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Studies on Uniaxial Compressive Strength, Uniaxial Tensile Strength, Young's Modulus, Poisson's Ratio of Iron Ore in relation their Influence in Optimum Rock Blasting Process…….Central Afghanistan

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Abstract— The aim of this study to find out some mechanical properties of iron ore in Haji Gak iron ore mine in order to design the optimal blasting parameters during mining activities. Totally 10 boulder surface samples of iron ore with more than 40kg weight were collected in 8 stations of different coordinates and altitudes limited between 3437.2 M till 3695 M above sea level. The Haji Gak iron mine reserve has estimated approximately 1.8 Billion tonnes iron ore with concentration of 67% of Fe and 96.15% of Fe_2O_3. The measurement of mechanical properties of iron ores were done with ASTM standard in high level technological and modern laboratory. The laboratory experiments reveal the uniaxial compressive strength value of collected ore sample 98.09 Mpa with elastic modules of 79.113 Mpa and 0.12 Poisson ratios in sample no. 18 shown the maximum amount of uniaxial compressive strength and Elastic modules. The point load test shown the maximum value of $I_{S(50)}$, 18.18 Mpa and 22.73 Mpa of uniaxial tensile strength in sample no.3. These parameters directly affected the blasting parameters, blasting pattern and explosive type in optimal mining activities. As this mine is not extracted yet, thus it is the first time to design the blasting pattern and parameters base on measured properties of rocks.

Keywords— Uniaxial compressive strength, Point load strength, Young's modulus, Piosson's Ratio, Blasting Pattern.

I. INTRODUCTION

Exploitation of ore contains the different processes such as drilling, blasting, hauling, crushing, loading and transporting. The 20-80% of mining cost referees to drilling process [1]. The blasting operation plays a pivotal role in the overall economics of opencast mines. The blasting subsystem affects all the other associated subsystems, i.e. loading, transport, crushing and milling operations [2]. Suppose generating a suitable muck pile having suitable size distribution of the rock that can be efficiently loaded, transported and milled [3]. Drilling blasting are the most important operation in mining activities in preparing mine structure and openings, i.e. shaft, and different methods to obtain ores from rock mass in open pit and underground methods of mines. The main objective of blasting in mine is profitable and economical extraction and decreases the cost of production. Drilling blasting operations are one of the most influential factors on the cost of minerals resources exploitation [4]. To carry out blasting operation in on optimum manner it is essential that the influence of rock properties on the blasting process, operations and the results is fully understood [5].

This study focused on some mechanical properties of Haji gak Iron ore and the major aim is to find out the significant properties of iron ore such as uniaxial tensile strength, uniaxial compressive strength, point load strength, Young's modulus, and Poisson's ratio and their influences and affects in blasting and drilling design and pattern of open pit method in Haji gak iron ore mine. It is the first time that experiments and measurements were done in iron ore samples in related to drilling blasting pattern to design and optimization of blasting parameters, selection of accessible explosives and modern drilling, loading machinery to future profitable and economical exploitation of Haji gak iron ore mine.

ROLE OF MECHANICAL PROPERTIES OF ROCKS IN DRILLING AND BLASTING PROCESS

The major property of rocks which plays a significant role in drilling blasting process is mechanical properties. Mechanical properties of rock contains tensile strength, Young's modulus, Poisson's ratio, and compressive strength of rock mass, and etc that are very important in design of bench blasting. Besides knowing geology and structure of area as well as through rock mechanical properties can design the proper method and pattern of blasting and drilling, loading machinery, type of explosives and optimization of blasting parameters. In opencast mining, where blasting is employed for excavation, the overall cost effectiveness of the production operation is compatible with optimization of drilling and blasting parameters [2]. The designing and processing of rock blasting method is dependent on the result of rock mass classification. It is very important to give an experimental and reasonable way to classify the blast ability of rock mass [6]. In addition assessment of rock mechanical properties depends on sample size and testing methodologies [7]. For example the uniaxial compressive strength test achieves on core specimens in compressive tester machine, and is record the maximum axial load sustained at the point of failure [8], also can be calculated through pinot load strength test of specimens.

II. Related Work

The Haji Gak iron deposit lies in the core of the central Afghanistan iron belt (CAIB) as the most important iron ore belt in Afghanistan, the deposit lies in a sequence between Neoproterozoic Kalu group and the Devonian Haji gak formation [9]. The Haji Gak deposit trends north-east–south-west for about 9 km and is made up of 16 separate ore bodies, each length up to 3 km. Iron occurrences were observed during initial geological mapping of the area in the mid thirties [10]. During 1963 and 1965 a joint project of Afghan-Soviet geologists in Haji Gak area carried out an intensive study and revealed the mining aspects of the Haji Gak deposit. The Haji Gak deposit map was drawn at scales of 1:10 000. Kusov and others (1965b) stated that the age of the Haji-Gak iron deposit, based on tectonic, magmatic, and stratigraphic conditions and connection of ore formation with fractured structures of post-Devonian age indicated the Haji-Gak iron deposit was of Early Jurassic age [11]. The stratigraphic sequence of the belt is mainly built up by Proterozoic, Paleozoic and Mesozoic rock units [9]. Kusov and others (1965b) suggested that much faulting occurred before ore formation, but that fractures and cleavage structures are present in all the ore bodies and in all rocks that constitute the ore field [11](Fig.1). According to mineralogical compositions, the main ore minerals are magnetite, hematite or martite and goethite [12], the minor ore minerals are pyrite, Siderite, Barite, Pyrrhotite, Chalcopyrite and Chamosite, the gangue minerals are Quartz, Calcite, Dolomite, some other minor/trace phases like mica (Sericite), albite, talc, and clay minerals. Ore textures are massive, semi-banded and fine to medium granular [13].

