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Laboratory Study of Basalts from Central India

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Abstract: In the present study, four basaltic variants of dense formation, from Central Indian region, were investigated for various geotechnical properties and parameters in laboratory. The variants were drawn – one from Central India, C (Waingangā basin), two from West-Central India, CW1 &CW2 (Betwa basin) and one from Western India, W (Damanganga basin). The assessments include: (i) density; porosity; slake durability; and (ii) point load strength index (diametric and axial); indirect tensile strength; uniaxial compressive strength, Tangent Modulus(E), Poisson's ratio(μ), shear strength parameters (c and ϕ) all in saturated state. In respect of all the assessed engineering parameters the Central India basalts are found to be lower strength than other variants of basalt. The existence of vesicles on surface of dense basalt from Central India(C), even in small quantities, resulted in substantial reduction of strength and deformability parameters with the exception of tensile strength. Rest of properties and parameters are similar in comparison with all basalts.
Keywords: dense basalt, laboratory assessment, uniaxial compressive strength, engineering parameters

1. Introduction

Basalt is an extrusive igneous rock, which formed from rapid cooling of magma near Earth's surface. During process, the gas bubbles may entrap in the volcanic lava. After cooling, these entrapped bubbles transform into vesicles. Sometimes, these vesicles may fill up with secondary minerals such as quartz, calcite or olivine. For massive or dense basalt, the presence of vesicles on surface shall deteriorate the engineering behavior of rock [1]-[3]. Hence, careful observation of intrinsic surface features of a rock is very essential in arriving representative property or parameter of an investigated rock.

The present study involves laboratory investigation of geotechnical properties and parameters of Dense or Massive Basalt from four different locations in the Central Indian region. The variants were drawn – one from Central India, C (Waingangā basin), two from West-Central India, CW1 &CW2 (Betwa basin) and one from Western India, W (Damanganga basin). In saturated condition, these rocks have been assessed for strength parameters – uniaxial compressive strength with deformability characteristics i.e., tangent modulus and Poisson's ratio, indirect tensile strength (Brazilian), apparent cohesion and angle of internal friction (through triaxial test), and point load strength index. In addition, the water-related and identification properties are discussed for rock variant. These include: water content at saturation, apparent porosity, slake durability index (first, and second, cycle), bulk density (dry and saturated, both) and grain density.

2. Methodology

As per ISRM suggested methods [4], dense basaltic rock has been assessed for different properties and parameters. The Uniaxial Compressive Strength and deformability characteristics are assessed using NX size i.e 54mm, saturated specimens, with length to diameter ratio of 2.5. The Indirect Tensile Strength is assessed using NX size saturated specimens, with length to diameter ratio of 0.5. The justification of the test is based on the experimental fact that most rocks in biaxial stress fields fail in tension at their uniaxial tensile strength when one principal stress is tensile and the other finite principal stress is compressive with a magnitude not exceeding three times that of the principal tensile stress.

For triaxial compression test, Hoek cell was employed, and saturated specimens, with length to diameter ratio of 2, were tested over the desired range of confining pressure. The Strength Envelops are drawn and shear strength parameters (i.e., c and ϕ) evaluated. Using NX size cylindrical samples, Is(50) is evaluated in saturated state – under diametral and axial, both, types of loading. The test is considered valid only if the failure plane passes through both the loading points. As per standard, size correction is subsequently applied to make it correspond to 50mm size sample.

3. Results and Discussion

Table 1 shows UCS, static deformability characteristics (E and μ), cohesion (c), angle of internal friction (ϕ), $\sigma_{t(sat)}$, and $I_{s(50)sat}$ in both diametral and axial conditions, for dense basaltic variants from different locations of India, namely-Western(W), West-Central(CW1&CW2) and Central(C).

3.1 Uniaxial compressive strength

Table-1 reveals that the representative values of the Uniaxial compressive strength(UCS)(or σc(sat))

indicates that dense basalt from Central India(C) failed at very low strengths compared to CW1 (around 30%). Figure 1 shows variation of UCS for four variants of basalt. Similar to UCS, variation in tangent modulus (E) data for four variants is shown in Fig.2. The variation of E is different for CW1 and CW2. The value of E for W is 40% that of CW2.

