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Study of Tensile Strength of Marble Stone (Indian White) and Black Granite Stone (Indian Black) With Ring Test by Varying Inner to Outer Diameter of A Disc

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Abstract -Rocks are weaker in tension compared to compression so tensile strength plays a very important role in rock engineering. Basically, rock structure designer avoid the tensile stresses in construction of tunnel & underground mines etc. Therefore it is very important to calculate the tensile strength of rock material before execution the project then it proofs economical. We can measure the tensile strength by various methods i.e by Direct method or Indirect methods. To measure the direct tensile strength is very difficult due to problem in gripping the rock specimens & applying a load parallel to the longitudinal axis. In other side we can measure tensile strength indirectly by various indirect methods. The indirect methods for measuring tensile strength are: Brazilian test, ring test. The drawback of brazilian test is that along the tensile stresses, shearing stresses also developed in the sample so for exclude this drawback we use ring test. This ring test gives the tensile stresses value with excluding the shear stresses. So in this report the tensile strength is calculated by ring test indirect method.
Keyword-Indirect tensile strength

I. INTRODUCTION

As we know that rocks have good strength. Sometimes reference is made that "strong like as rock". It has been noticed that rocks have very high compressive strength as compared to other materials which are used for construction. But it has been found that rocks are strong in compression & very weak in tensile strength/stresses. Tensile strength is low due to cracks available in the rock. This presence of cracks may fail the rock in tension even a small deformation. Rocks are subjected to high tensile stresses in many civil engineering projects such as around underground openings in tunnels & mining areas. The rocks also subjected tensile stresses when rocks are located in a slope surface or under the abutment. Tensile stresses in rocks also generated due to blasting & when drilling in a rock. At the time of determining the tensile strength of rock we face so many difficulties. As we know that rock is a brittle material & fail under very low tensile stress. So analysis the tensile strength cautiously. The simple & original way of measuring tensile strength of rock is apply pull to the rock sample but it is not done with the rock sample due to difficulty in making sample, apply loading & eccentricity is also generated. This direct method (i.e simply pull) is easily done for calculating the tensile strength of bar or any metal. Because metals have some amount of ductility & high tensile strength. So at the time of pulling a bar if small amount of eccentricity produced then it does not create problem. It is also recorded that when grip the sample of rock from the ends then it transfer the stresses in an non uniform way & results comes erroneous. So to avoid these types of problem with direct tensile strength measurement the indirect methods for calculating the tensile strength have been came from time to time. Normally before a large construction like the construction of a dam or tunnel it is common to drill holes for obtaining the data regarding rock which would be underneath or surrounding the structure. During this rock is obtained in cores. If we conduct test on the sample which is obtained from rock core, it save amount of money & time both. Such a test has been used & is known as ring test. This is an indirect method for determining the tensile strength of rock & this same test is adopted in this study. In this Paper we calculate the tensile strength of marble & granite both. The study of tensile strength for construction in hilly region is very important. Basically, rock structure designer avoids the tensile stress in construction of tunnels & underground mines etc. Therefore it is very important to calculate the tensile strength of the rock by appropriate method i.e by indirect method. When we know the tensile strength of the rock material before execution the project then it proofs economical. For calculating this tensile strength we require accurate relations such as external diameter, internal diameter, thickness, applied load, best test procedure, test sample etc.

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A. Various Methods Are Used For Calculating The Tensile Strength Of Rock

1) *Direct method:* Tensile strength may be defined as the maximum tensile stresses developed without any deformation against external tensile load. When a rock slab or beam subjected to bending then along with tensile stresses also generated. But rock is weak in tension we take average tensile strength is one tenth of its compressive strength. So for this method select a cylindrical, prismatic, dog-bone or dumbbell shape specimen. Then apply tensile load to a rock. But this is difficult to perform this test due to difficulty in making sample, gripping problem at two ends. So due to difficulty with direct tensile strength test we prefer indirect test method. Obert, windes and dunall (1945) used a grip as shown in fig (1) shown below, in this a cylindrical specimen of size 116 inch to 218 inch and 4 inch length is held in place with lead. The test sample forms a bearing surface around each of its end. But leading compound is not suitable to hold specimen of tensile strength greater than 8.27 M.Pa (1200 lbs/in2)

