

Investigation of Physicochemical and Mechanical Property of UTAN Granites for Building Applications

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Abstract The granite formation for production of dimension stone blocks at Utan was investigated in three different locations A, B and C in a view to examine the physical properties of Utan granite using saturation and Buoyancy technique; evaluate some of its mechanical properties; determine its rate of emission of radioactive elements with Geiger Muller Counter; examine its polish-ability; and carry out chemical analysis of the granite samples with the aid of energy dispersive x-ray florescence (ED-XRF). The average porosity obtained is 0.53, 1.08; and 0.86 while the respective average density of 2.58, 2.62 and 2.60 g/cm³ were obtained for A, B and C. The compressive strength of 207.5, 204.6 and 203.4 MPa; and tensile strength of 13.86, 13.68 and 13.60 MPa were obtained for A, B and C respectively. Rockwell hardness values obtained are 89.0, 89.9 and 86.6 while the morh's hardness values are 6.90, 6.96 and 7.03 respectively for sample A; B and C. The impact values obtained are 0.089, 0.092 and 0.094 for A, B and C respectively. The radioactive rates of samples A, B and C are 6.42, 8.86 and 8.16 Mrem respectively. Sample B is observed to be more radioactive. Both samples are polish able. Conclusively, the three tested granite rocks have suitable physical and mechanical properties that meant the requirement for building purposes; from the polish-ability test, it shows that the three (3) granite outcrops are suitable for the production of granite tiles; countertops; slabs. The chemical analysis revealed that the granite is dominated by quartz (SiO₂) which contributes greatly to the hardness of the rock. Also from the radioactive test, the granite samples proved conclusively that the rate of radiation found occasionally in a slab of granite is not harmful to humans when exposed to it. Hence, granite the formation of Utan will be a good building stone material.

Keywords: granite, building, radioactive, impact, strength

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1. Introduction

Granite being an igneous rock formation is widely recognized all over the world as one of the most valuable mineral which can earn both local and foreign currency. European countries such as Italy, Spain, Germany, South America like Brazil and countries such as India and Singapore engaged in large scale exploitation and production of granite resources have been greatly benefited due to the high demand and use of granite. While African countries like Kenya, South Africa and Zimbabwe have also taken up large-scale production of granite blocks and recently, Nigeria has also started on a fairly smaller scale compared to the African countries

mentioned above. During the early centuries, the cost of producing granite blocks were regarded as luxury as only few wealthy countries could afford it, but nowadays granite is extensively use in almost all the countries in the world due to their beautiful end product. Apart from it being quarried, cut into sizes and polished as monuments, slabs and tiles, granite is commonly quarried and crushed into various sizes from dust size to half inch size which are used in making concretes in the construction industries [1].

Nigeria is blessed with vast mineral resources which can be harnessed for industrial and technological development to improve the quality of life of the people. The natural resources are widely distributed across the country among them are; solid minerals, petroleum and natural gas. Minerals are naturally occurring, usually solid substances which posses definite or well defined physical

and chemical features, shape, structure and chemical composition. They are and will always be the source of wealth for any nation endowed with them. The posterity of any nation is often directly related to the development and utilization of its resources. The minerals in Nigeria's landscape are distributed in all the geopolitical zones of the country and are found to be associated with the major rock types that constitute its geology. The rock types have produced numerous mineral raw materials such as gold, lead, zinc, tantalite, coal, bitumen, limestone kaolin, and others [2].

About fifty solid minerals have been discovered in five hundred locations in the country [3]. As a result of this, mining is done virtually in all the states of the federation. Mining industries have been viewed as key drivers of economic growth and the development process, as lead sectors that drive economic expansion which can lead to higher levels of social and economic well being [4]. Coal and tin ranked high as Nigeria's foreign exchange earners during the colonial period and after the country's independence in 1960, other minerals such as granite, limestone, gold, marble, clay and a host of others were mined to a lesser degree mainly for local consumption [5].