The basalt variant from Central India shows vesicular formation on surface. Even though, these vesicles in small quantities, the reduction in strength and tangent modulus is substantial for Central India basalts in comparison with other variants of basalts. It is therefore, quantification of vesicular forms is greatly necessary in assessment of strength of basaltic rocks and to arrive a representative parameter. Figure 3 shows the failed samples of Central India basalts. Most of the samples were failed axially. For Central India having vesicles has resulted failure along chain of vesicles under uniaxial compression.

Table 1: Strengths (in saturated state) of Dense Basalt

Parameters	*W*	*CW1*	*CW2*	*C*
$\sigma_{c(sat}$ (MPa)	55	100	70	35
E (GPa)	55	65	80	35
Poisson's ratio, μ	0.25	0.28	0.29	0.25
c (MPa)	4.5	4.5	4	3.5
φ (Degrees)	50	55	50	50
$\sigma_{t(sat)}$ (MPa	11	11	13	10
$I_{s(50)sat-Dia}$(MPa)	5	9.5	7	9
$I_{s(50)sat-Axial}$ (MPa)	6	9.5	7	11

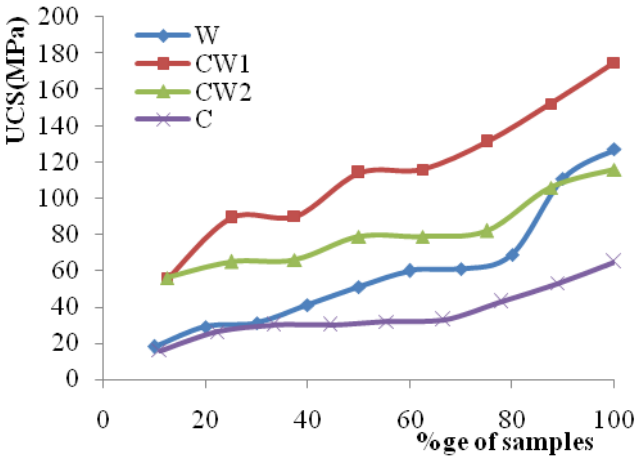


Figure 1 : Variation of UCS

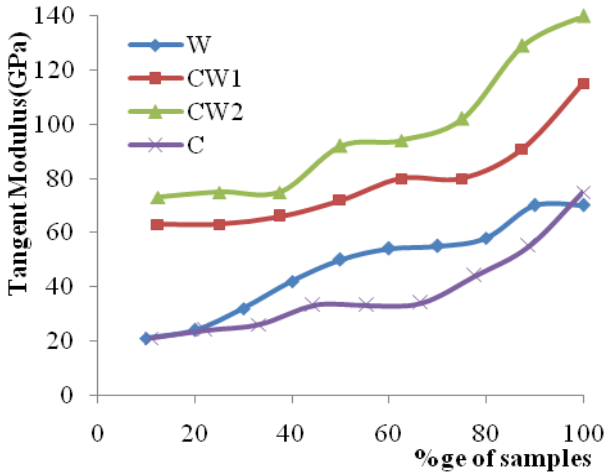


Figure 2 : Variation of tangent modulus (E)

Figure 3: Failed samples of Central India basalt

3.2 Indirect Tensile Strength (Brazilian)

Figure 4 shows the variation of Brazilian strengths for four variants of basalt. It infers that except the result of CW2((steeply varies from 40 to 90%), other values of $\sigma_{t(sat)}$ from W, CW1 and C are consistent from 10 to 90%, hovering around 11MPa.

Unlike in the case of uniaxial compressive strength, Central India basalt has shown better improvement in Brazilian strength. It is inferred that existence of vesicular forms on surface of small size samples (L/D=0.5) has minimum effect on tensile strengths compared to large scale samples (L/D=2.5) tested under uniaxial compression.

