International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET)

| e-ISSN: 2319-8753, p-ISSN: 2320-6710| www.ijirset.com | Impact Factor: 7.512|

||Volume 9, Issue 12, December 2020||

A Study on Mechanical Properties and Durability of Vermiculite Concrete

Kiran Kumar Narasimhan[1]*. B Damodhara Reddy[2], C.Sasidhar[3]

Research Scholar (PhD), Jawaharlal Nehru Technological University, Anantapur, Andhra Pradesh, India[1*]

Professor, Department of Civil Engineering, SVCET (Autonomous), R.V.S. Nagar, Chittoor, Andhra Pradesh, India[2]

Professor, Department of Civil Engineering, Jawaharlal Nehru Technological University, Anantapur, AP, India[3]

ABSTRACT: Concrete is a material which is used in construction. Weight of concrete plays a major role in the construction industry. If the weight of the concrete is increased, it will pose more structural problems on the later date of construction. It also increases the cost of construction, without any specific benefit. So if lightweight concrete is used, it not only reduces cost of construction, but also not poses any structural problems unnecessarily. Light weight concrete also aids workers in smooth handling of materials. In this study, vermiculite in the form of exfoliated form is used to replace partially natural sand. By this action dead weight of the structure is reduced. Once the dead weight of structure is reduced, it in turn reduces cost of construction. In this study three mixes were casted with the cement content of 383 kg/m3 in M20 concrete and the water cement ratio of 0.45 is chosen. Vermiculite at 10%, 20% and 30% are choosing to partially replace the natural sand. The Tests conducted on concrete for evaluating mechanical properties include compressive strength and split tensile strength. For evaluating durability properties, tests like acid resistance, sulphate resistance, chlorine penetration and water absorption.

KEYWORDS: concrete, light weight, vermiculite, natural sand, mechanical properties and durability properties

I. INTRODUCTION

In India, concrete is used as a constructional material in the casting of beams, floors, columns, slabs and foundation. Natural sand is one of the materials used in concrete and its availability is coming down year after year. So obviously the cost of Natural sand is increasing and there is a need for choosing an alternative material possessing the same qualities. In his study vermiculite is used to partially replace Natural sand. Vermiculite is a hydrous phyllosilicate which is formed by weathering action. Exfoliated vermiculite can resist higher temperatures and exhibits low thermal conductivity. Due to its high sound insulation property, fine aggregate is replaced with vermiculite by 10%, 20% and 30% by weight and their strength parameters like compressive strength, split tensile strength and durability of concrete specimen are tested.

II. RELATED WORK

Seong-kyum kim et.al[1](2019), studied about the resistance of reinforced concrete to High sulfate attack. Reinforced concrete flumes containliquid crystal display waste glass powder. They carried out sulphate resistance test by immersing specimens in sodium sulphate and magnesium sulphate solutions. They expressed that there is less reduction in weight and volume of the specimens when immersed in sodium sulphate when compared with magnesium sulphate. Bhuvaneshwari. K, Dr. Dhanalakshmi.G, Kaleeswari.G[2](2017) carried out an experimental study on light weight concrete using perlite (a material similar to vermiculite) partially replacing of sand at 5%,10%,15%, 20% and 25% of the total weight of sand. They carried out various tests like compressive strength test, split tensile strength test and flexural test. Their study showed that the optimum percentage of sand by perlite was 10%.

A. V. V. Sairam et.al[3] (2017) made an attempt to study the mechanical properties of M35 grade concrete when natural sand is partially replaced by vermiculite with different percentages at a range of 5%, 10%, 15%, 20%, 25% and 30% along with mineral admixtures like Fly ash (FA) is replaced with cement by various percentages i.e., 10%, 15% and 20%.Also, silica fume (SF) isadded at 5%, 7.5%, 10% and 12.5% of weight of cement. Water cement ratio is 0.42. Their study showed that although the compressive strength decreases with increase of vermiculite, but with the

| e-ISSN: 2319-8753, p-ISSN: 2320-6710| www.ijirset.com | Impact Factor: 7.512|

||Volume 9, Issue 12, December 2020||

replacement of fly ash at 15% and addition of silica fume at 10% to cement replacement of vermiculite to fine aggregate up to 20% maybe accepted as it is giving required target mean strength.
One more study done byS.Sharmila and L.Vijayan[4] (2016) concluded that the when Vermiculite replaced natural sand in concrete, there was not much decrease in density up to 15%, when compared to normal concrete. When split tensile strength was evaluated, the results showed no much variation in the conventional concrete sample.