Therefore, the discovery of crude oil in 1956, oil glut of the 1970s and early 1980s have drastically affected the solid minerals industry to an extent that the overall contribution of mining to the national Gross Domestic Product (GDP) has been declining and was about 0.5% in 2009. This has led Nigerian economy to become a mono product economy and hence vulnerable to international oil politics and its repercussions. The domineering role of oil did not allow past governments to attend to global challenges that evolved in the development of solid minerals. No doubt, the petrodollar from these oil booms led to the neglect of these huge economic potential. This made Nigeria to experience the "Dutch disease" reflected by an appreciating exchange rate, subsidize imports while discouraging non-oil exports; which in Nigeria's case includes the solid mineral sector which hitherto the discovery of crude oil was a major contributor to economic growth [6]. However, the collapse of oil price, increasing unemployment among youths, the restiveness in the Niger Delta, the global economic recession among others have combined to force government on the need to diversify the revenue base of the Nigerian economy towards solid minerals development.

Previous work in different parts of the Nigerian Basement Complex has shown that the older granites are high level intrusions emplaced by stoping and diapiric process [7]. [8] investigated the physical and mechanical properties of granites and limestone in Kogi State using hardness tests and discovered that the two tested rocks have very high mechanical properties that can be used for engineering applications. Experimental analysis such as tests for tensile strength and compressive strength of the rock can dictate load or energy that can be absorbed before failure of rock mass [9]. [10] observed that the physicomaterial properties influencing fragmentation of rocks include young modulus, compressive and tensile strength.

The strength of rock decreases with increase in water content due to reduction in the coefficient of internal friction of the rock particles. Presence of water in rock

also increases the deformability of the rock mass [11]. [12] also carried out an extensive study on large number of rock samples representing different types of rocks (basalt, diabase, dolomite, gneiss, granite, limestone, marble, quartzite, rock salt, sandstone, schist, siltstone, and tuff) to develop an engineering classification system for the intact rock and he discovered that classification is strongly affected by rock mineralogy, texture, and anisotropy. [13] carried out a research for a wide range of strength values *i.e* uniaxial compressive strength; UCS (5.7 - 464MPa), Brazilian tensile strength; BTS (0.5 - 30.5 MPa) and discovered a strong correlation between UCS and BTS of the different rock types. However, this research aims to investigate the suitability of the granite formations of Utan, in Jos North Local Government of Plateau State, Nigeria for building applications.

2. Materials and Methods

2.1. Materials

The raw material used in this research is granite obtained from three different locations of the same latitude $7^{\circ} 67^1$ N and longitude $7^{\circ} 50^1$ E from Utan; Jos, Plateau State, Nigeria. The equipment used in this work include: Jaw crusher, electronic weigh balance, range of 100 g Sample container (not-corrodible) with airtight lid; sieve, measuring cylinder, beaker, measuring tape, ruler, camera, marker, GPS, Oven, Desiccators, Caliper with accuracy of 0.1mm, Sledge hammer.

2.2. Methods

2.2.1. Sample Preparation

The ore was crushed and ground using jaw crusher (BD 1028), cone crusher (HZ24KL) and ball milling machine to obtain a fine powder of particle size less than 2 mm at the Mineral Processing Laboratory of National Metallurgical Development Centre, (NMDC) Jos, Nigeria. The samples for the porosity and density were prepared in an irregular form and the preparation was carried out in the Mineral Processing Laboratory at NMDC, Jos. The samples were prepared according to the standards suggested by [14] and conform to American Standard for Testing Method [15].

2.2.2. Porosity

The saturation and Buoyancy technique for irregular rock samples were adopted and the procedures follow the standard suggested by [14] and conform to [15]. Three samples of irregular form from a representative sample of granite rock were prepared as shown in Figure 1. The size of the specimens was made such that the following conditions were fulfilled: the specimen mass should be at least 50 g of irregular form and the minimum specimen dimension should be at least ten times the maximum grain size of the rock. The specimen bulk volume (V) was determined by measuring the saturated-submerged mass (M_1) and the saturated mass (M_2) of the samples for each dimension of the specimen. The specimen was saturated by immersion in water in a vacuum of less than 800 Pa for

a period of 60 Seconds with periodic agitation to remove trapped air.