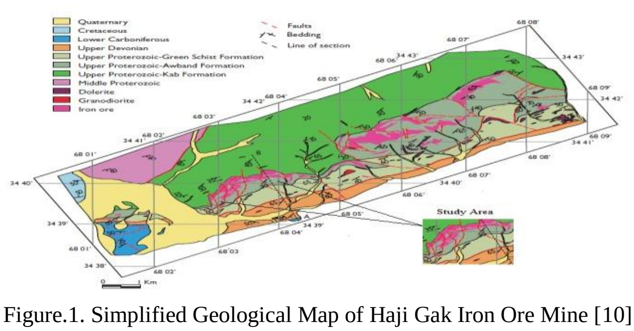

Figure.1. Simplified Geological Map of Haji Gak Iron Ore Mine [10]

STUDY AREA

The Haji Gak iron ore deposit is situated in central Afghanistan, nearby the Haji Gak pass in Bamyan province, about 200km west of Kabul. It is the largest iron ore reserve located in Afghanistan [13]. The reserve estimation shows 1.8 Billion tons of iron ore with 67% concentration of iron and 96.15% iron ore in this mine [12]. The study area located on Haji Gak prospect subarea and enclosed between latitudes (34° 39′ 40″ - 34° 40′ 25″N) and Longitudes (68° 03′35″ - 68° 04′ 25″ E) (Fig. 1) (Fig. 2) (Photo.1).

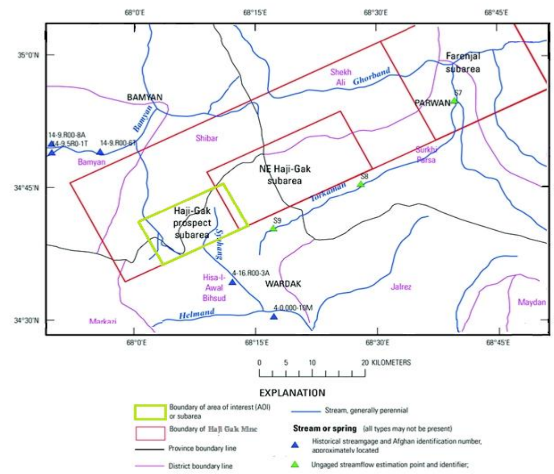

Figure. 2. Geological Map of Study Area

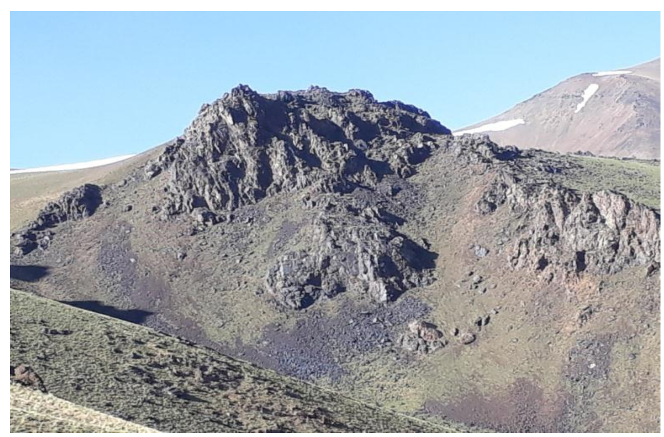

Photo. 1- Haji gak Iron Ore Mine, Bamyan Province, Afghanistan (Photographer: Fatima Rezaye, May 2017)

III. Methodology

Material

GPS, Compass, Geological hammer, steel pen, heavy hammer (5 kg weight), Geological swing magnet pen, Safety jacket, Safety shoes, Safety helmet, Daily surveying notebook, White and blue marker, Sample bags.

Sampling

In current research the sampling of ore carried out manually in iron ore mine area. Totally 10 boulder surface samples of iron ore were collected at 8 stations that cover a west south valley of a part of Haji Gak prospect subareas (Fig. 2). In order to have iron components, by geological swing magnet pen checking of out crops were done. The samples have been collected from individual out crop of each station by the help of geological hammer, heavy hammer and steel pen sometimes (photo.2). The obtaining samples have numbered by white special marker pen, and have stored in sampling bags. A total of 10 boulder surface iron ore samples were collected in different altitudes of interested area which limited between 3437.2 M till 3695 M above sea level (Table. 10). Field location and altitudes of samples were identified and recorded through digital GPS (Fig. 2) (Photo. 3) (Table. 10). The weights of individual iron ore sample were more than 40 kg and totally entire samples weight about half tonnage of iron ore. The entire collected ore samples were transferred manually from individual stations to Haji gak main high way, and then have transported by vehicle to rock mechanic test laboratory in Kabul city (State Government permission).

MICHANICAL TESTS

Mechanical tests are involves with deformation and/or breakage of material samples. This study involves the measurement of uniaxial compressive strength, point load strength, elastic modulus, and Poisson’s ratio of ore samples of interested area. The uniaxial compressive test is used to determine uniaxial compressive strength, Poisson’s ratio, and Young’s modulus, this test is also called unconfined compressive test [14].

For measurement of uniaxial compressive strength and point load strength of ore samples, firstly cutting done for entire ore samples through cutter machine, for getting in a desired size of ore sample, then the samples referred to EINHELL cutter machine (Serial No-08/2009/IRAN-2212) Model-RT-SC 920 I, Made in China. After that the ore samples were getting ready to make core based on required ASTM system of laboratory. The ore samples have made core through HILTI core making machine with diamond bit, Model- DD-HD 30 01, Serial No-062985, made in Liechtenstein.

Photo. 2- Collection of Ore Sample from outcrop In Pay Kottal area of Haji gak iron ore mine

Photo. 3- Coordinate Recording of the Stations of Ore Samples by GPS in Haji gak iron ore mine

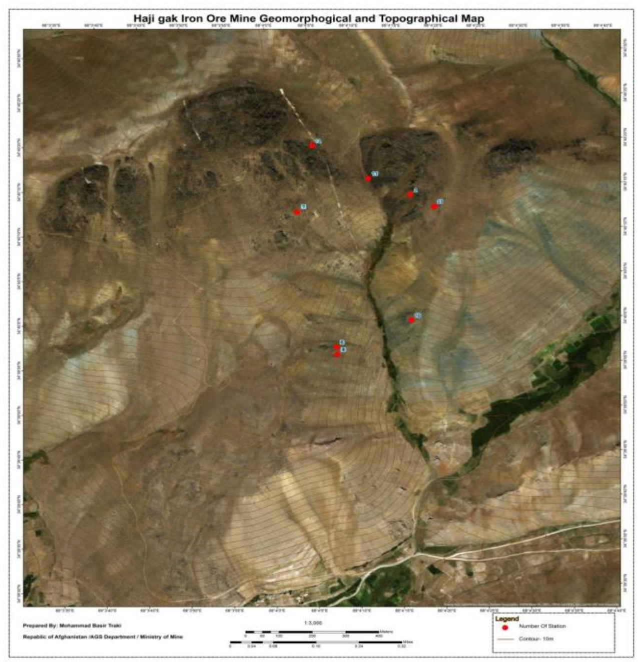

Figure. 2. Topographical and Morphological Map of Study

After making the core of ore sample (Photo. 4), they were ready to do compressive strength tests, and measurement of Young’s modulus (E) and Poisson’s ratio (υ) based on manual of ASTM D 7012 (ASTM Standards Annual book 2009), and point load strength test based on ASTM D 5731-08 (ASTM Standards Annual book 2009). The compression machine made in UK with model ELE International brand, ADR Touch 2000 Standard compression machine with digital reader out 220- 240 V, Serial No.36-3090/01 (Photo.5). The core diameters of specimens were 55mm with different thickness for compressive strength test of ore samples. The individual samples have placed exact on center of testing machine. The load has applied continually on specimen and gradually increased the load to occur failure in specimen; the reading of lateral deformation recorded in every 20 KN applied force on sample under testing machine continuously till the failure occurred in sample and finally were recorded the total force and compressive strength of each samples (ASTM D 7012, Method D).

