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Preliminary Field Measurement of the Uniaxial Compressive Strength of Migmatite Using N - type Schmidt Rebound Hammer.

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ABSTRACT
N-type Schmidt rebound hammer data were collected from a low lying Migmatite outcrop in Ilorin. The data were collected with the view to ascertaining the suitability of Schmidt rebound hammer for a quick, cheap and less cumbersome estimation of the Uniaxial Compressive Strength of Migmatite. This is important because of the ubiquitous and wide application of Migmamite in Nigeria, especially for construction purposes. The data collection was strictly carried out according to ASTM standard. Nine empirical models suggested by previous workers were used to analyse the data collected. Five of the used models having a range of 75.82MPa – 98.82MPa reasonably predict the Uniaxial Compressive Strength of Migmatite in comparison with published data.
The three other models with a range of 11.16MPA – 47.27MPa on the contrary, significantly underestimate the Uniaxial Compressive Strength of Migmatite. The results show a strength classification of Migmatite and also affirm the possibility of a quick, cheap and easy field determination of the uniaxial compressive strength of Migmatite.

KEY WORDS: *Migmatite, Uniaxial compressive strength, Rebound hammer, Empirical model*

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I. INTRODUCTION

Uniaxial Compressive Strength (UCS) of rocks is extensively employed in the design calculations of surface structures and underground openings by rock engineers. As a result of its pre-eminence in rock mechanics and engineering, both the American Society for Testing and Materials (ASTM) and the International Society for Rock Mechanics (ISRM) have standardized the procedure for measuring Uniaxial Compressive Strength (ASTM, 2005 and ISRM, 1981). However, due to the stringent sample preparation requirements of these original procedures and the high cost of test equipments, indirect strength indices have been devised. The strength indices include: point load index, Schmidt hammer rebound number (Rn), shore scleroscope hardness and cone penetration test amongst others. The indirect strength indices are increasingly being used because they require relatively simple test equipments and less cumbersome experimental procedures (Guney *et al*., 2005). More importantly, many of these indices could be obtained from both laboratory and field sources. The Schmidt rebound hammer test in particular, is desirable and sought after due to the portability, ease of use, rapidity of use, relative low cost of the hammer as well as the non-destructive procedure of application (Torabi *et al.*, 2010). The non-destructive nature makes it possible for the same set of samples to be subjected to other tests and measurements. The test was originally developed in 1948 for a quick assessment of the competence of concrete, but later adapted for the determination of the Uniaxial Compressive Strength of rock (Schmidt, 1951).

Table 1: Empirical relationships developed by previous workers.

Source	Equation	Coefficient of correlation (R)
Nasir (2013)	$UCS = 12.8e^{0.0487R(L)}$	0.91
Katz *et al*.(2000)	$UCS = 0.729 + 0.6R_{(N)}$ (γ in Kg/M^3)	0.96
Aggistalis(1996)	$UCS = 1.31R_{(L)} - 2.52$	0.55
UCS(MPa) Sachpazi(1990)	$UCS = (R_{(L)} - 15.7244)/0.2329$	0.91
Singh *et al*.(1985)	$UCS = 2R_{(L)}$	0.73
Harammy and Dermarco(1985)	$UCS = 0.994R_{(L)} - 0.383$	0.70
Shorey *et al*.(1984)	$UCS = 0.4R_{(L)} -3.6$	0.94
Deere and Miller(1966)	$UCS = 10(0.00014\gamma R_{(L)}+31.6)$ (γ in KN/M^3)	0.94
Miller(1965)	$Log_{10} JCS=0.00088\gamma R_{(L)} +1.01$ (γ in KN/M^3)	

$R_{(L)}$ is L-type rebound number, $R_{(N)}$ is N-type rebound number and γ is density.

A number of workers have suggested models and equations for the estimation of UCS from Schmidt hammer rebound number. However, Ferner *et al.* (2005) suggested that rock specific models may be more reliable.

The empirical relationships summarized in table 1 were chosen based on the variability of the lithologic units considered, since no prior research utilising the Schmidt hammer rebound number for UCS determination has been centred on the Nigerian Migmatite. This is intended to compensate for the inherent lithological and structural variations in Migmatite.

In spite of the several available models, much more is still needed to be done specifically on Nigerian rocks. This current study is intended to evaluate the possibility of estimating the Uniaxial Compressive Strength of Migmatite from Schmidt hammer rebound number. Migmatite is a rock that belongs to the unit of the Nigerian basement rocks called the Migmatite–Gneiss–Quartzite complex, which covers 30% 0f Nigeria's surface area (Rahaman, 1988). Considering the wide spread occurrence of this rock in different parts of the country, the need for a quick and reliable means of its evaluation cannot be over emphasized.