The specimen was then removed from the water and its surface was dried with a moisten cloth carefully to remove the water on the surface only and to ensure that no fragments were lost. The specimen was placed in a container to avoid loss of mass during subsequent sample handling. The mass of specimen with container (Y) was determined with an accuracy of 0.01 g. The specimen (in the open container) was oven dried at 105 °C for a day to a constant mass. After closure of the container and cooling in a desiccator for 30 minutes, the mass (X) of the dry sample with the container (and lid) was determined with an accuracy of 0.01 g. The container with the lid was cleaned and dried and its mass (Z) was also determined with an accuracy of 0.01 g. Hence, the porosity was determined using equation (5)

$$\text{saturated - surfacedrymass; Volume; } V = \frac{M_2 - M_1}{\rho_{\text{water}}} \quad (1)$$

$$\text{saturated - surfacedrymass; } M_2 = Y - Z \quad (2)$$

$$\text{Mass of specimen; } M_s = X - Z \quad (3)$$

$$\text{Pore Volume; } V_v = \frac{M_s - M_2}{\rho_{\text{water}}} \quad (4)$$

$$\text{Porosity; } \varnothing = \frac{V_v}{V} \times 100\% \quad (5)$$



Figure 1. Alogitech GTS 1 Thin Section Cut Off Saw

2.2.3. Density

Three different samples each of A, B and C were prepared from the pulverized granite sample to determine its density.

Step 1: different mass (g) of each of the sample was weighed from electronic weigh balance and recorded as (M g).

Step 2: 250 cm³ of distilled water was measured with the aid of measuring cylinder as initial volume (v₁)

Step 3: the mass M g was poured into the distill water inside the measuring cylinder and allowed to settle for 1 hour before taking the reading

Step 4: the final reading on the measuring cylinder was taking as the final volume (v₂)

Step 5: the density (P) of the sample was determined using equation (6)

$$P = \frac{\text{Mass}(M)}{\text{Change in volume}(\Delta V)} \quad (6)$$

2.2.4. Uniaxial Compression Test

The uniaxial compression tests were conducted on Testometric Universal Testing Machine (UTM) FS 300-1023 in the Materials Testing Laboratory of National Metallurgical Development Centre Jos, Nigeria as in Figure 2. In this research, compressive stress was applied uniaxially to five (5) samples each of dimension 2mm x 2mm with a crosshead speed of 2 mm/minute to determine the behavior of the granites under a compressive load. Both load cell and strain gauges were wired to a data logging system so as to record the data. The stress-strain data was continuously logged into a computer and the stress at failure was considered as the uniaxial compression strength (UCS) of granite. The average values were obtained and recorded.



Figure 2. Showing a Universal Testometric machine

2.2.5. Indirect Tensile Strength

The purpose of tensile test is to verify tensile strength of granite or its resistance against fracturing. Direct tensile test on granite sample is relatively difficult to carryout but correlation between Brazilian test (BTS) (indirect tensile strength) and uniaxial compression tests by [13] which offers an indirect method to measure tensile strength was used in this research as in equation 7 and the average values were obtained as in UCS.

$$\text{UCS (MPa)} = 12.38 * \text{BTS}^{1.0725} \quad (7)$$

2.2.6. Hardness Test

Rockwell and Mohs hardness test were used to evaluate the hardness of the granite sample.

Rockwell hardness test

The Rockwell hardness test was carried out in the Materials Testing Laboratory of National Metallurgical Development Centre (NMDC); Jos, Using a Rockwell hardness testing machine of model Karl Frank GMBH 38506 shown in Figure 3. Four (4) irregular samples each of A, B and C were prepared. Each of the samples has a thickness of 10 mm. The indenter was fixed on the digital Rockwell hardness tester. The load selector was turned to 100 kgf to attain Rockwell class C. The rank and pin was turned to make the sample in contact with the indenter for the primary load of 9.8 kgf to be applied. The secondary load was automatically applied and the result was displayed. Several indentations were made on each sample

for accuracy purpose. The average values were then recorded. The same procedures were repeated on each of the samples.