S Syed Abdul Rahman and Gijo K Babu[5](2016) revealed that vermiculite was used in concrete with water cement ratio of 0.40. Concrete specimens are prepared using cement content of 479kg/m3 for M30 grade concrete. The proportion of 0%, 5% and 10%, as vermiculite replacement to fine aggregate is used. When compared to conventional concrete, vermiculite when replacing natural sand at 10% yielded better results. Similarly for the same grade of concrete one more study was done by M.R. Divya et.al[6](2016). Vermiculite has partially replaced natural sand by 40%, 50% and 60% of the total weight of fine aggregate. The properties like compressive strength, split tensile & flexural strength of concrete are evaluated.The result is promising at50%.

Praveen Kumar et.al[7] (2015) carried experimental study of vermiculite insulated concrete by replacing 20% of fine aggregate by vermiculite along with the use of super plasticizer. For M20 grade concrete due to the low density of vermiculite the weight of the concrete was reduced up to 40% of its weight depending upon the mixproportions. P. Santosh Murugan et.al[8] (2015) investigated on strength properties of M25 lightweight concrete with vermiculite. In their study vermiculite was used as fine aggregate and coarse aggregate in two different mixes. The mix using vermiculite as fine aggregate was found to possess higher workability compared to the mix using vermiculite as coarse aggregate. The strength parameters were similar for both the cases and the specimen cast with vermiculite had less weight compared to normal concrete.

From the literature Review following objectives are drafted

1. To perform preliminary tests on cement, sand, vermiculite, and Normal gravel as coarse aggregate.
2. To perform slump cone Test on Fresh concrete to measure workability.
3. To performCompression Strength test and Split Tensile test on Vermiculite concrete (for different proportions) with normal gravel as coarse aggregate and compare it with conventional concrete.
4. To performdurability tests like Water absorption test, acid resistance test, Sulfate attack test and Carbonation chloride test on Vermiculite concrete (for different proportions) with normal aggregate and compare it with conventional concrete.
5. To execute cost analysis on various mixes and arrive at optimal mix that can be adopted.

III. METHODOLOGY

The materials used in the experimental investigation include Ordinary Portland Cement (OPC – 53Grade), Fine aggregate (confirming to ZoneII), Vermiculitemineral, Coarseaggregate and Water. The properties of these materials are given in the following sub-section. In this study Portland cement of 53 grades is used. The cement is in dry condition and in the powder form. The physical tests were done and cement free from lumps was selected.**Cement**is prepared by subjecting limestone and clay together to high temperatures.

Aggregate comprises of both fine and coarse aggregate. In the concrete major portion is occupied by the fine and coarse aggregate. The aggregate when used in concrete, not only contributes to strength, durability and volume stability but also reduces costs. Because of superior properties possessed by vermiculite, it is adopted in this study to partially replace the natural sand. The superior properties include improved resistance to cracking and shrinkage and also make concrete light. In this study exfoliated vermiculite passing through 2.36 mm sieve size is adopted.

Table 1 Sand properties

S.NO	Properties	units	Results
1	Specific gravity	-	2.75
2	Bulking of sand	%	4
3	Particle size variation	mm	0.15 to 4.75
4	Water absorption	%	1,5
5	Bulk density of sand	Kg/m^3	1465
6	Fineness modulus	%	3.58

| e-ISSN: 2319-8753, p-ISSN: 2320-6710| www.ijirset.com | Impact Factor: 7.512|

||Volume 9, Issue 12, December 2020||

Table.2 sieve analysis data for the sand

IS sieves (mm)	Weight retained (grams)	% of weight retained	Cumulative % of weight retained	% passing
4.75	13	1.3	1.3	98.7
2.36	102	10.2	11.5	88.5
1.18	315	31.5	43.0	57
0.6	206.5	20.65	63.65	36.35
0.3	294	29.4	93.05	6.95
0.15	61.5	6.15	99.2	0.8
Pan	8	0.8	100	0

The properties of vermiculite include the Prismatic crystal form with Greasy lustre and with a yellowish shiny streak. The Mohr scale hardness and specific gravity of vermiculite are 1.75 and 2.6.