The Schmidt rebound hammer is extensively used for rock characterisation and quality evaluation of concrete. They are usually designed in different energy levels. However, L and N types are commonly employed. The L–type has impact energy of 0.74Nm which is one third of the N- type.

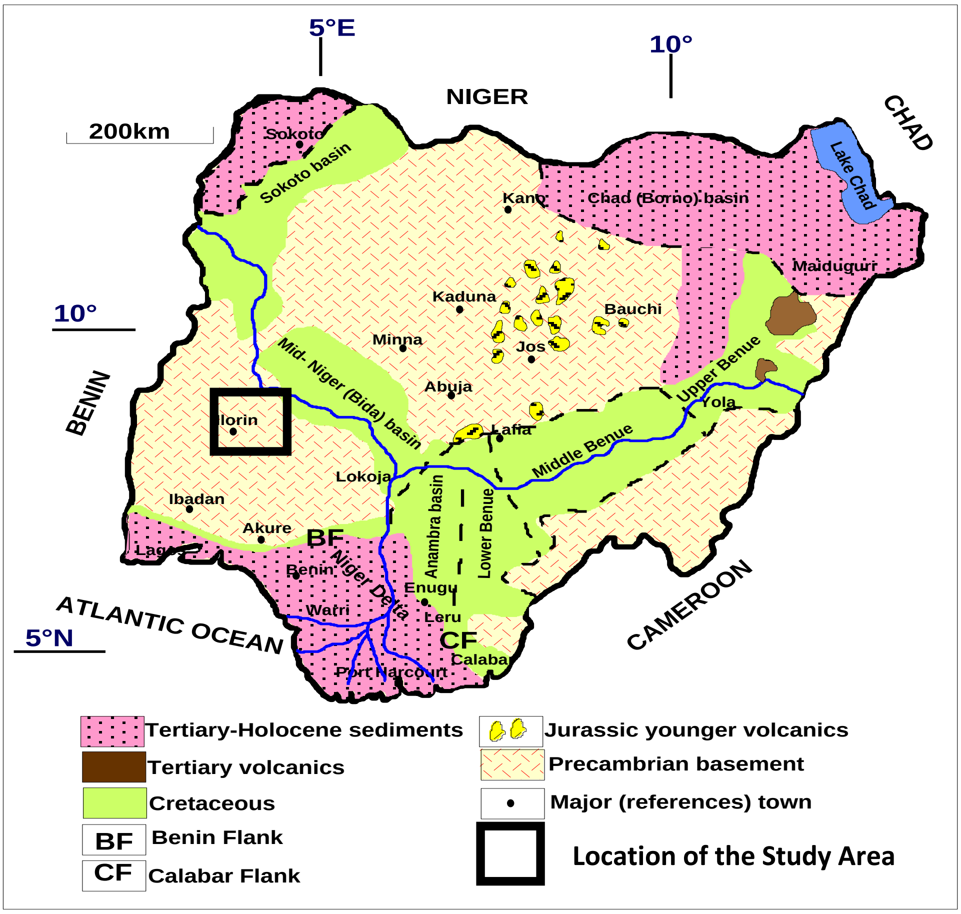

Figure 1: Geological map of Nigeria showing the location of study area (Modified after Obaje, 2009)