Figure 3. Rockwell hardness testing machine

Mohs Hardness

The Mohs hardness test was as well carried out at the Mineralogical Laboratory of the Mineral Processing Department of NMDC, Jos. Four (4) samples each of A, B and C were prepared; the test was carried out five (5) times on each sample and the average were determined and recorded. The granite samples were scratched against the minerals on the Mohs scale. The value of the mineral on the Mohs scale which corresponded to where the rock and the mineral did not scratch each other was recorded as the relative hardness of each of the sample. The procedure was repeated for all the samples and the average value was obtained and recorded.

2.2.7. Impact Value Test

The resistance of the granite to impact was found by carrying out impact test on three samples each of A, B and C. The impact values were determined using the relevant British Standard BS 812 part 112 [15] Granite sample of size 10 mm to 12.5 mm was weighed as w_1 and filled in a cylinder in three (3) equal layers; each layer was tamped 25 times. The same was transferred to the cup and again tamped 25 times. The standard hammer was then released to allow a free fall on the specimen 15 times. The sample was sieved with 2.36 mm sieve and the weight (w_2) of the fines resulting from the impact was measured. The procedure was repeated for all the samples and the average values were obtained and recorded. The impact value was obtained using equation 8

$$\text{Impact Value} = \frac{w_2}{w_1}. \quad (8)$$

2.2.8. Chemical Analysis

The chemical analysis was carried out with the aid of ED-XRF (Energy Dispersive X-ray fluorescence) at Centre for Energy Research and Development (CERD) Obafemi Awolowo University, Ile-Ife, Nigeria.

2.2.9. Polish Test

The polish test indicated in Figure 4 was carried out at the metallographic laboratory of NMDC, Jos on the

granite samples so as to determine the display of good abrasiveness and yielding attractive color tints using the following procedures:

- i. The granite rock samples were cut into 10mm x 10mm sizes
- ii. Each of the samples above was pre-polished to remove saw mark and other uneven surfaces using abrasives of different size grade, starting with the coarsest and finishing with the finest.
- iii. The pre-polishing slabs were immersed into accurate manufacture moulds and thereafter removed and placed on “Road wheels” of accelerated polishing machine (Ecomet II) slurry Abrasive of grade 1: 200 were continuously fed through fixed mechanical feeders.
- iv. Flow emery was then loaded on lyre wheel by a spring loader spreader plate with the corn emery directly debating fed to the specimen through a feed chute and introducing water at a controlled rate.
- v. Using a mechanical device, the ‘tyre wheel’ was then raise and lowered to the ‘read wheel’. The revolution counter was fitted to 315/325 rpm and polishing was allowed for about 25 minutes.
- vi. The completed polished slabs were removed and washed with distilled water to remove contaminants and dried with pressurized air.
- vii. After drying, the slabs were then viewed under a “Vicker Misa” microscope fitted with cirso hardness testing equipment for microstructure analysis as in Figure 5



Figure 4. Showing polishing of granite sample



Figure 5. Vicker Misa” microscope



Figure 6. Radioactive test using Geiger muller counter

sensor of this device was able to pick radiation from the granite samples. 100 g each of the samples was weighed with kern EMD 600 weighing balance in order to have a uniform quantity of granite to be exposed to radiation. The samples were leveled before Ludlum Micro R Meter, model 19 radioactive counter machine was applied by placing it on the sample for sixty (60) seconds; after which the Ludlum readings were taken and recorded. The same procedure was repeated on each sample and the average was determined.

2.2.10. Radioactivity Test

The test was carried out with the aid of Geiger muller counter, (Model 19 Micro R meter, Ludlum measurements Inc. Sweefwate, Texas) as indicated in Figure 6. Five (5) samples each were prepared for the radiation test. The

3. Results and Discussion

3.1. Results

The results obtained during the course of this research are presented as follows:

