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Study on Mechanical Properties of Fiber Reinforced Vermucilite Concrete with Partial Replacement of Cement with Quarry Dust

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Abstract— **Concrete being the mostly used building material in the world out of its inherent strength and durability properties, yet it leads to the depletion of many natural resources like raw materials of cement limestone and other constituents like aggregates. Apart from this, it is very weak in tension because of its brittle nature. To enable the concrete with tensile nature the concept of fibre reinforced concrete has been develop my adding a variety of natural or synthetic fibers to the concrete. Also, the production of lot of by-products from the industries like quarry dust, metakaolin, fly ash putting a lot of thrust on environment as the quarry dust is directly released into the environment and there were no proper disposal methods. In the present study the mechanical properties of M30 grade of concrete with partial replacement of cement with quarry dust at 10%, 15%, 20%,25%, 30% and Vermiculite at 5%, 10%, 15%, 20%, and 25% replacement to fine aggregate. After getting the optimum, basalt fibres added to the concrete at 0.5%, 1%, 1.5%, 2%, 2.5% and 3%. From the experimental results it is found that the replacement of quarry dust and the vermiculite improved the strength properties of concrete with an optimum of 25% and 20% respectively. Addition of basalt fibers has increased the split tensile and flexural strength considerably at 2% optimum. Durability studies using 5% HCl has also resulted in enhanced performance compared with conventional concrete.**

Index Terms— **Fiber reinforced concrete, quarry dust, vermiculite, basalt fibers, durability**

1.INTRODUCTION

Vermiculite is a hydrous phyllosilicate mineral group and is micaceous in nature. It is found in so many parts of the world but only a limited number of sources are worked as commercial deposits. The vermiculite is mined and refined using as a variety of techniques and supplied commercially in a range of particle size grades of vermiculite concentrate (unexpanded).

Vermiculite owes its commercial utility to its property of exfoliation when heated. It exfoliates into a yellow to light bronze colored mass giving an appearance of a cluster of worms - vermicular, an Italian word for worm from which it has derived its name as vermiculite. Some authorities quote the Latin word vermicular from which the name vermiculite might be derived.

Vermiculite is the name used in commerce for a group of micaceous minerals that expand or exfoliate many times (commercial varieties exfoliate 8 to 20 times or more) the original thickness when heated. They show the characteristic micaceous structure of basal cleavage and occur as soft, pliable inelastic lamina. Their basal cleavages are not so perfect as those of mica. Vermiculite exists in so many colors from black through various shades of brown to yellow. Its chemical composition varies widely consisting of a complex hydrated aluminum, magnesium silicate and hence the analysis of the mineral is of little use in determining the vermiculite for commercial utility a technical trial of the material provides the only satisfactory test. Therefore, this is a process with several challenges and opportunities for improvement. It comes in two different forms with varying grades: crude and exfoliated.

1.1 Crude Vermiculite

Crude vermiculite is vermiculite that has not been heated or expanded and is divided into five primary grades based upon particle size. The grades are large, medium, fine, superfine and micron. Crude vermiculite from the mine consists of golden / brown

/ silver, flakes which are carefully classified into five grades – each having a specified range of particle sizes. The coarsest grade comprises particles ranging between 1mm and 7mm, while the finest grade consists of particles between 0.710mm and 0.250mm in size. The loose bulk density of crude vermiculite varies with the grade but is typically between 700 and 1050 kg/m^3.

1.2 Exfoliated Vermiculite

Exfoliated vermiculite is the most widely available in the marketplace. It too is available in five different grades, which are based upon weight rather than particle size. Like crude vermiculite, exfoliated vermiculite comes in micron, superfine, fine, medium, and large grades. The particular grade used depends upon soil needs and intended results. The exfoliation process is carried out commercially by-passing crude vermiculite through a furnace chamber in a controlled manner. The crude vermiculite then expands at right angles to the cleavage planes, producing concertina-shaped particles many times their original volume.