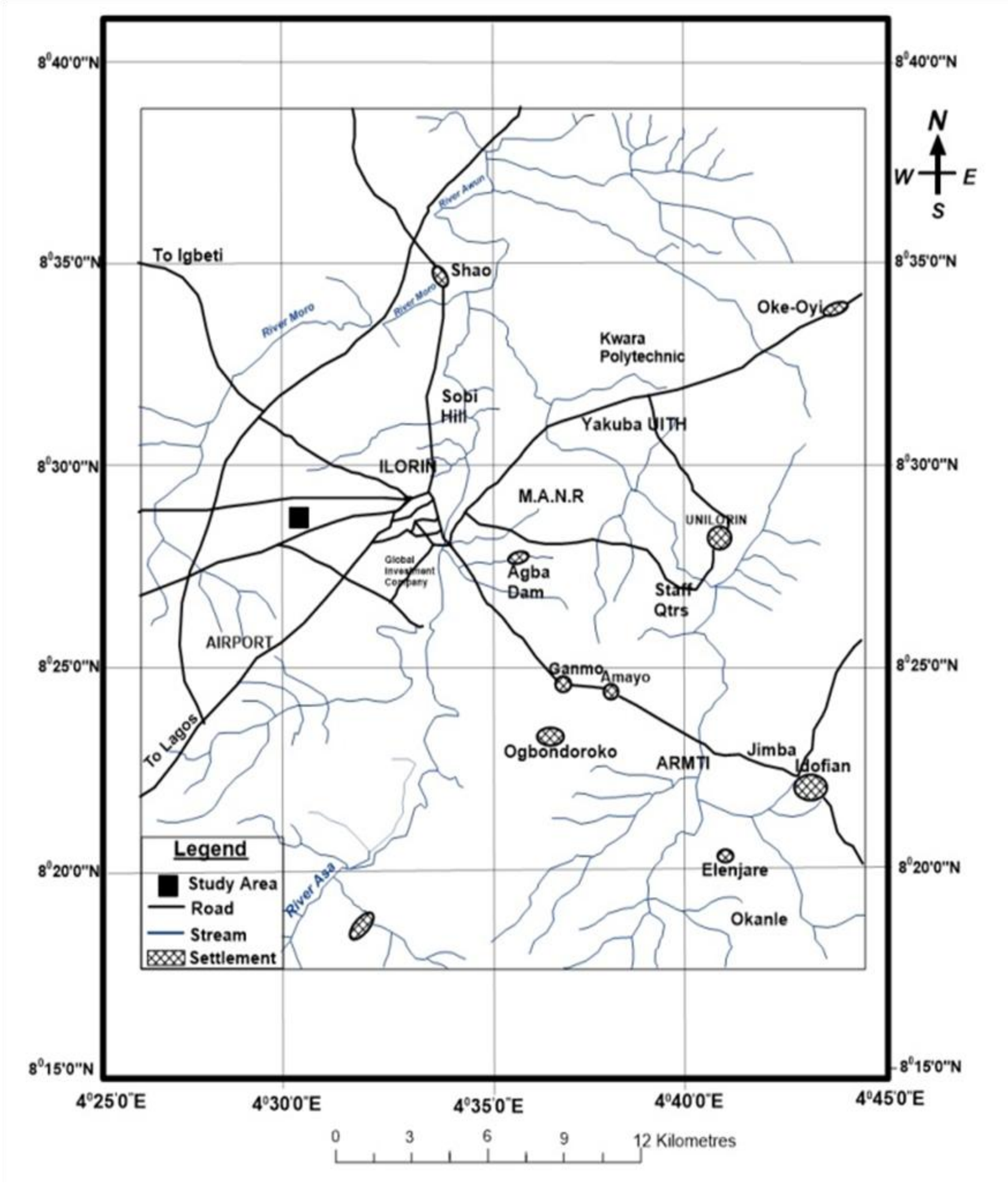

Figure 2: Map of Ilorin and environs showing the location of the study area (Modified after Olasehinde *et al.*, 1998)

Methodology

The focal point of this research is an E-W trending Migmatite outcrop demarcated by the following coordinates: N 08^{0} $28^{'}$ $58.8^{''}$, E 004^{0} 3' $36.3^{''}$; N 08^{0} $28^{'}$ $59.6^{''}$, E 004^{0} $31^{'}$ $36.4^{''}$; N 08^{0} $29^{'}$ $00.1^{''}$, E 004^{0} $31^{'}$ $33.9^{''}$; N 08^{0} $28^{'}$ $59.4^{''}$, E 004^{0} $31^{'}$ 33.5". The N-type rebound hammer was used to evaluate the hardness of the outcrop at 20 randomly selected points. At each of the sampled points, data was collected at an area of 20cm by 20cm according to ASTM (2005) specified procedure. Twenty measurements were made at each point, and any value that differs from the average by more than seven is discarded. Also, the density of the Migmatite was determined according to ISRM specification (ISRM, 1979c). The average density was obtained from ten randomly collected samples.

Plate 1: The rebound hammer used for the study.

Results and Discussion

This work is essentially based on data collected from the study location , which is an outcrop close to the Kwara State Polytechnic, Institute of Technology, Ilorin. The data were collected by the means of N-type rebound hammer. Considering the fact that most of the models employed in this study are based on L-type rebound data, the N- type rebound data collected were subsequently converted to L- type data. This was done using the correlation relationship proposed by Aday and Goktan (1992). It is on record that they have carried out a very comprehensive work on the comparison of N and L type hammers. Their equation is stated below:

$R_n(N) = 7.124 + 1.249R_n(L)$.

Where $R_n(N)$ is the N- type rebound number and $R_n(L)$ is the L-type rebound number.

Table 2: Conversion of N-type rebound hammer data to L-type data.