Table 1. Porosity of granite

Sample	Mass(M ₁) (g)	Ms (g)	M ₂ (g)	Vv	V	∅	Average
A1	26.50	34.50	34.47	0.03	7.97	0.38	0.53
A2	32.00	42.30	42.24	0.06	10.24	0.59	
A3	28.05	41.00	40.92	0.08	12.87	0.62	
B1	30.65	40.00	39.90	0.10	9.25	1.08	1.08
B2	27.36	35.30	35.21	0.09	7.85	1.15	
B3	31.50	43.50	36.40	0.05	4.90	1.02	
C1	34.0	43.10	43.02	0.08	9.02	0.89	0.86
C2	29.74	34.70	34.66	0.04	4.92	0.81	
C3	30.00	38.06	37.99	0.07	7.99	0.88	

Table 2. Density of granite

Sample	Mass(g)	v ₁ (cm ³)	V ₂ (cm ³)	Δv (cm ³)	P(g/cm ³)	Average p(cm ³)
A ₁	23.00	250.00	259.06	9.06	2.54	2.58
A ₂	27.00	250.00	260.11	10.11	2.67	
A ₃	25.00	250.00	259.58	9.58	2.61	
B ₁	29.00	250.00	260.74	10.74	2.70	2.62
B ₂	31.00	250.00	261.83	11.83	2.62	
B ₃	26.00	250.00	260.19	10.19	2.55	
C ₁	33.00	250.00	262.74	12.74	2.59	2.60
C ₂	26.00	250.00	260.40	10.40	2.50	
C ₃	28.00	250.00	260.73	10.73	2.61	

Table 3. Uniaxial Compression Test

S/N	I(MPa)	II(MPa)	III(MPa)	IV(MPa)	V(MPa)	AVERAGE (MPa)
A	200.0	208.5	205.0	208.0	216	207.5
B	205.0	198.8	211.0	208.0	200.0	204.6
C	194.0	205.0	203.0	209.0	206.0	203.4

Table 4. Indirect Tensile Test

S/N	I(MPa)	II(MPa)	III(MPa)	IV(MPa)	V(MPa)	AVERAGE (MPa)
A	13.39	13.92	13.70	13.89	14.39	13.86
B	13.70	13.32	14.08	13.89	13.39	13.68
C	13.02	13.70	13.58	13.95	13.77	13.60

Table 5. Rockwell Hardness Test (HRC)

S/N	I	II	III	IV	AVERAGE
A	86.3	86.2	90.0	93.5	89.0
B	89.0	94.5	92.5	83.7	89.9
C	78.3	80.5	95.6	91.8	86.6

Table 6. Mohs Hardness of granite

S/N	I	II	III	IV	AVERAGE
A	6.6	7.0	6.8	7.2	6.90
B	7.4	6.5	6.9	7.0	6.96
C	6.8	7.1	6.9	7.3	7.03

Table 7. Impact value of granite

Sample	W ₁	W ₂	Impact value
A	80.5	7.12	0.089
B	85.6	7.88	0.092
C	78.7	7.40	0.094

Table 8. ED-XRF of samples A, B and C

Chemical Composition	A	B	C
SiO ₂	74.72	75.19	76.01
Al ₂ O ₃	12.36	12.24	12.09
Fe ₂ O ₃	1.80	1.46	1.38
FeO	1.07	0.52	0.48
MgO	0.28	0.22	0.08
CaO	0.92	0.73	0.75
Na ₂ O	3.54	3.95	3.70
K ₂ O	3.37	3.38	3.55
H ₂ O ⁺	0.61	0.33	0.22
H ₂ O ⁻	0.13	0.10	0.05
TiO ₂	0.25	0.09	0.10
P ₂ O ₅	0.04	0.03	0.03
MnO	0.01	0.02	0.01
LOI	0.90	1.74	1.54
Total	100	100	100

Table 9. Polish ability

Sample	Polish ability	Remarks
A	95	Excellent for lapidary
B	91	Excellent for lapidary
C	93	Excellent for lapidary

Table 10. Radioactivity of granite samples

Samples	I (mrem)	II(mrem)	III (mrem)	IV(mrem)	V(mrem)	Mean (mrem)
A	6.0	6.5	6.8	6.1	6.7	6.42
B	8.5	8.7	8.5	9.4	9.2	8.86
C	7.8	7.5	8.5	8.7	8.3	8.16