1.3 Vermiculite Structure and Chemical Composition

Vermiculite minerals are formed through the hydration of either biotite or phlogopite under the influence of weathering or hydrothermal alteration. This process involves the alteration of the parent biotite or phlogopite by the reaction of hydrothermal fluid (mostly hot water). During this process of vermiculite formation from mica minerals (biotite and phlogopite), which are bound together by strong assemblage of bonds and have low moisture content, there is a slight rearrangement of the atoms (cationic exchange) within the crystal lattice layers followed by the introduction of water molecules into the interlayer space. The interlayer potassium ions (K^+) of the parent mica are replaced by other cations such as Mg^{2+}, or combination of Mg^{2+} and Ca^{2+} ions. Vermiculite produced from this process has hydrated interlayer space and is bound together by a weak Van der Walls bonds. The weaker bond and presence of water in vermiculite interlayer space causes its ability to swell and exfoliate. Following is the general molecular formula for trioctahedral vermiculite.

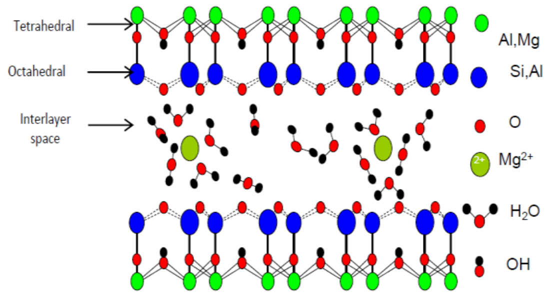

Figure: Vermiculite structural diagram

2. BASALT FIBER

2.1 Lava to Rock

Basalt is a type of igneous rock formed by the rapid cooling of lava at the surface of a planet. It is the most common rock in the Earth's crust. Basalt rock characteristics vary from the source of lava, cooling rate, and historical exposure to the elements. High quality fibers are made from basalt deposits with uniform chemical makeup. Millions of years ago, eruptions from the center of the Earth expelled an enormous quantity of lava in the planet surface. In contact to atmosphere the lava has cooled creating the first continents in the planet, the Pangaea. Later on, new eruptions and still unknown phenomenal had split the first continent in the today's structure.

The Earth mantle has a thin layer called sphere, this thin lava when in contact with superficies will create the basalt Rock, in many places in the earth is possible to find great canyons and natural sculptures made in basalt by the nature, as result of long years of earth center temperature and pressure stabilization.

Even though quality basalt can be found in abundance in the nature, volcanoes keep throwing tons of lava in earth atmosphere which reinforced the concept of Advanced Basalt Fiber as a high technology and green composite.

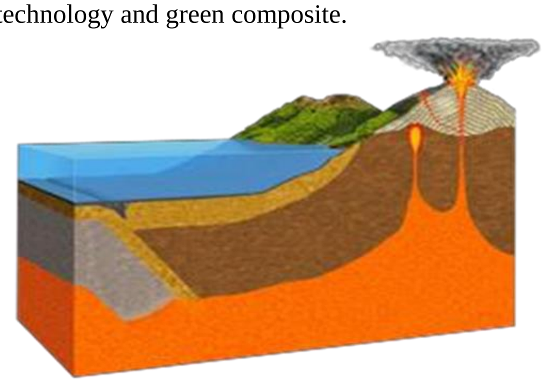

Figure: Volcanic Lava to Rock

2.2 Rock to Fiber

The process of producing fibers from basalt is based on selecting the richest chemical proprieties basalt rocks with the use of quality tests, crushing the rocks and melting to high temperatures. The melted basalt falls from a specific calculated hole where its temperature gradually decreased and forms a yarn which thickness reduces over the cooling process where it gets rolled in a roving. The Continuous Basalt Fiber is short for CBF, which is make use of the natural volcanic rock as the raw material and put them in the furnace after being crushed into power and then which are produced by the platinum rhodium drawing filament laminate. Compared to the carbon fiber, Aramid fiber which has many unique advantages. Such as the physical property, the high temperature resistance, good acid & alkali-resistance, the good UV resistance, the low hygroscopic property, the environmental resistance and sound insulation, high temperature filterability, radiation resistance and the excellent wave-adsorption and wave-penetration and soon. Many sorts of composites which are use of the basalt fiber as the reinforced material can be used many fields such as fire, environmental protection, aerospace, armament, automotive & vessels' manufacture, infrastructural material and so on. Crushed basalt rock is the only raw material required for manufacturing the fiber. It is a continuous fiber produced through igneous basalt rock melt drawing at about 2,700°F (1,500°C). Though the temperature required to produce fibers from basalt is higher than glass, it is reported by some researchers that production of fibers made from basalt requires less energy by due to the uniformity of its heating.