Test Location Number	N- Type Rebound Number($R_n(N)$)	L- Type Rebound Number($R_n(L)$
1	60.9	43.05
2	57.8	40.57
3	59.2	41.69
4	51.8	35.76
5	61.8	43.78
6	56	39.13
7	55.2	38.49
8	58.2	40.89
9	52	35.92
10	53.6	37.1
11	52.9	36.65
12	52.8	36.57
13	45	30.32
14	50.6	34.8
15	64.8	46.17
16	58.5	41.13
17	54.4	37.85
18	48.4	33.05
19	47.5	32.33
20	51.6	35.61

In order to calculate the UCS, the statistical average of the rebound hammer results for each of the twenty locations were used with empirical models developed by the workers earlier stated (Table 1).

The measured rebound hammer values display a wide range of properties. This may be as a result of the composite nature and well known compositional and structural variations of Migmatite (Van de Wall and Ajalu, 1997; Baskerville, 1987).The correlations between rebound hammer numbers and UCS were statistically assessed and compared with published data.

Table 3: Statistical summary of UCS estimates.

Estimate	Minimum value	Maximum value	Mean	Standard deviation
UCS (MPa) Nasir *et al*.(2013)	56.14	112.48	83.21	16.72
UCS (MPa) Miller(1965)	49.77	117.22	75.82	16.08
UCS(MPa) Deere and Miller(1966)	50.35	112.20	78.33	17.74
UCS(MPa) Katz *et al*.(2000)	45.01	169.01	90.63	31.37
UCS(MPa) Singh *et al*.(1985)	60.64	92.34	76.08	8.09
UCS(MPa) Shorey *et al*.(1984)	8.53	14.87	11.61	1.62
UCS(MPa) Harammy and Dermarco(1985)	29.75	45.51	37.43	4.02
UCS(MPa) Sachpazi(1990)	98.82	130.72	98.82	21.09
UCS(MPa) Aggistalis(1996)	37.20	57.96	47.27	5.21

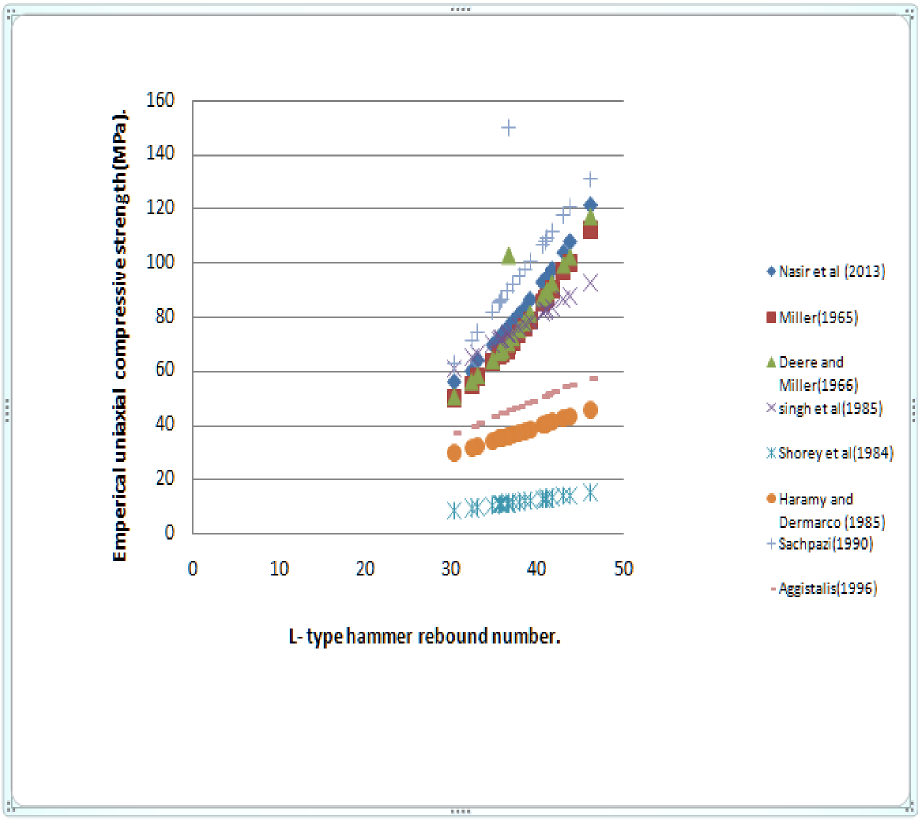

Figure 3: Relationship of empirical Uniaxial Compressive Strength to L-type rebound hammer number.