The point load strength tests done in ENERPAC point load tester machine, Model No - GP-10 S. There is two types of tests have done based on specimen shape, diametric and axial. In diametric test, it is suitable that core specimen should have specific size; length per diameter ratio greater than one ($\frac{length}{Diameter} > 1$). The diameter and length of core sample determination done then inserted it in the tester machine or device and close the platens to make contact along a core diameter. The distance between the contact points of device and the nearest free end should be at least 0.5 times then the core diameter. Gradually increased the load of tester machine within 10-60 second that failure to be occurred in core sample, and have recorded failure load (Maximum Load). It must be note, if there is one small failure occurred on surface of core sample, the test should be rejected. In axial test, it is suitable that core specimen should have size of length per diameter ratio of 1/3 ($\frac{length}{Diameter} = \frac{1}{3}$). The diameter and length of core sample determination done then inserted it in the tester machine or device and close the platens to make contact along a line perpendicular to the loading direction. Gradually increased the load of tester machine within 10-60 second that failure to be occurred in core sample, and have recorded failure load (Maximum Load). The point load strength index determination by point load test must be corrected to the standard equivalent diameter (De) of 50mm [14]. If the cores being tested have approximately 50mm diameter, then correction is not needed, in case of differs diameters, the correction suggested for point load index value by ASTM, the equation is as follows [15],

$$I_{s(50)} = \frac{(D_e/50)^{0.45} P_u}{D_e^2} \quad (1)$$

Where,

P_u- The failure load, De – equivalent diameter

During calculation F is the size correction factor (Table. 1), for tests near the standard 50 mm size, only slight error is introduced by using the approximate expression:

$$F = \sqrt{D_e / 50} \quad (2)$$

Based on point load strength result, the estimation of uniaxial compressive strength (σ_c) to be done through of uncorrected point load strength (I_s) multiply to Index (K) , as following formula,

$$\sigma_c = K \times I_s \quad (3)$$

Where:

K = Strength conversion factor Index that depends on site specific correlation between σ_c and I_s for a specific specimen with a test diameter (D), [MPa].

The elastic modulus and Poisson's ratio can be calculated by result of uniaxial compressive strength test of studied specimens. Jaeger and Cook (1979) presented the equation No (4) to calculate the elastic modulus (E). The Poisson's ratio and elastic modulus can calculate by equation No (5) and (6) [16] [17].

$$\sigma = E\epsilon \quad (4)$$

$$\text{Young's Modulus}, E = \frac{\text{Axial Stress}}{\text{Axial Strain}} = \frac{\sigma_a}{\epsilon_a} \quad (5)$$

$$\text{Poisson's Ratio}, v = \frac{\text{lateral Strain}}{\text{Axial Strain}} = \frac{\epsilon_1}{\epsilon_a} \quad (6)$$

Where, σ - The stress, ϵ - The strain

According the experiments which have done in compression tester machine, and point load tester machine, there is a description of individual strengths result of ore samples of studied area in Hajigak iron ore mine available in Table .1 till Table .8.

Photo. 4- Numbering of Cores of Iron Ore Samples (Kabul. 2017)

Photo. 5- Testing of Uniaxial Compressive Strength of ore sample (Omran Geotechnical Company. Kabul. 2017)

IV. RESULTS AND DISCUSSION

RESULT

According the laboratory tests of iron ore samples, there is a description of individual mechanical properties of 10 iron ore samples in 8 stations in Pai Kottal village of Hajigak iron ore mine.

POINT LOAD STRENGTH

The laboratory test of axial point load test reveals that the point load strength ($I_{S(50)}$) values of ore samples in a range of (2.6-18.18) Mpa (Table.1) and the average value of axial point load strength index is 7.86 Mpa for entire ore samples, the maximum value of point load strength is 18.18 Mpa in sample no 3 of station No.2, whereas the minimum value of point load strength is 2.6 Mpa in sample no.4. The laboratory test of diametric point load test shows the point load strength ($I_{S(50)}$) values of ore samples in a range of (3.5 - 7.4) Mpa and the average value of diametric point load strength index is 4.96 Mpa. Point load strength is approximately equal to 0.8 of uniaxial tensile strength (T_0), thus the calculation done and shown in Table.1. It should be mention that should not used point load index to determine the compressive strength. The point load index is used as an independent strength index. Whereas Peng and Zhang (2007) stated the point load test can be used for determining rock uniaxial compressive strength [14]. Therefore the uniaxial compressive strength (UCS) is rather equal to 20-25 times of point load strength [18]. The UCS calculation could be done by formula; $\sigma_c = K \times I_s$ the correlation factor (K) can be vary from 10 to 30. By theoretical analysis, the correlation factor is 12.5. Early studies by Bieniawski (1975) were conducted on hard, strong rocks, and found that relationship between UCS and the point load strength could be expressed as UCS = 24 $I_{s(50)}$ [19].