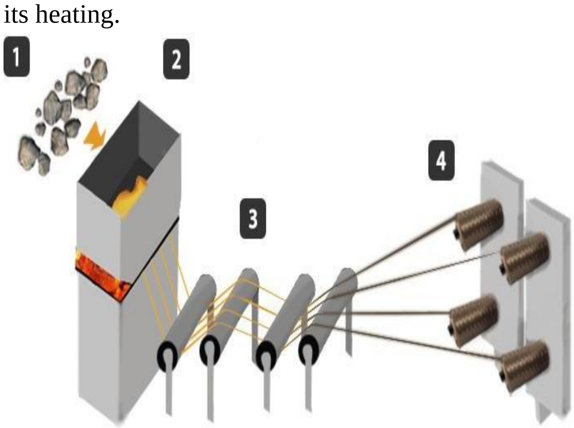

Figure: Rocks to Fiber

Figure: Basalt Fiber

3. QUARRY DUST

Quarry dust is a by-product from the crushing process during quarrying activities. Quarry dust has been used for different activities in the construction industry. The dust produced by quarrying has already been used in the construction industry for projects such as road building and making materials such as bricks and tiles. The dust has been found to be suitable for these practices, and this makes its transformation into a useful cement mix replacement more likely.

3.1 Environmental Benefits of Using Quarry Dust

The use of Quarry dust as partial cement replacements with lower environmental load provides chance for significant reductions in energy use and carbon dioxide emissions.

The use of Quarry Dust in concrete results in following environmental benefits in reducing the emission of carbon dioxide.

4. LITERATURE REVIEW

M. R. Divya, Prof. M. Rajalingam and Dr. Sunilaa George (2016) have studied their study M30 grade concrete, the strength parameters such as compressive strength, split tensile & flexural strength of concrete using vermiculite as partial replacement with 40%, 50% and 60% by weight. The study result shows the optimum strength in comparing the strengths for different vermiculite was observed to be 50%.

S Syed Abdul Rahman and Gijo K Babu (2016) In their study, structural light weight aggregate concrete was designed with the use of natural vermiculite aggregate that will provide an advantage of reducing dead weight of structure and to obtain a more economical structural light weight concrete by the use of vermiculite power as a partial replacement of sand. Three mixes were produced with the cement content of 479kg/m^3 in M30 grade and water cement ratio is 0.40. Moreover, the group had proportion of 0%, 5%, 10%, as vermiculite replacement. And finally, they concluded that the 10% replacement of vermiculite well compared to nominal mix.

Mr. M. Gunasekaran et al., (2016) In their study, Vermiculite replacing natural sand at the range of 5%, 10%, 15%, 20%, 25% and 30%. Design mix having the mix proportion 1:3 with the water cement ratio 0.5. On their study the super plasticizer conplast SP430 is added to the samples at a range of 1.5% to the total weight of cement. And finally conclude by comparing the various compression test of the samples by 10% replacement of vermiculite to the total weight of sand gives better results.

Md. Tabsheer Ahmed et al. (2013) showed the use of basalt chopped fibers advantageously improves the compressive as well as flexural strength irrespective of affecting the workability of concrete mixes. The inclusion of basalt fibres does not affect the slump value significantly. The slump value ranges between 95 to 110 mm respectively.The increase in the content of percentage of fibres increases the compressive strength marginally. Addition of 1% basalt fibres increases the strength to 46% for 7 & 28 days. Similarly for every increase in fibre content the strength shows an increasing trend.The flexural strength also shows similar variation compared to compressive strength of concrete. The graph shows an increasing trend in strength as the content of basalt fibres increases in the concrete mix. Maximum increase in flexural strength is also reported at 1%. 64 % increase is obtained at the age of 28 days.

