, M. and Bakar, M. (2007):** "Correlation between Uniaxial Compressive Strength and Point Load Index for Salt-Range Rocks". Pakistanian Journal of Engineering and Applied Science, Vol.1.pp 179-184

[2]. **ASTM (1994)**: “Standard practice for determining Buoyancy correction during precision Weighing of low weight samples”, American Society for Testing and Materials,Vol. 04.08.978, p. 975

[3]. **Bell, F.G. (1992):** Engineering in rock masses, Butterworth – Heinemann,Jordan Hill, Oxford 580 p.

[4]. **Broch, E. And Franklin, J.A. (1972):** The point load test, Int. J. Rockmech.Min sci. (9) pp669-697.

[5]. **Dey K., (1999):** Performance Analysis of Continuous Surface Miner in Indian Surface Coal Mine – A case Study, Unpublished M. Tech Dissertation submitted to Indian School of Mines, Dhanbad, pp. 1 – 40.

[6]. **Eskikaya S. and Tuncdemir H. (2007):**A Handy Tool for Every Type of Tunnelling Road header, Journal of Mines, Metals & Fuels, Vol. 55, No. 12, December, pp. 524 – 538.

[7]. **Franklin, J.A., Broch, E. (1971):** Logging the Mechanical Character of rock. Transactions of the Institution of Mining and Metallurgy 80A, 1–9.

[8]. **Hadjigeorgiou, J., Scoble, M.J. (1999):** Ground characterization for assessment of ease of excavation. In: Singhal, R.K., Vavra, M. (Eds.), Proceedings of the 4th International Symposium on Mine Planning and Equipment Selection, Calgary, AB. Balkema, Rotterdam,pp. 323–331.

[9]. **ISRM, (1989):** *Rock Characterization, Testing on Monitoring.* In: Brown, E.T. (edition)

[10]. **Pettifer, G.S., Fookes, P.G., (1994):** A revision of the graphical method for assessing the excavatability of rock. Quarterly Journal of Engineering Geology 27, 145–164.

[11]. **Shehu S. A and Saliu M. A(2014)**: Assessment of Excavation Method of Obajana and Ewekoro Limestone Deposits. Earth Science.Vol. 3, No. 2,

[12]. **Tsiambaos, G. and Saroglou, H. (2010):**Excavability assessment of rock masses using the geological strength index (GSI): Bulletting of Engineering Geology and Environment, Vol.69, pp. 13–27.

[13]. **Weaver, J.M. (1975):** Geological factors significant in the assessment of rippability. Civil Engineer in South Africa 17, 313–316.