UNIAXIAL COMPRESSIVE STRENGTH

uniaxial compressive strength based on compression tester machine: The laboratory experiments in compressive strength tester machine revealed the uniaxial compressive strength values of studied samples limited in a range of (33.10-98.09) Mpa, with average value of 60.31 Mpa. The maximum values shown in station no.18, 14, and 20 whereas the minimum values located in station no. 17, 3, 19, and 4 respectively. The point load test showed the average uniaxial compressive strength 147 Mpa. The International Society for Rock Mechanics (ISRM) standard terminology states that the rock UCS is very low (< 5 MPa), low (5–25 MPa), moderate (25–50 MPa), medium (50–100 MPa), high (100–250 MPa), and very high (> 250 MPa). UCS for most iron ores varies between low to medium, with Bonded Iron Formation and hard hematite ores in the high to very high range [8]. According the ISRM standard terminology the uniaxial compressive strength of studied samples of interested area is moderate (25–50 MPa), medium (50–100 MPa), and high (100–250 MPa). The uniaxial compressive strength is a key physical test that relevant to iron ore blasting design and geo mechanics for mining [8]. Peng and Zhang (2007) stated that uniaxial compressive strength is the widely used rock strength parameter for geo mechanical analyses [14] that practically just can be obtained from core sample test in lab experiments, but it is very expensive and time consuming. Therefore in the field can also estimate the UCS based on field characteristics of rocks (Table. 11) [14]. Bhandari (1997) stated elastic rocks are those having relatively higher compressive strength, which stress energy is better utilized in elastic rocks [5]. The test result shown the studied area's rocks have moderate, medium and high uniaxial compressive strength with elastic nature which good utilize stress energy and cause to better fragmentation in rock blasting operation of mining activities.

ELASTIC MODULUS (E)

According to compressive strength tests of ore samples under compression tester machine, shown the varies values of elastic modulus in a rage of (42 - 79) Gpa for ore samples of study area, it reveals the maximum value of elastic modulus in sample no. 18 (Table. 6), and the minimum value of elastic modulus in sample no. 3 (Table.2). Elastic modulus is called Young's modulus that describes the capacity of rock deformation and stiffness. It is an important parameter to describe stress and strain relationship [14][16] (Equation. 4), and assumes that rock acts elastically behavior in uniaxial loading conditions.

The rock with high elastic modulus, its deformation property is less, and the starting part of complete stress-strain curve is would be steep. The rock with low elastic modulus, its deformation is more, and the starting part of complete stress-strain curve maybe gentle [17]. This theory is clearly demonstrated in ore specimens of studied area in Fig. 3 till Fig. 8. Thus the young's modulus value of station no.11 is higher than other stations of studied area (Table. 6) that indicates the low deformation rate of rocks with more stiffness in this area. The young's modulus is one of the important geo-mechanical characteristic of rock mass which affects the blasting result [5] and plays significant role in blasting design of mining activities especially in use of explosive type and bits selection. It is difficult for the explosive gases to compress and stretch the rock if young's modulus of the rock is high. It is found that gas pressure should be less than 5% of Young's modulus for efficient blasting [20].

POISSON'S RATIO (V)

According to compressive strength tests of ore samples under compression tester machine, and related calculation, the Poisson's ratio of collected ore samples are limited in a rage of (0.07- 0.16). The rock possessing the lowest Poisson's ratio fails directly by a brittle failure and those having a high Poisson's ratio fail by plastic means [5]. Sussa and Ito (1994) stated that the rock is having lower Poisson's ratio value are likely to given better fragmentation in rock blasting operation [21]. The Poisson ratio varies over a wide range of possible values in rocks from 0 to 0.5 in principle. Most minerals have values in the range of 0.1-0.3, but cracks tend to lower the value of ν, while liquid saturation causes ν to increase [22]. Peng (2007) demonstrated that the Poisson's ratio varies significantly with the burial depth that is say Poisson's ratio increases as the depth increase [16]. The rock near to surface with dry and highly weathered condition, the v value may be around 0.15 [5], as the studied iron ore samples belong to surface and having same condition of these criteria and based on the finding of researchers such as Bhandari, Sussa, Ito and Han, the studied ore samples of Haji gak mine shows lower Poisson ratio that indicates this area's rocks fail directly by brittle failure and given better fragmentation in blasting operation.

BLASTABILITY, DRILLABALITY, STABILITY AND FRAGMENTATION

Blast ability is an important index to evaluate drilling efficiency in different drilling process. The major influential factor on the blastability (resistance of the rock to blasting) of the rock is strength of the rock [5]. As blastability affected by its strenght as well as the brittle index also affects on it [21]. Brittle index shows the ratio of uniaxial compressive strength per uniaxial tensile strength. This ratio is vary between 10-100, the higher ratio or brittle index indicates the rocks are easier to blast. The lobratory tests of studied iron ore samples shown the lower brittle index that indicates these rocks are defficult to blast (Table.9).

Rock drill ability is used as a comprehensive index in drilling blasting operation of mining. It is directly related to hardness, toughness, and strength of rock such compressive strength, tensile strength i.e. the rock with higher strength it is more difficult to drill, in addition the rock is assumed to be more stable if its UCS is higher [22]. Therefore all the rock classifications by drill ability are presented in terms of the uniaxial compression strength [23]. Laterally rock drill ability related to specific gravity of rock, rate of penetration, and drill bit wear.

Rock mechanical strength is the most crucial rock property in stability analysis, and it appears in different forms such as shear strength, uniaxial compressive strength, tensile strength, and residual strength [22]. Stability of rock in triaxial compression is more than the uniaxial compression. The statibilty of iron ore in tensile strength limited to 20-45 kg/cm^3 and in uniaxial compressive strength is 400-800 kg/cm^3 [24].

The elastic rocks have high compressive strength and high elastic modulus and transmit stress waves well, therefore cause greater fragmnetation result. Thus the lobratorty tests of studied samples shown the elastic type of rocks by having high value of compressive strength, that cause to good fragmentation of rocks. In same case by selection of proper explosive type could be obtained good result of fragmentation. Although the strength of the rocks is an important criteria for selecting explosive type [5].

INFLUENCE OF WATER ON ROCK STRENGTH

The strength of rock such a uniaxial compressive strength, tensile strength and compressive strength of rock mostly affects by water contains of rock. The increases water saturation and moisture level of rock cause decreases the strength of rock [25]. Hawkins and McConnell (1992) stated the decease rate of strength could be in a range of 8% till 98% [26] [27], the variation rate of rock strength depending on texture and mineralogy of rock, also the fluid chemistry. Mellor (1971) stated increasing moisture content of rock lowers strength in both frozen and unfrozen rock, that in normal ambient temperature the strength of water saturated rock is about 60% of the strength of oven dry rock [28], also the deformability increases with increasing water content.

The rock Elastic modulus decreases with increased water saturation and moisture [25]. The effect of water moisture on Poisson's ratio is complicated. May be increases and/or decreases or constant remain in higher water saturations [26] [29]. Bhandari stated that the water content play a significant role in determining the effective Poisson's ratio [5].