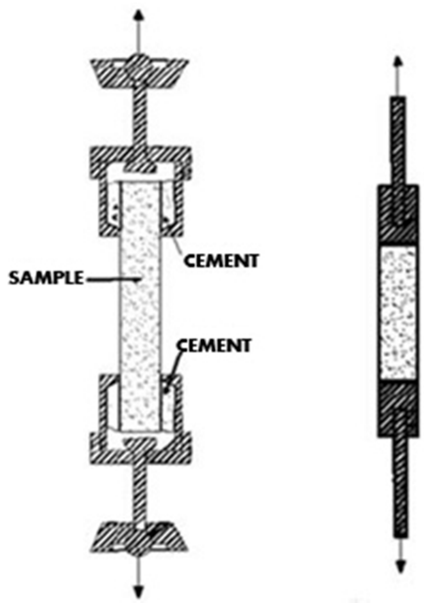

Fig 1. Direct tensile strength test

Wuerker (1955)[3] used briquent shaped sample (fig. 2 b) from rock in different ways; the major difficulty in this method is in the preparation of test sample. Fairhuat (1961) is in the view that a typical method using ¾ inch to 1 inch dia and 2 inch length sample with epoxy resign as a cementing (gripping) material.

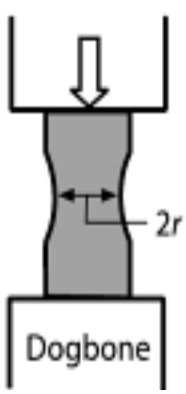

Fig 2 (a) dog bone type sample

Fig 2 (b) briquette type sample

In these direct methods of tensile strength, there are some drawbacks as if there is any plane of weakness; the failure will take place along that plane and then gives wrong results.

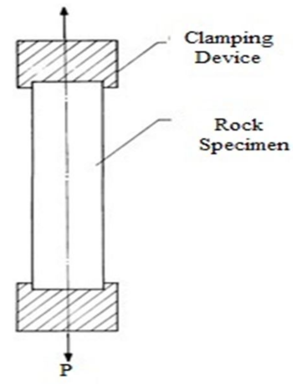

Fig 3 layout for a direct tensile test

2) *Indirect Method:* Due to difficulty in performing direct tensile strength test this indirect tensile strength method become popular. There are many indirect methods are available such as

a) *Brazilian test*: For this test requires a thin disc shape specimen which is cut out by diamond saw. A disc is any circular solid piece without any central hole. Which is easily prepare & should be smooth boundary & test procedure involves apply compressive load diametrically on a disc by compressive testing machine gradually till failure takes place. One loading platen should be fixed & other will be move by the effect of external load & apply compressive load on the specimen. We apply loading rate is 200 N/sec. continuously so that rock fails within 15 to 30 sec. A force/displacement recorder should be attached with machine so that we record the load of primary fracture precisely. Although we apply load is compressive but specimen fails due to induce of tensile stresses in the specimen. So by this method we can easily measure the tensile strength of the rock indirectly but the main drawback of this test is that along the tensile stresses, shearing stresses also generated in the specimen & this drawback is overcome by ring test & now a day mostly engineers prefers ring test for calculating tensile strength of the rock. The detailed analysis of the Brazilian test by Fairhust (1964)[5], as early as 1964 has indicated that the failure of the disc may occur away from the centre of the test disc for small angles of loading contact area with materials of low compressive – tensile strength ratios. In this case, the tensile strength calculated from the test result is lower than the actual value. It has been studied (Sundaram and Corrales, 1980) that if the elastic properties of rock in tension by the Brazilian test (fig 4) could lead to erroneous results.

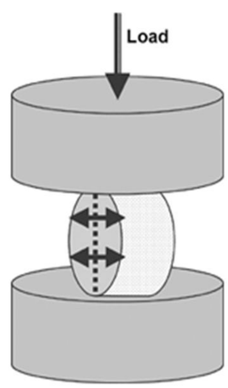

Fig 4 brazilian test

Calculation

Tensile strength of rock can be calculated by Brazilian test from given below expression

$$\sigma_B = \frac{2F}{\pi DT}$$

σ_B= Brazilian tensile strength in Kg/cm^2
F= Failure load in Kg

D= diameter of the specimen in cm
T= Thickness of the specimen in cm

b) *Ring test*: This is also an indirect tensile strength test. This test is used to remove the drawback of Brazilian test. Because in Brazilian test main drawback is when we apply compressive load by compressive testing machine then along the tensile stresses, shearing stresses also induce in the sample & Sometimes failure starts from loading points with the generation of wedges. This is not the correct mode of failure, so to overcome this drawback we put a central hole in the Brazilian specimen (disc sample) & then on this ring specimen we apply the compressive load by unconfined compression testing machine & whole of the procedure of testing also same as that of Brazilian test. So we make main difference between these two test is, in Brazilian uses disc sample & in ring test uses ring specimen. This ring specimen gives only tensile stress value with excluding the shearing stresses & failure of sample also starts from centre & rises to the loading point which is desirable mode of failure. According to the stress distribution obtained by Hobbs (1964)[6] the stress σ_θ at the intersection of the loading diameter with the hole can be computed from the relation given below

$$\sigma_R = \frac{(2F(6+38(d/D)^2))}{\pi DT}$$

where, σ_R=Ring tensile strength KN/cm^2
d = Central hole diameter in cm
D = outer diameter in cm
T =Thickness of the sample in cm