A.V.S.Sai Kumar, Krishna Rao B studied the effect on mechanical properties of M30 grade concrete made with partial replacement of cement with Quarry dust, (0%, 10%, 15%, 20%, 25% and 30%) and Vermiculite, (0%, 2.5%, 5.0%, 7.5%, 10.0% and 12.5%) .Tests for compressive strength, split tensile strength and flexural strength were conducted. The compressive strength, flexural strength and split tensile strength of concrete increased when cement is replaced by Quarry dust and Vermiculite at 25% and 10%.

4. MIX DESIGN FOR M30 CONCRETE

Mix proportions for concrete mix of M 30 Grade is Cement: FA: CA: Water = 1:1.35:2.89:0.45

5. TEST RESULTS AND DISCUSSIONS

The cubes are casted with the prescribed percentages of quarry dust, vermiculite and basalt fibers and the Mechanical and durability properties were identified and tabulated in the following tables and also shown in the form graphical representation. Initially the specimens were casted with percentage replacement of the quarry dust and the optimum is obtained.to the optimum percentage of the quarry dust, percentage vermiculite is replaced, and the combined optimum is obtained after which making the quarry dust and vermiculite as constant, basalt fibers are mixed to find the final properties of the concrete.

5.1 Compressive strength

Table: Compressive strength for different Quarry dust percentages

S. NO	% of Quarry dust	7 days strength (Mpa)	28 days strength (Mpa)
1	0	26.21	37.12
2	10	26.36	38.45
3	15	26.85	39.85
4	20	27.45	40.65
5	25	27.99	41.21
6	30	26.45	40.19

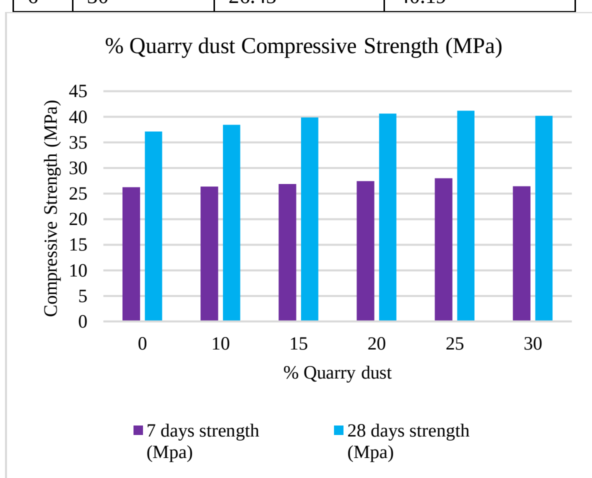

Figure: Compressive strength of Quarry dust for 7 & 28 days

From the test results, the optimum percentage replacement of Quarry Dust was found to be 25%.

Table: Compressive strength for 25% QD and Vermiculite

S. NO	% of Quarry dust	% Vermiculite	7 days (N/mm^2)	28days (N/mm^2)
1	0	0	28.56	41.85
2	25	5	29.41	41.96
3	25	10	30.25	42.35
4	25	15	31.47	43.06
5	25	20	32.58	43.96
6	25	25	30.18	41.92

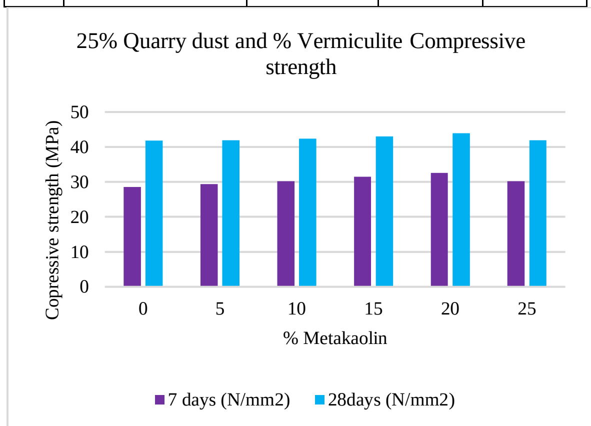

Figure: Compressive strength of Vermiculite for 7 and 28 days

From the above graph, it is observed that the compressive strength value is higher for the mix 25% QD with 20% Vermiculite compared with other mixes.