Table.1. Point Load Strength Index of Ore Samples (Sample Type - Core)

Sample No	Type of Sample	Diameter (D)	Length (L)	Max load (P)	D_e^2	F	I_s	Point Load Strength ($I_{s(50)}$)	Uniaxial Tensile Strength (T_0)
		mm	mm	KN	mm^2		Mpa	Mpa	Mpa
2	Axial	55	39	28	2732	1.02	10.16	10.36	12.95
2	Diametric	55	85	20	5955	1.22	3.33	4.05	5.06
3	Axial	55	28	377	1962	0.95	19.20	18.18	22.73
4	Axial	55	46	8	3223	1.06	2.46	2.61	3.26
15	Diametric	55	60	28	4204	1.12	6.56	7.38	9.22
17	Axial	55	40	16	2803	1.03	5.63	5.78	7.23
19	Axial	55	33	26	2312	0.98	11.24	11.05	13.81
19	Diametric	55	75	16	5255	1.18	2.97	3.51	4.38
	Average							**7.86**	**9.83**
Average Uniaxial Compressive Strength (UCS) = 147 Mpa									

Table.2. Uniaxial Compressive Strength of Iron Ore Samples

Sample Dimension			**Sample No**	**3**
Sample Diameter	mm	55	Rock Type	Magnetite
Sample Height (L_0)	mm	110	Dry	√
Area	cm^2	23.77	Depth	Surface Sample
Sample Volume	cm^3	261.45	Saturate	No
Test Result				
Vertical Load	**Deformation (mm)**		**Axial Strain (εa)**	**Vertical Stress**

(KN)	Axial	Lateral	Axial	Lateral	(MPa)
0.00	0.00	0.00	0.0000	0.0000	0.00
20.00	-0.60	0.01	-0.0055	0.0002	8.38
40.00	-0.86	0.02	-0.0078	0.0004	16.69
60.00	-1.05	0.03	-0.0095	0.0005	24.93
80.00	-1.12	0.04	-0.0102	0.0007	33.10
100.00	-1.22	0.05	-0.0111	0.0009	41.21
107.00	-1.27	0.06	-0.0115	0.0011	43.91
UCS (MPa)	**43.91**	**Elastic Modulus (Gpa)**	**41.996**	**Poisson Ratio**	**0.09**

Table.3. Uniaxial Compressive Strength of Iron Ore Samples

Sample Dimension			**Sample No**	**4**
Sample Diameter	mm	55	Rock Type	Magnetite
Sample Height (L_0)	mm	110	Dry	√
Area	cm²	23.77	Depth	Surface sample
Sample Volume	cm^3	261.45	Saturate	

Test Result

Vertical Load (KN)	**Deformation (mm)**		**Axial Strain (εa)**		**Vertical Stress (MPa)**
	Axial	**Lateral**	**Axial**	**Lateral**	
0.00	0.00	0.00	0.0000	0.0000	0.00
20.00	-0.24	0.00	-0.0022	0.0000	8.41
40.00	-0.38	0.00	-0.0035	0.0000	16.83
60.00	-0.47	0.01	-0.0043	0.0002	25.14
80.00	-0.55	0.02	-0.0050	0.0004	33.38
100.00	-0.60	0.03	-0.0055	0.0005	41.55
120.00	-0.69	0.04	-0.0063	0.0007	49.65
125.00	-0.72	0.05	-0.0065	0.0009	51.51
UCS (MPa)	**51.51**	**Elastic Modulus (Gpa)**	**50.766**	**Poisson's Ratio**	**0.16**

Table.4. Uniaxial Compressive Strength of Iron Ore Samples

Sample Dimension			**Sample No**	**14**
Sample Diameter	mm	55	Rock Type	Magnetite
Sample Height (L_0)	mm	110	Dry	√
Area	cm²	23.77	Depth	Surface sample
Sample Volume	cm^3	261.45	Saturate	No

Test Result

Vertical Load (KN)	**Deformation (mm)**		**Axial Strain (εa)**		**Vertical Stress (MPa)**
	Axial	**Lateral**	**Axial**	**Lateral**	
0.00	0.00	0.00	0.0000	0.0000	0.00
20.00	-0.40	0.00	-0.0036	0.0000	8.41
40.00	-0.46	0.00	-0.0042	0.0000	16.83
60.00	-0.54	0.01	-0.0049	0.0002	25.14
80.00	-0.62	0.01	-0.0056	0.0002	33.52
100.00	-0.72	0.02	-0.0065	0.0004	41.72
120.00	-0.75	0.03	-0.0068	0.0005	49.86
140.00	-0.80	0.04	-0.0073	0.0007	57.93
160.00	-0.84	0.04	-0.0076	0.0007	66.20
180.00	-0.89	0.05	-0.0081	0.0009	74.17
200.00	-0.93	0.05	-0.0085	0.0009	82.41
220.00	-0.98	0.06	-0.0089	0.0011	90.28
UCS (MPa)	**90.28**	**Elastic Modulus (Gpa)**	**72.869**	**Poisson's Ratio**	**0.15**

Table.5. Uniaxial Compressive Strength of Iron Ore Samples

Sample Dimension			**Sample No**	**17**
Sample Diameter	mm	55	Rock type	Magnetite
Sample Height (L_0)	mm	110	Dry	√
Area	cm²	23.77	Depth	Surface sample
Sample Volume	cm^3	261.45	Saturate	No

Test Result

Vertical Load (KN)	**Deformation (mm)**		**Axial Strain (εa)**		**Vertical Stress (MPa)**
	Axial	**Lateral**	**Axial**	**Lateral**	
0.00	0.00	0.00	0.0000	0.0000	0.00
20.00	-0.15	0.01	-0.0014	0.0002	8.38
40.00	-0.60	0.02	-0.0055	0.0004	16.69
60.00	-0.87	0.03	-0.0079	0.0005	24.93
80.00	-1.00	0.04	-0.0091	0.0007	33.10
UCS (MPa)	**33.10**	**Elastic Modulus (Gpa)**	**45.515**	**Poisson Ratio**	**0.07**

Table.6. Uniaxial Compressive Strength of Iron Ore Samples

Sample Dimension			**Sample No**	**18**
Sample Diameter	mm	55	Rock Type	Magnetite
Sample Height (L_0)	mm	110	Dry	√
Area	cm²	23.77	Depth	Surface Sample
Sample Volume	cm^3	261.45	Saturate	No