3) *Objectives:* Marble, Granite (rock) is a brittle material. Both of them weaker in tension compared to compression or shear. So tensile failure also plays a very important role for both civil and rock mechanics application such as construction of tunnel, underground mining, drilling, cutting & blasting of rocks etc. However, rock structure designer usually neglected the tensile strength of rock. But rocks exist some amount of tensile strength, which is vary rock to rock. So if tensile strength of rock calculated before execution the project then it proofs economical. To measure the direct tensile strength we face problem. In other side we can easily measure the tensile strength indirectly by various indirect methods.

II. METHODOLOGY

Large slabs of the whitish marble and black granite were purchased from a stone company. Choose homogeneous without micro cracks with equal thickness slabs of whitish marble and black granite. Then according to number of specimen required, cut these slabs by diamond saw into number of cube blocks. When cutting of block in progress then we use water as a coolant for diamond saw blade & also for removing cutting small pieces from the job. Then after preparing marble blocks and black granite stone blocks were cored by a drilling machine fitted with diamond core barrel. After obtaining the core, finally finishing will done by diamond saw machine. We make flat uneven surface, as a properly rounded in shape. After collecting the number of circular discs of whitish marble and black granite stone. These circular discs were drilled centrally with drill bits of 20mm, 35mm &50mm.

By these bits we make central holes in whitish marble of d-20.8mm, 21.5mm, 22.7mm, 22.9mm, 25.0mm, 29.2mm, 30.6mm, 31mm, 35.2mm, 38mm, 39.8mm, 40mm, 41mm, 43mm, 45mm, 47.5mm, 50mm, 50.3mm, 55mm, 56.7mm, 58.3mm, 59.3mm, 60mm, 65.2mm. The central hole range from 20.8mm to 31mm called A series & from 35.2 to 47.5 mm called B series & from 50 to 65.2mm called C series of whitish marble.

SIMILARLY by drill bits of 20mm, 35mm &50mm make central holes in black granite stone of d-20.5mm, 21.4mm, 22.2mm, 23.2mm, 24.2mm, 28.6mm, 30.0mm, 33.8mm, 35.4mm, 37.5mm, 39.5mm, 41.0mm, 41.5mm, 42.8mm, 44.7mm, 47.2mm, 50mm, 50.8mm, 55.5mm, 57.0mm, 58.5mm, 59.5mm, 61.0mm, 65.0mm. The central hole range from 20.5mm to 33.8mm called L series & from 35.4 to 47.2 mm called M series & from 50 to 65.0mm called N series of black granite stone. Then all the specimens of whitish marble and black granite should be either air dried in open air for 15 to 20 days or oven drying at temperature of 60°C for 48hrs after the specimen preparation & then tested.

A. Procedure

1) The adhensive paper type of low strength should be wrapped around the periphery of each ring. This tape is used to preserve the whole ring after fracture.

2) After that this disc specimens with centrally hole i.e. ring specimen should be mounted between two loading platens designed to apply compressive load on the specimen. One by one with loading rate of 200 N/sec in such a way that no eccentricity will produce.
3) The number of specimens included with constant external diameter & varying diameter of central hole with constant thickness.
4) With the unconfined compression testing machine a force/displacement recorder were attached so from which we record the value of primary fracture & calculate the tensile strength of various samples individually.

III. RESULT AND DISCUSSION

A. Ring test result of white marble for A, B and C Series

Basically, we take 24 samples of marble stone and then these 24 samples are further divided into A series, B series, C series. These A series contain 1-8 samples, B series contain 9-16 samples, C series contain 17-24 samples.

By conducting ring test with varying inner to outer diameter of the ring sample we obtained the average tensile strength (σ_t) in KN/cm^2 . A specimen of A series having outer diameter i.e 10.3cm,10.5cm,10.5cm,10.5cm,10.4cm,10.5cm,10.4cm &10.6cm respectively with a inner central hole diameter are 2.08cm, 2.15cm, 2.27cm, 2.29cm, 2.50cm, 2.92cm, 3.06cm & 3.10 undergoes failure load from 3.4 KN to 2.2 KN (Compressive in nature) gives the average σ_t = 0.995 KN/cm^2.Then the result of A series shows that as the R=d/D increases the σ_t of the specimen decreases. This obtained result similar to Hobbs (1965) result.