Table: 25% QD + 20% V and % Basalt fiber compressive strength

S. NO	% Basalt Fibers	7 days strength (Mpa)	28 days strength (Mpa)
1	0	25.41	39.52
2	0.5	26.52	39.98
3	1.0	27.85	40.52
4	1.5	28.08	41.82
5	2.0	29.12	42.63
6	2.5	28.02	41.85
7	3.0	27.17	40.25

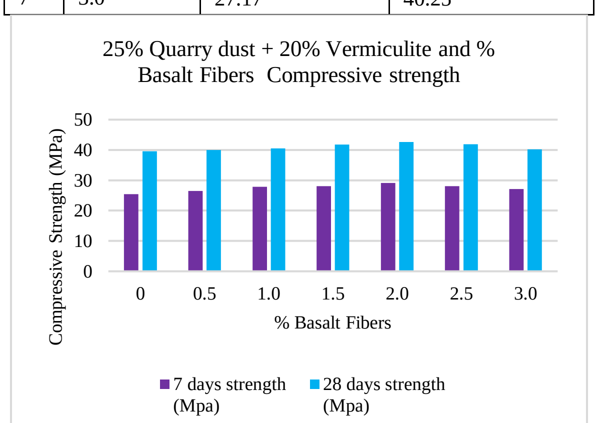

Figure: Compressive strength 25% QD + 20 % V and % Basalt fiber for 7and 28 days

From the above graph, it is observed that the compressive strength value is higher for the mix 25% QD+20 % V with 2% basalt fibers compared with other mixes.

5.2 Flexural Test

Flexural test was performed on beams by placing them on universal testing machine to find out the flexural strength.

Table: Flexural strength of Quarry Dust

S.NO	% of Quarry dust	7 days strength (Mpa)	28 days strength (Mpa)
1	0	4.36	5.45
2	10	4.56	5.65
3	15	4.63	5.89
4	20	4.75	6.06
5	25	4.89	6.29
6	30	4.45	6.03

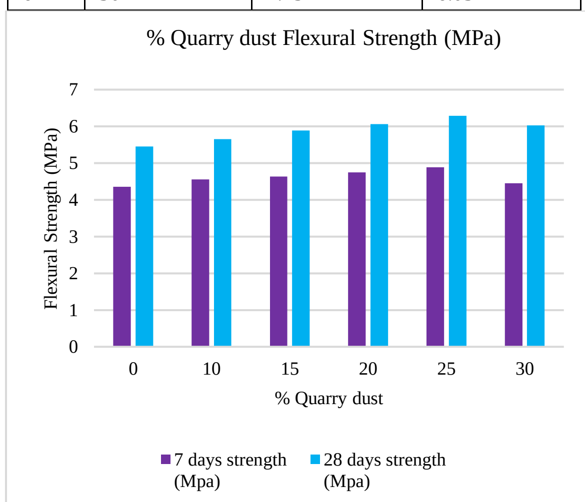

Figure: Flexure test of Quarry Dust at 7 & 28 days

From the above graph, it is observed that the Flexural strength value is higher for the mix 25% QD compared with other mixes.