Test Result

Vertical Load (KN)	**Deformation (mm)**		**Axial Strain (εa)**		**Vertical Stress (MPa)**
	Axial	**Lateral**	**Axial**	**Lateral**	
0.00	0.00	0.00	0.0000	0.0000	0.00
20.00	-0.38	0.00	-0.0035	0.0000	8.41
40.00	-0.52	0.00	-0.0047	0.0000	16.83
60.00	-0.63	0.01	-0.0057	0.0002	25.14
80.00	-0.75	0.01	-0.0068	0.0002	33.52
100.00	-0.80	0.02	-0.0073	0.0004	41.72
120.00	-0.85	0.03	-0.0077	0.0005	49.86
140.00	-0.90	0.03	-0.0082	0.0005	58.17
160.00	-0.94	0.04	-0.0085	0.0007	66.20
180.00	-1.02	0.04	-0.0093	0.0007	74.48
200.00	-1.06	0.05	-0.0096	0.0009	82.41
220.00	-1.10	0.06	-0.0100	0.0011	90.28
240.00	-1.15	0.07	-0.0105	0.0010	98.09
UCS (MPa)	**98.09**	**Elastic Modulus (Gpa)**	**79.113**	**Poisson Ratio**	**0.12**

Table.7. Uniaxial Compressive Strength of Iron Ore Samples

Sample Dimension			**Sample No**	**19**
Sample Diameter	mm	55	Rock Type	Magnetite
Sample Height (L_0)	mm	111	Dry	√
Area	cm²	23.77	Depth	Surface Sample
Sample Volume	cm^3	263.82	Saturate	No

Test Result

Vertical Load (KN)	**Deformation (mm)**		**Axial Strain (εa)**		**Vertical Stress (MPa)**
	Axial	**Lateral**	**Axial**	**Lateral**	
0.00	0.00	0.00	0.0000	0.0000	0.00
20.00	-0.44	0.00	-0.0040	0.0000	8.41
40.00	-0.58	0.01	-0.0052	0.0002	16.76
60.00	-0.72	0.02	-0.0065	0.0004	25.03
80.00	-0.82	0.03	-0.0074	0.0005	33.24
100.00	-0.92	0.04	-0.0083	0.0007	41.38
111.00	-1.10	0.04	-0.0099	0.0007	45.93
UCS (MPa)	**45.93**	**Elastic Modulus (Gpa)**	**53.247**	**Poisson Ratio**	**0.09**

Table.8. Uniaxial Cmpressive Strength of Ore Samples

Sample Dimension			**Sample No**	**20**	
Sample Diameter	mm	55	Rock Type	Magnetite	
Sample Height (L_0)	mm	111	Dry	√	
Area	cm²	23.77	Depth	Surface Sample	
Sample Volume	cm³	263.82	Saturate	No	
Test Result					
Vertical Load (KN)	**Deformation (mm)**		**Axial Strain (εa)**		**Vertical Stress (MPa)**
	Axial	**Lateral**	**Axial**	**Lateral**	
0.00	0.00	0.00	0.0000	0.0000	0.00
20.00	-0.44	0.00	-0.0040	0.0000	8.41
40.00	-0.56	0.01	-0.0050	0.0002	16.76
60.00	-0.67	0.02	-0.0060	0.0004	25.03
80.00	-0.71	0.03	-0.0064	0.0005	33.24
100.00	-0.76	0.03	-0.0068	0.0005	41.55
120.00	-0.81	0.04	-0.0073	0.0007	49.65
140.00	-0.90	0.04	-0.0081	0.0007	57.93
144.00	-1.05	0.05	-0.0095	0.0009	59.34
UCS (MPa)	**59.34**	**Elastic Modulus (Gpa)**	**63.896**	**Poisson's Ratio**	**0.11**

Table. 9. Brittle Index of Iron Ore Samples Obtained from Haji Gak Mine**.**

Sample No	**Uniaxial Compressive Strength (Mpa)**	**Uniaxial Tensile Strength (Mpa)**	**Brittle Index**
3	43.91	22.73	1.93
4	51.51	3.26	15.80
17	33.10	7.23	4.58
19	45.93	13.81	3.33

DISCUSSION

Haji Gak iron ore mine located in central part of Afghanistan with 1.8 Billion tons reserve of iron ore, but still un extracted, it is the first time that mechanical properties of iron ore studied for future exploitation purpose [30]. Mechanical properties are the major influential factor of rocks in response and resistance to external loading and stretching in drilling and blasting operation of mining activities. Strength properties are one of the most important mechanical properties of rock that includes such as uniaxial compressive strength, uniaxial tensile strength, point load strength, etc, which demonstrates the loading limit of a rock could be afford and its plastic behavior [22], rock stability, and rock drill ability during drilling process and blasting efficiency, in addition helps to design of optimum blasting parameters, proper drilling machineries, loading equipments. Especially uniaxial compressive strength is essential in evaluation the stability of rock structures against loads. Whereas the test is time consuming, and expensive [31].

The next one is elastic properties of rock that could be found during the laboratory tests and calculation of rock strength such as Young's modulus, Poisson's ratio, etc. These describe the elastic nature or elastic deformation of rock under loading which is very significant in understanding failure types and fragmentation of rock in drilling blasting process. In addition the modulus of elasticity or Young's modulus is characteristics the rigidity of rock and shows the capacity of rock to resist external influences.

The mechanical behavior of rock could be describe through water contains or/and water saturation. This property of rock more effective and essential in selection of explosive type such water resisting explosive, efficiency of blasting, and decreasing strength of rock. The mentioned mechanical properties of rock related to each others, suppose the rock with high uniaxial compressive strength, shows lower value of Poisson's ratio higher value of Young's Modulus with less amount of water contain.

V. CONCLUSION AND FUTURE SCOPE

The influence of loading rate on rocks is different, depending on the rock type, rock properties, geological structure, and rock formation in drilling blasting process. In current study, research done on some mechanical properties of iron ore of Haji Gak mine to optimum drilling blasting process in future blasting design of exploitation. The finding of current study as follows,

The strength of rocks plays important roles in the blasting process. The experiments shown that the axial point load strength ($I_{S(50)}$) of studied iron ore samples in a range of (2.6-18.18) Mpa (Table. 1) that maximum value located in station No-2, and the diametric point load strength ($I_{S(50)}$) values in a range of (3.5 - 7.4) Mpa.
The calculation of point load strength showed 3.26-22.73 Mpa of uniaxial tensile strength (T_0).