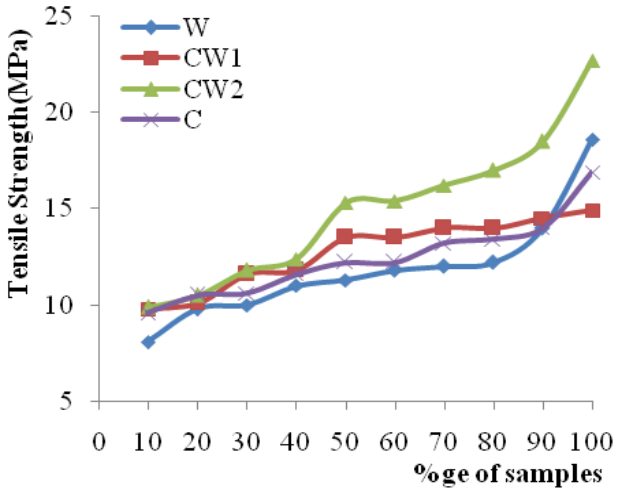
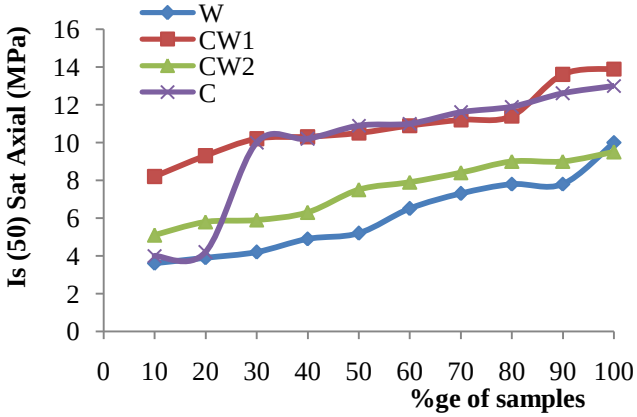


Figure 4 : Variation of tensile strength

Figure 5 : Failed samples of basalt (C)

3.3 Other properties

In case of other properties like shear strength and point load indices both under axial and diametral loadings (Figure 6 & Figure 7) for all the variants of basalts the variation is marginal. However, basalts from Damanganga basin have shown lower strength in comparison with the rest of variants.



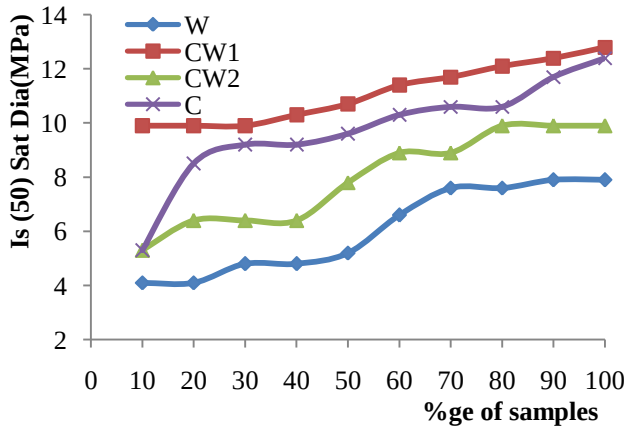


Table 2 shows water-related and identification properties. The bulk density (dry and saturated) and grain densities of Central India basalts were marginally lower in comparison with the rest of variants. It is inferred that, the vesicular structure with secondary mineral fillings in Central India basalts has resulted in lower densities.

Table 2: density and durability properties of basalts

Properties	*W*	*CW1*	*CW2*	*C*
w.c(%)	2.5	3	2	2
n (%)	7	8	6.5	5.8
$S.D.1_1$ (%)	98.5	99	99	98.5
$S.D.I_2$ (%)	98	98.5	98.5	98
$\gamma_{dry}(kg/m^3)$	2750	2700	2810	2720
$\gamma_{sat}(kg/m^3)$	2800	2780	2870	2760
$\gamma_{grain}(kg/m^3)$	2840	2810	2910	2810

The Anisotropy index, is "the ratio of $I_{s(50)}$ under axial loading to diametral loading". It is 1.2 (for W and C) and 1(for CW1 and CW2). The foregoing clearly demonstrates that the uniaxial compressive strength cannot be taken as a fixed multiple of either the point load strength index or the tensile strength, even when the rock involved has little, if any, strength anisotropy.

4. Conclusions

In the present study, four basaltic variants of dense formation, from Central Indian region, were investigated for various geotechnical properties and parameters in laboratory. Based on the results, the following conclusions were drawn.

The existence of vesicles on surface of dense basalt from Central India(C), even in small quantities, has resulted in substantial reduction of strength and deformability parameters. In the case of tensile strength, an improvement of strength was noticed due to insignificant effect of vesicles on small scale samples (l/d 0.5). Rest of properties and parameters are similar in comparison with all basalts.

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