Table: Flexural strength for Vermiculite

S. NO	% of Quarry dust	% Vermiculite	7 days strength(Mpa)	28 days strength(Mpa)
1	25	0	4.89	6.29
2	25	5	4.78	6.12
3	25	10	4.65	5.98
4	25	15	4.51	5.72
5	25	20	4.46	5.61
6	25	25	4.38	5.48

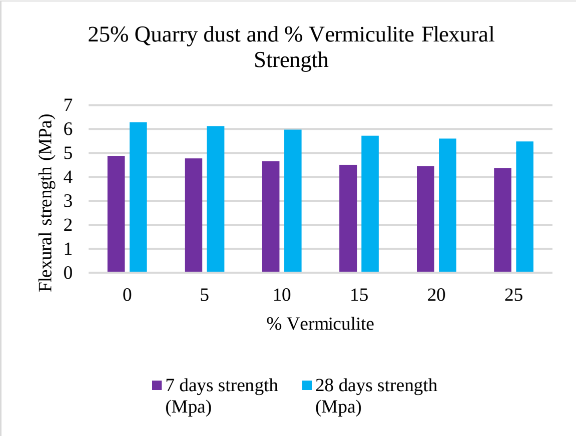

Figure: Flexural strength of Vermiculite for 7 & 28 days

From the above graph, it is observed that the flexural strength value is higher for the mix 25% QD with 20 % V, compared with other mixes.

Table: Flexural strength 25% QD + 20 % V and % Basalt fiber for 7and 28 days

S.NO	% Basalt Fibers	7 days strength (Mpa)	28 days strength (Mpa)
1	0	4.46	5.61
2	0.5	4.56	5.75
3	1.0	4.68	5.96
4	1.5	4.72	6.13
5	2.0	4.96	6.39
6	2.5	4.79	6.11
7	3.0	4.68	6.01

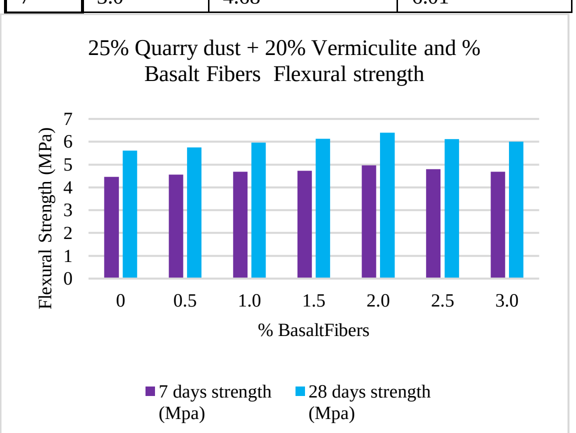

Figure: Flexural strength 25% QD + 20 % V and % Basalt fiber for 7and 28 days

From the above graph, it is observed that the flexural strength value is higher for the mix 25% QD with 20 % V, and 2% basalt fibers, compared with other mixes.

5.3 Split Tensile Test

Split tensile was performed on cylinders 150mm dia. and 300mm height on compression testing machine. The failure load was recorded to find out split tensile strength.

Table: Split tensile strength for Quarry Dust

S.NO	% of Quarry dust	7 days strength (Mpa)	28 days strength (Mpa)
1	0	3.48	4.78
2	10	3.59	4.91
3	15	3.78	4.91
4	20	3.95	5.12
5	25	4.03	5.24
6	30	3.86	5.07

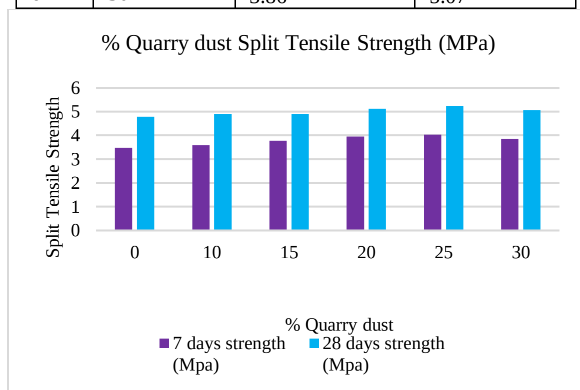

Figure: Split tensile test for Quarry Dust for 7 & 28 days

From the above graph, it is observed that the split tensile strength value is higher for the mix 25% Quarry Dust, compared with other mixes.