Uniaxial compressive strength values of studied samples limited in a range of (33.10-98.09) Mpa. The maximum values shown in station no.18, 14, and 20, whereas the minimum values in station no. 17, 3, 19, and 4 respectively. According the ISRM standard terminology the uniaxial compressive strength of studied samples of interested area is moderate (25–50 MPa), medium (50–100 MPa), and high (100-250 MPa). The uniaxial compressive strength is very important index to relevant to iron ore blasting design and geo mechanics for mining. The test result shown the studied area's rocks have moderate, medium and high uniaxial compressive strength with elastic nature which good utilize stress energy and cause to better fragmentation in rock blasting operation of mining activities.

The young's modulus or elastic modulus (E) is one of the important geo-mechanical characteristic of rock mass which affects the blasting result and plays significant role in blasting design of mining activities especially in uses of explosive type and bits selection. The elastic modulus is in a rage of (42 - 79) Gpa for iron ore samples of studied area, it reveals that station No.11 has the high value of elastic modulus (Table.2), whereas the rock with high elastic modulus, its deformation property is less. Then this station shows low deformation rate of rocks with more stiffness. As well as it is difficult for the explosive gases to compress and stretch the rock if young's modulus of the rock is high. It is found that gas pressure should be less than 5% of young's modulus for efficient blasting.

The Poisson ratio (ν) of collected ore samples are limited in a rage of (0.07- 0.16). The rock possessing the lowest Poisson's ratio fails directly by a brittle failure and those having a high Poisson's ratio fail by plastic means. Then the station No. 10 has a lower value of Poisson's ratio that indicates to fail directly by brittle failure and given better fragmentation in blasting process. The Poisson's ratio of rock increases while liquid saturation occurs and burial depth increases, but cracks tend to lower the value of Poisson's ratio. In addition the rock may be has the Poisson's ratio value around 0.15 which located close to surface with dry and highly weathered condition, as the studied iron ore samples belong to surface and having same condition of these criteria. The finding of current research, the studied ore samples of Haji gak mine shows lower Poisson ratio that indicates this area's rocks fail directly by brittle failure and given better fragmentation in blasting operation.

Blast ability is another important index to evaluate drilling efficiency in different drilling blasting process. It is the resistance of the rock to blasting, the major influential factor on blastability is strength and brittle index of the rock.

Brittle index is the ratio of uniaxial compressive strength per uniaxial tensile strength. The higher brittle index indicates the rocks are easier to blast. The test of studied iron ore samples shown the lower brittle index of iron ore samples that indicates these rocks are defficult to blast (Table.9).

Rock drill ability is directly related to hardness, toughness, and strength of rock such compressive strength, tensile strength i.e. the higher strength rock is more difficult to drill as well as would be more stable. The rock classifications by drill ability presented in terms of uniaxial compression strength. As the UCS of studied area is moderate and medium thus it is assume medium drill ability. In addition drill ability is related to specific gravity of rock, rate of penetration, and drill bit wear.

Stability of rock in triaxial compression is more than the uniaxial compression. The statibilty of iron ore in tensile strength limited to 20-45 kg/cm^3 and in uniaxial compressive strength is 400-800 kg/cm^3.

The elastic rocks have high compressive strength and high elastic modulus and transmit stress waves well, therefore cause greater fragmnetation result. Thus the samples test of studied area shown elastic type of rocks by having high value of compressive strength, that cause to good fragmentation of rocks. In same case, selection of proper explosive could be obtain good result of fragmentation. Although the strength of the rocks is an important criteria in selection of explosive type.

The strength of rock mostly affects by water contains. While the water saturation and moisture level increased, the strength of rock decreases. The decease rate of strength could be in a range of 8% till 98%, this variation rate depending on texture, mineralogy of rock, and the fluid chemistry. Higher moisture content of rock lowers rock strength and Elastic modulus in both frozen and unfrozen condition, but in normal ambient temperature the strength of water saturated rock is less about 60% of the strength of oven dry rock as well as the deformability increases with increasing water content. The effect of water moisture on Poisson's ratio is complicated. Maybe increases and/or decreases, constant remain in higher water saturations.

SUGGESTION

The authors would like to recommend that this study be considered as a starting point of an intensive study in Haji Gak iron ore mine and major research in a large scope in development of mining sector of Afghanistan. The authors would like to suggest that the research should be continued and more research should be conducted on the different aspects of exploitation's process of this valuable and great iron ore mine to introduce Afghanistan as iron ore production country in national and international level.

FUTURE WORK

To enhancement of blasting operation the individual area of interest should be surveyed in very accuracy level and data collection should be done for entire tests, analysis and experiments based on ASTM standard from individual stations with higher altitudes and fresh samples for more accuracy.

To optimum blasting operation, the blasting design should be done base on rock properties results, geology of area, accessible and economical explosive, proper drilling machinery, and suitable loading equipments as well as should be taken the environmental impacts issues in blasting design such as sound pollution, air pollution, and water pollution issues. Especially the habitant and villages located close to the blasting area.

To understanding iron ore characteristics of Haji Gak mine for mining purpose, more research and study should be conducted on another two sub areas of this mine (Farengal Subarea and NE Haji gak subarea).

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Appendix

Table. 10. Coordinate of Iron Ore Samples Obtained from Haji Gak Mine**.**

Station No	Sample No	Coordinates		Altitude (M)
		Northern	Eastern	
2	2 3 4	34° 40′ 13.96″	68° 04′ 16.53″	3582.0
6	11	34° 39′ 57.01″	68° 04′ 07.46″	3459.8
7	14	34° 40′ 12.24″	68° 04′ 03.18″	3627.4
8	15	34° 39′ 56.2″	68° 04′ 07.50″	3460.0
10	17	34° 39′ 59.91″	68° 04′ 16.36″	3437.2
11	18	34° 40′ 15.86″	68° 04′ 11.62″	3588.0
12	19	34° 40′ 19.67″	68° 04′ 05.10″	3695.0
13	20	34° 40′ 12.57″	68° 04′ 19.34″	3579.6

Table. 11. Field Estimates of Rock Uuiaxial Compressive Strength [14]

	UCS (MPa)	Field Characteristics
Extremely strong	> 250	Specimen can only be chipped with a geologic hammer
Very strong	100- 250	Specimen requires many blows of a geological hammer to fracture it
Strong	50-100	Specimen requires more than one blow to fracture it
Medium strong	25-50	Cannot be scraped or peeled with a pocket knife. Specimen can be fractured with a single blow

		from a geological hammer.