Marble Sample series B shows that the outer diameters are 10.5cm, 10.5cm, 10.5cm,10.5cm,10.5cm,10.4cm, 10.5cm, 10.5cm respectively with diameters of central hole are 3.52cm, 3.8cm, 3.98cm, 4.0cm, 4.1cm, 4.3cm, 4.5cm, 4.75cm respectively. Shows the result of C series having ratio of inner diameter and outer diameter i.e value of R=d/D are 0.476, 0.479, 0.528, 0.542, 0.555, 0.570, 0.576, 0.620 gives the average σ_t is 0.805 KN/cm^2 & 0.389 KN/cm^2 respectively.

At last, from the results of ring test shows that if diameter of central hole of the ring increases causes tensile strength (σ_t) of the marble decreases. From the observation of ring test, that type of failure of ring sample is similar to Hobbs (1965) result.

B. Ring test result of granite stone for L, M, & N Series

Similarly, marble sample above take 24 samples of black granite stone and then these 24 samples are further divided into L series, M series, N series similarly to marble stone above. These L series contain 1-8 samples, M series contain 9-16 samples, N series contain 17-24 samples.

By conducting ring test with varying inner to outer diameter of the ring sample we obtained the average tensile strength (σ_t) in KN/cm^2. A specimen of L series having outer diameter i.e 10.5cm,10.4cm,10.6cm,10.5cm,10.6cm,10.3cm,10.5cm &10.4cm respectively with a inner central hole diameter are 2.05cm, 2.14cm, 2.22cm, 2.32cm, 2.42cm, 2.86cm, 3.00cm & 3.38 undergoes failure load from 8.1 KN to 3.2 KN (Compressive in nature) gives the average σ_t = 1.826 KN/cm^2. Then the result of L series shows that as the R=d/D increases the σ_t of the specimen decreases. This obtained result similar to Hobbs (1965) result.

Sample series M shows that the outer diameters are 10.5cm, 10.4cm,10.5cm,10.4cm,10.5cm,10.3cm,10.6cm,10.4cm respectively with diameters of central hole are 3.54cm, 3.75cm, 3.95cm, 4.10cm, 4.15cm, 4.28cm, 4.47cm, 4.72cm respectively. Shows the result of N series having ratio of inner diameter and outer diameter i.e value of R=d/D are 0.480, 0.49, 0.53, 0.543, 0.56, 0.570, 0.582, 0.622 gives the average σ_t is 1.016 KN/cm^2 & 0.62 KN/cm^2 respectively.

At last, from the results of ring test shows that if diameter of central hole of the ring increases causes tensile strength (σ_t) of the granite stone decreases like as marble. From the observation of ring test, that type of failure of ring sample is similar to Hobbs (1965) result.

C. Discussion of test result

1) Tensile strength of the marble and granite is estimated by ring test. In this indirect test, the outer diameter kept constant & inner diameter of the central hole varies.
2) The tensile strength directly depends upon the total volume of the sample. If the inner central hole of the sample varies then directly the tensile strength also varies & results shows that as the R=d/D increases the σ_t of the specimen decreases. The material is not perfectly elastic in nature so calculated stress is not real stress. This explanation creates importance for the ring test.

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COMPARISON OF MEAN TENSILE STRENGTH OF WHITE MARBLE AND BLACK GRANITE STONE

	White Marble	Black Granite stone
Indirect Tensile Strength	A series (1-8 samples) Mean Tensile strength in KN/cm^2 σ_t= 0.995	L series (1-8 samples) Mean Tensile strength in KN/cm^2 σ_t= 1.826
Indirect Tensile Strength	B series (9-16 samples) Mean Tensile strength in KN/cm^2 σ_t= 0.805	M series (9-16 samples) Mean Tensile strength in KN/cm^2 σ_t= 1.016
Indirect Tensile Strength	C series (17-24 samples) Mean Tensile strength in KN/cm^2 σ_t= 0.389	N series (17-24 samples) Mean Tensile strength in KN/cm^2 σ_t= 0.62

IV. CONCLUSIONS

A. Mean tensile strength of equal volume of samples of whitish marble & black granite is different. The tensile strength of the black granite stone is greater than whitish marble & strength point of view granite is better than marble.

B. Rock properties interference on tensile strength of the rock. Because we see that whitish marble have different properties than black granite stone. Due to this difference in properties the tensile strength is also different for both marble and granite stone.

C. The weight of equal volume of samples of whitish marble & black granite is also different. The weight of the black granite is higher than marble stone.

D. When the central hole diameter increase step by step in both white marble and black granite stone the volume of the test specimens goes decrease & due to this reason sample will fail at lesser tensile stress. i.e internal diameter is inversely proportional to tensile strength of the sample.

E. The tensile strength is not a material property because it depends upon the test method & sample size.

V. ACKNOWLEDGMENT

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