Table: Split tensile test for 25%QD+MK

S. NO	% of Quarry dust	% Vermiculite	7 days strength(Mpa)	28 days strength(Mpa)
1	25	0	4.03	5.24
2	25	5	3.95	5.12
3	25	10	3.82	5.03
4	25	15	3.69	4.95
5	25	20	3.56	4.81
6	25	25	3.45	4.76

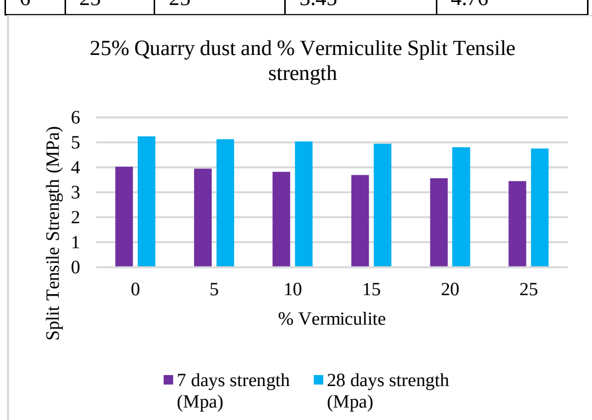

Figure: Split tensile strength of Vermiculite for 7 & 28 days

From the above graph, it is observed that the split tensile strength value is higher for the mix 25% QD and 20 % V, compared with other mixes.

Table: Split tensile strength 25% QD + 20 % V and % Basalt fiber for 7and 28 days

S.NO	% Basalt Fibers	7 days strength (Mpa)	28 days strength (Mpa)
1	0	3.56	4.81
2	0.5	3.75	5.01
3	1.0	3.96	5.23
4	1.5	4.21	5.36
5	2.0	4.45	5.45
6	2.5	4.22	5.41
7	3.0	4.01	5.17

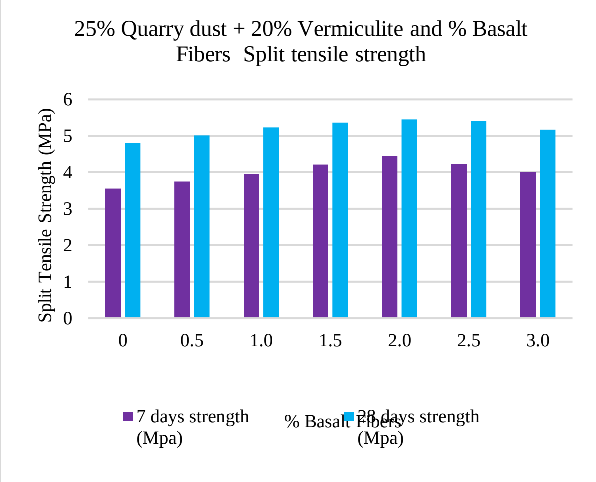

Figure: Split tensile strength 25% QD + 20 % V and % Basalt fiber for 7and 28 days

From the above graph, it is observed that the split tensile strength value is higher for the mix 25% QD, 20 % V and 2 % basalt fibers, compared with other mixes.

6.DURABILITY STUDIES

5.1 General

Concrete is not fully resistance to acids. Most acid solutions will slowly or rapidly disintegrate Portland cement concrete depending upon the type and concentration of acid. The durability of concrete in this experimental work was carried out by measuring acid resistance at different ages of curing. The concrete acid resistance was observed by two types of tests named as Acid attack factor test and Acid durability factor test. The concentrations of acids in water are 5% HCL and 5% H_2SO_4.concrete can be attacked by liquids with pH value less than 6.5 and attack is severe when pH value is below 5.5. At pH value below 4.5, the attack is very severe. As the attack proceeds, all the cement compounds are broken down and leached away. Here HCL andH_2SO_4 which are having pH value 3.01 and 2.75 which cause a very severe attack are used to study the durability properties.

Concrete with Ordinary Portland Cement is the major composition in present constructional activities. A concrete structure was good in strength can also be good in providing service life. Durability is of concrete structure is justified only when it shows reliability in its lifetime. More durability means more service life of structure. The concrete under marine environment and exposed to aggressive chemical attack through water are the major problems in reducing the lifetime of structure. To overcome this problem, proper durability studies are needed for concrete before concreting a structure.