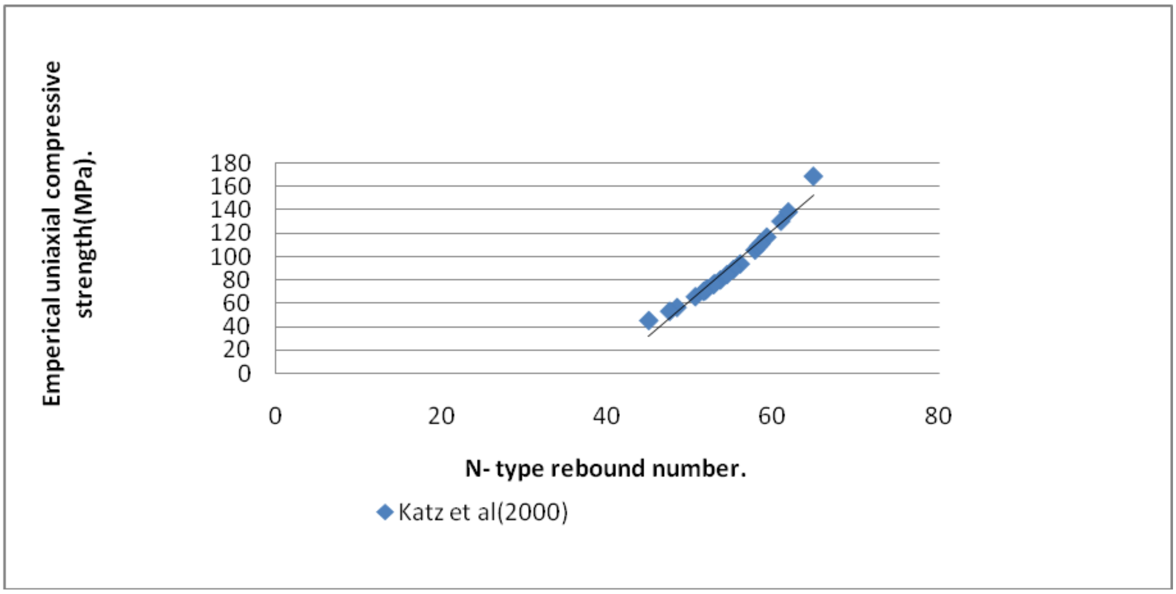

Figure 4: Relationship of empirical Uniaxial Compressive Strength to N- type rebound hammer number.

Figures 3 shows the relationship between L-type rebound hammer numbers and the UCS derived from the different suggested models. The UCS obtained by the empirical relationships of Nasir *et al.* (2013), Miller (1965), Deere and Miller (1966) Singh *et al.* (1985), Sacphazi (1960) and Katz *et al.* (2000) provide reasonable comparison with UCS data presented by Rao *et al*. (2011) and Siren *et al.* (2000). The experimental data of these authors essentially classify Migmatite to be of medium to high strength based on ISRM (1979) and Deere and Miller (1966) classifications. However, the models of Shorey *et al.* (1984), Haramay and Dermarco (1985) and Aggistalis (1996) significantly underestimate the UCS of Migmatite when compared with published data. They essentially classify the UCS of Migmatite to be of low strength to very low strength with respect to ISRM (1979) and Deere and Miller (1966) classifications respectively.

Figure 4 shows the relationship between the Uniaxial Compressive Strength and the N-type rebound hammer number as suggested by Katz *et al* (2000). It also shows a reasonable comparison with published data. It also classifies migmatite to be of medium to high strength.

CONCLUSION

The need to test rocks in order to determine their physical and mechanical properties cannot be overemphasised. However, expensive laboratory testing procedures and equipments may be required to do this for engineering projects. However, the Schmidt rebound hammer number (Rn) has been used by many researchers to measure the strength and other engineering properties of rocks. This usually enables a quick, easy and cheap means of measurement.

Migmatite, being a ubiquitous rock, is very important in Nigeria. Characteristically, it is defined by diverse mineralogy, metamorphic grade and geological structures. It is essentially a composite rock that is widely used and applied in Nigeria, especially for construction purposes.

This preliminary study was undertaken to estimate the Uniaxial Compressive Strength of Migmatite from field hammer rebound data. The statistical average of the collected field rebound hammer data were used with the empirical models suggested by previous workers for comparison with published data. The results show that the relationships of some of the researchers provide reasonable correlations of Uniaxial Compressive Strength and rebound hammer number. These initial results are encouraging and make the need for further studies pertinent. The development of Migmatite specific relationships, to more accurately predict the Uniaxial Compressive Strength and other engineering properties is desirable as a sequel to this work.

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