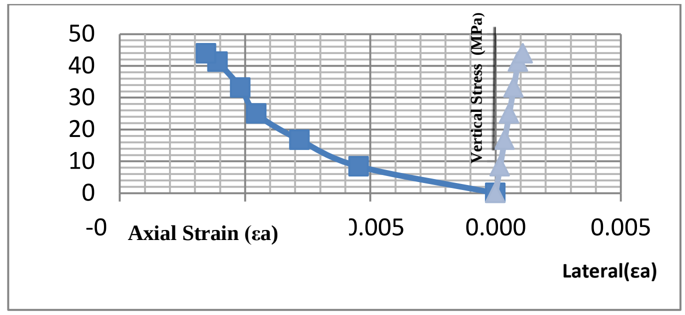

Fig. 3. Stress and Strain Curve of Sample No. 3

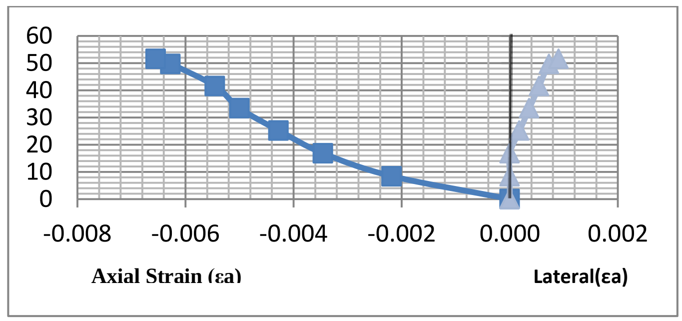

Fig. 4. Stress and Strain Curve of Sample No. 4

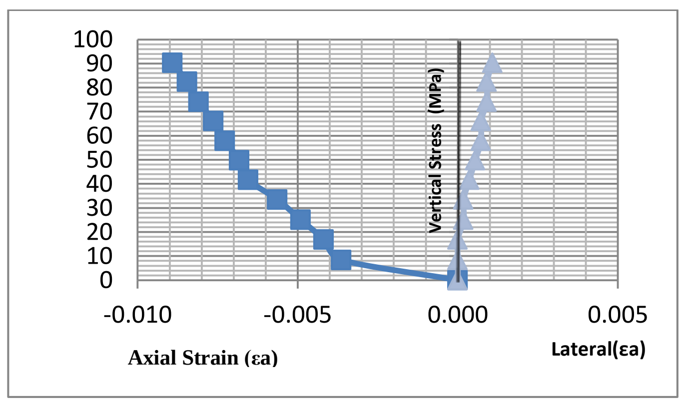

Fig. 5. Stress and Strain Curve of Sample No. 14

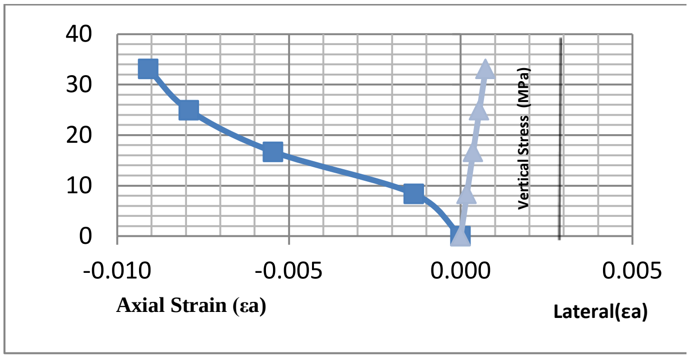

Fig. 6. Stress and Strain Curve of Sample No. 17

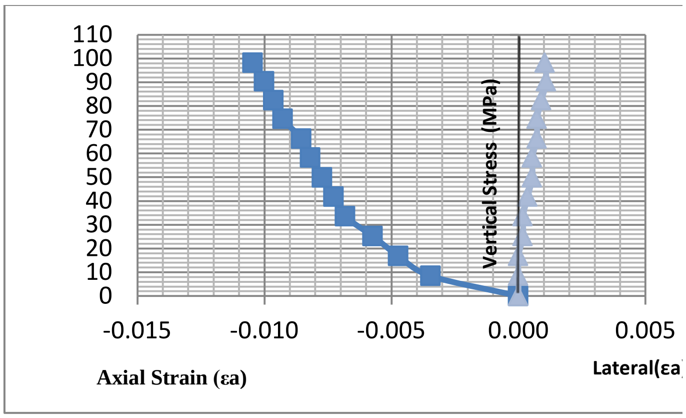

Fig. 7. Stress and Strain Curve of Sample No. 18

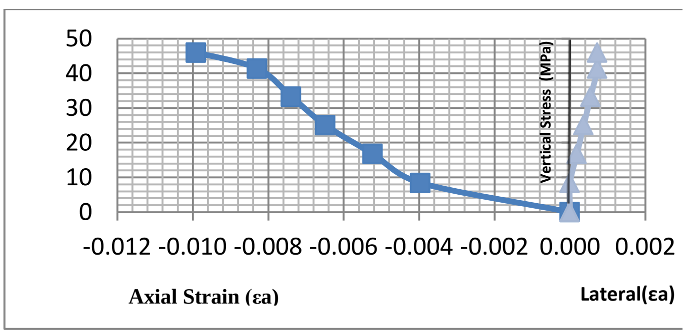

Fig. 8. Stress and Strain Curve of Sample No. 19

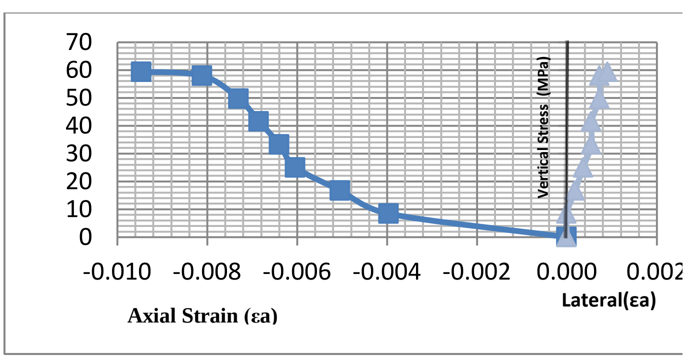

Fig. 9. Stress and Strain Curve of Sample No. 20