5.2 Requirements of Study

To check the Acid resistance of concrete, Hydrochloric acid (HCl) is considered in the present study. The concentrations of acids in water are taken as 5%. The standard specifications for this study are IS 516-1959 and ASTM C666-1997.

Table 5. 1 Percentage weight loss after Acid curing

S.NO	% Basalt fibers	% weight loss after 28 days
1	0	2.68
2	0.5	2.61
3	1.0	2.52
4	1.5	2.47
5	2.0	2.36
6	2.5	2.45
7	3.0	2.59

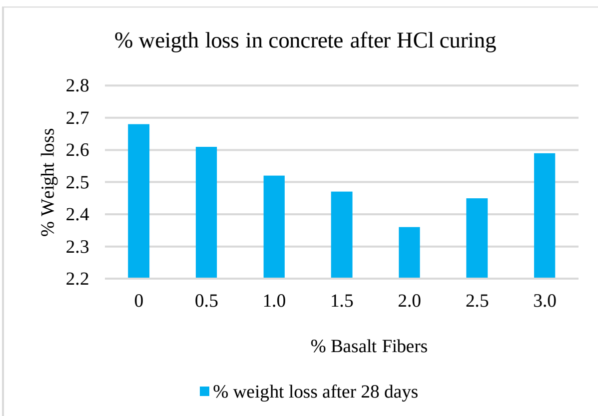

Figure 5. 1 Percentage weight loss after acid curing

Table 5. 2 Percentage Strength loss after Acid curing

S.NO	% Basalt fibers	28 days strength	28days Strength (5%HCl)	% Strength loss
1	0	39.52	37.36	5.47
2	0.5	39.98	37.85	5.33
3	1.0	40.52	38.42	5.18
4	1.5	41.82	39.85	4.71
5	2.0	42.63	41.13	3.52
6	2.5	41.85	40.12	4.13
7	3.0	40.25	38.56	4.20

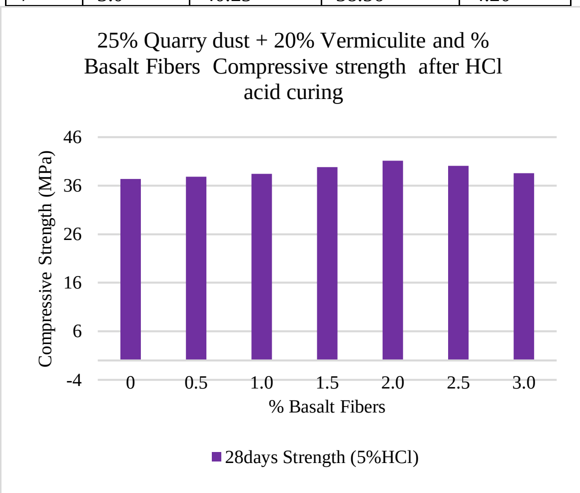

Figure 5. 2 Percentage compressive strength loss after acid curing

7.CONCLUSIONS

Based on the experimental investigations conducted on the casted cubes and cylinders the following conclusions were drawn.

- The compressive strength is increased 11.68% for replacement of cement by 15% fly ash and addition of 10% silica fume when compared with the nominal mix and it is considered as the optimum mix.
- The Split tensile strength is increased 11.96% for replacement of cement by 10% fly ash and addition of 10% silica fume when compared with the nominal mix and it is considered as the optimum mix
- Though the compressive strength of concrete decreases with increase of percentage of vermiculite, but with the replacement of fly ash at 15% and addition of silica fume at 10% to cement with replacement of vermiculite to fine aggregate up to 20% may be accepted as it is giving required target mean strength.
- Though the Split Tensile strength of concrete decreases with increase of percentage of vermiculite, but with the replacement of fly ash at 10% and addition of silica fume at 10% to cement with replacement of vermiculite to fine aggregate up to 20% may be accepted as it is giving required target mean strength.

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