3.2. Discussion

3.2.1. Porosity

Porosity is the volume of the pores within a porous material sample, expressed as a percentage of the total volume of the sample. All stones have pores and hence absorb water. The reaction of water with granite leads to disintegration. Building stone should not be porous because if it is porous, rain water will enter the pore and reacts with the stone and hence crumbles it. In higher altitudes, the freezing of water in pores takes place and hence disintegrate the stone [11]. It can therefore be deduced from Table 1 that the average values of the porosity obtained are 0.53, 1.08 and 0.86 % respectively for A, B, and C which is in accordance to 0.5 to 1.5 % recommend for building stones [16].

3.2.2. Density

Denser stones are stronger while light weight stones are weak. Therefore, stones with specific gravity less than 2.4 are not suitable for building constructions. Heavier varieties of stones are required for the construction of buildings, dams, retaining walls, docks and harbours. The specific gravity of good building stone ranges between 2.4 and 2.8 [15] while the values obtained in Table 2 are 2.58, 2.62 and 2.60 respectively for A, B and C are suitable for building constructions.

3.2.3. Mechanical Property

Strength is a paramount property when selecting stone for building purposes. The stone should be able to resist the load coming on it. The average compressive strength obtained in Table 3 is 207.5; 204.6; and 203.4 MPa for

sample A, B and C respectively which is within the range of the compressive strength (100 – 250 MPa) specified for building stone [17].

Tensile strength is also a useful mechanical property for the building stones. From Table 4 it can be observed that the average tensile strength obtained in this work is 13.86; 13.68 and 13.60 MPa respectively for sample A, B and C which is in accordance to the tensile strength of granite 7 – 25 MPa [18].

The average Rockwell hardness value are 89.0, 89.9 and 86.6 respectively for A, B and C as indicated in Table 5 while in Table 6, it can be deduced that the average Mohr hardness value of the granite sample A, B; and C are 6.90; 6.95 and 7.03 respectively. When granite stone is applied for flooring and pavement then hardness is an important mechanical property to be considered. Hence, the hardness value of the granite obtained here meant the requirement of the building stone used in floors and pavements to resist abrasive forces caused by the movement of men and materials over them [19]. When permanent, enduring color and texture, and complete freedom from deterioration and maintenance are prime requirements, then granite is highly heat, scratch and stain resistant, and is commonly used to face commercial and institutional buildings and monuments. It is unequaled as a material for fireplaces, steps, road and driveway curbing, terraces, and to pave plazas and public spaces. Granite is the traditional favorite of countertop materials for its unique colors and patterns, proven durability and lasting value [20]. Therefore, this granite due to its high hardness value will be suitable for building purposes.

Building stone should be tough enough so as to sustain stress developed due to the vibrations. The vibrations may result due to the machinery mounted over them or as a result of the loads moving over them [21]. The impact value gives a relative measure of the resistance of the granite to sudden shock of impact. The lower the impact value the tougher and stronger the granite. From Table 7, the impact value obtained for A, B and C is 0.089, 0.092 and 0.094 respectively. The result obtained shows that all the granite samples fall within the suitability limits for concrete that are to be used for heavy-duty flooring and pavement wearing surfaces [22].

3.2.4. ED-XRF Analysis

In Table 8, it can be observed that the granite sample is dominated by 74.72 % SiO₂, 75.19 % SiO₂, and 76.01 % SiO₂ for A, B and C respectively. It can then be inferred that the granite is acidic with silica content greater than 65 % and also reveal that the critical mineral of granite is quartz. The silica content contributes to the hardness value of this granite since the oxide quartz and a large group of silicates are the most important rock forming minerals.

Silica (SiO₂) one of the oxides of silicon occurs as quartz, chalcendony, agate and flint etc. Silica is a hard mineral having a 'Moh's Hardness 7 [23]. The quality of granite varies according to the proportions of the constituents and to their method of aggregation, this kind of stone is generally durable, strong, and hard. The hardest and most durable granites contain a greater proportion of quartz and a smaller proportion of feldspar and mica. Feldspar makes granite more susceptible to decomposition by the solution potash contained in it, potash feldspar being less durable than lime [24].

3.2.5. Polish Test

From Table 9, the luster value test on the slabs revealed that both samples A, B and C display more attractive colour tint. The pattern, texture, and colour of all the samples are affected by how the stone is fabricated and finished. Granites tend to hold their colour and pattern, while limestone colour and pattern changes with exposure. Textures may range from rough and flamed finishes to honed or polished surfaces. The harder the stone, the better it takes and holds a polish.

3.2.6. Radioactivity

The Radioactivity test was carried out to determine the rate of emission of radioactive elements present in the granite samples and examine whether the rate of emission would be harmful to man when exposed to radiation. Table 10 reveals that all the granite rocks samples were very slightly radioactive. The rate of emission of radiation of the granite samples is as a result of the presence of the naturally occurring radioactive elements like radium, uranium and thorium which decay into radon. The radon gas may then be released from the granite over time. However, since this granite is not very porous as seen in Table 1, less radon is likely to escape from it than from a more porous stone such as sandstone. Also, any radon from granite countertops in kitchens or bathrooms is likely to be diluted in the typical home since those rooms are usually well ventilated [25].

Very high radiation doses can increase the occurrence of certain kinds of disease (e.g., cancer) and possibly negative genetic effects. international agencies such as (Environmental Protection Agency [EPA], Nuclear Regulatory Commission [NRC], and Department of Energy [DOE]) and state agencies (e.g., Agreement States) have established recommended dose limits as in Table 11 for both workers and the general public for different types of activities to limit cancer risk. Other radiation dose limits are applied to limit other potential biological effects with workers' skin and lens of the eye Table 12. Due to the low rate of radiation of the granite sample, it will be less harmful to man when exposed to it.

Table 11. Annual Radiation Dose Limits

Group	Dose (mSv)	Dose (Mrem)	Agency
Radiation Worker	50	5000	NRC, 'occupationally' exposed
General Public	1	100	NRC, member of the public
General Public	0.25	25	NRC, decommissioning and decontamination of all pathways
General Public	0.1	10	EPA, air pathway
General Public	0.04	4	EPA, drinking water pathway

Source: [25].

Table 12. Annual Maximum Permissible Dose Limits

mrem	rem	
5,000	5	Whole Body Deep Equivalent (Head, trunk, active blood-forming organs and reproductive organs)
50,000	50	Whole Body Shallow Dose Equivalent (skin of the whole body)
15,000	15	Lens of Eye Dose Equivalent
50,000	50	Extremities (hands, forearms, feet and ankles)

Source: [25].

4. Conclusion

The granite formation for production of dimension stone blocks at Utan was investigated in three different locations A, B and C. The physical, chemical and mechanical properties were investigated. The average porosity obtained is 0.53, 1.08; and 0.86 while the respective average density of 2.58, 2.62 and 2.60 g/cm³ were obtained for A, B and C. The compressive strength of 207.5, 204.6 and 203.4 MPa; and tensile strength of 13.86, 13.68 and 13.60 MPa were obtained for A, B and C respectively. Rockwell hardness values obtained are 89.0, 89.9 and 86.6 while the morh's hardness values are 6.90, 6.96 and 7.03 respectively for sample A; B and C. The impact values obtained are 0.089, 0.092 and 0.094 for A, B and C respectively. The radioactive rates of samples A, B and C are 6.42, 8.86 and 8.16 Mrem respectively. Sample B is observed to be more radioactive but both samples are far below the annual maximum permissible dose limits. Both samples are polish able. Therefore, the three tested granite rocks have suitable physical and mechanical properties that meant the requirement for building purposes; from the polish-ability test, it shows that the three (3) granite outcrops are suitable for the production of granite tiles; countertops; slabs. The chemical analysis revealed that the granite is dominated by quartz (SiO₂) which contributes greatly to the hardness of the rock while the radioactive test indicate that the granite samples proved conclusively that the rate of radiation found occasionally in a slab of granite is not harmful to humans when exposed to it. Hence, the granite formation of Utan will be a suitable building stone material.

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