Table.3 Coarse aggregate properties

S.NO	PROPERTIES	RESULTS
1	Specific gravity	2.72
2	Particle size (mm)	6.3 TO 20 mm
3	Fineness modulus	4.506
4	Water absorption (%)	0.5
5	Bulk density(Kg/m^3)	1469.8

Table.4 Sieve Analysis for Coarse Aggregate

IS Sieves (mm)	Weight retained	% weight retained	Cumulative % weight retained	% passing
25	0	0	0.00	100
20	50.44	50.44	50.44	49.56
12.5	47.32	47.32	97.76	2.24
10	2	2.00	99.76	0.24
4.75	12	0.24	100	0

Water when mixed with cement and fine aggregate forms mortar that can be used to bind the coarse aggregate. Hydration is a process by which major compounds in cement react with compounds in aggregate forming stable compounds. A lot of heat is released during the hydration process.

Table.5 Characteristics of Water

S.No	Parameter	Units	Concentration
1	pH	-	6.75
2	Total Dissolved Solids	mg/l	360
3	Alkalinity	mg/l	108
4	Acidity	mg/l	11
5	Hardness	mg/l	129
6	Sulphates	mg/l	14
7	Chlorides	mg/l	57

Table 6 Mix Proportions for M20 Grade Concrete

Water	Cement	Fine aggregate	Coarse Aggregate
167.4 (W/C Ratio 0.45)	372	637	1227
	1	1.72	3.3

| e-ISSN: 2319-8753, p-ISSN: 2320-6710| www.ijirset.com | Impact Factor: 7.512|

||Volume 9, Issue 12, December 2020||

Table 7 Specimen specifications

S.No	Replacement (Sample Number)	Specifications
1	CC	Conventional concrete with 0% vermiculite
2	M1	Concrete With 10% vermiculite
3	M2	Concrete With 20% vermiculite
4	M3	Concrete With 30% vermiculite

The slump test conducted on fresh concrete indicates the consistency of concrete. This test indicates the ease with which concrete can flow. The test is conducted using Cone with a diameter of 10 cm at top, 20cm at the bottom and a height of 30cm. The empty cone is placed on a flat surface. The fresh concrete is filled in cone in three stages. Every time, every layer is tamped 25 times with a 60 cm long and 1.6 cm diameter rod. After the three stages, the top of the mould is leveled to remove excess concrete. The cone is lifted vertically upwards. After lifting concrete cone slumps or collapses. The difference of height of the top of the cone to the top of slumped concrete gives the slump of concrete.

Using the Compression testing Machine, compressive strength test and split tensile strength is conducted. To test compressive strength, the cubes of 15cm X 15cm X 15cm are adopted. To carry out the Split Tensile strength test, the cylinders with internal diameter of the mould as 15 cm and the height as 30 cm. Split tensile Strength is carried out to determine the load at which the concrete members may crack.

Durability tests are carried out to determine the capacity of a material to withstand the attack of acids, alkalis, sulphates and chlorides. The results will clearly indicate whether concrete can exist long or may deteriorate due to an attack of acids, alkalis, sulphates and chlorides. Here in these tests after casting, curing of concrete for 28 days, the specimens are taken out of the water cleanly wiped off with cloth, dried in the sun to remove the surface moisture then weighed. After noting down the weight of concrete specimen, it is soaked in acid, alkali, sulphate, and chloride solution for another 28 days. During this period, care is taken to maintain pH conditions constant. After completion of 28 days, specimen soaked in acid and alkali, are taken out and wiped out with a dry cloth, kept in the sun to remove surface moisture. After surface moisture is completely removed, the specimens are weighed and tested for compressive strength. This process is repeated for concrete specimens soaked in chloride, sulphate solution also but instead of testing for compressive strength we test for chloride penetration of concrete specimens soaked in chloride solution and split tensile strength for concrete specimens soaked in sulphate solutions.

IV. EXPERIEMENTAL RESULTS

The results of the present investigations are presented in the tabular form. In order to facilitate the analysis, interpretation of the results is carried out in each phase of the experimental work. This interpretation of the results obtained is based on the current knowledge available in the literature as well as on the nature of the results obtained. When the slump test was conducted on concrete made with plain normal gravel, the slump noted is 10.

Table. 8 Compressive strength

S.No	Mix	COMPRESSIVE STRENGTH (N/mm^2)						
		3 Days	7 Days	14 Days	28 Days	56 Days	90 Days	180 Days
1	CC	11.04	17.94	24.84	27.324	27.71	27.96	28.23
2	M1	14.8	21	26.3	31.2	31.56	31.87	32.12
3	M2	14.3	20.5	25.9	30.5	30.85	30.98	31.02
4	M3	11.3	16.7	20.1	25.4	25.75	25.91	26.11

From the results it is evident that M1 mix is giving slightly better compressive strength values when compared with conventional concrete mix and other mixes. M1 mix gave better results for 3 days, 7 days, 14 days, 28 days, 56 days, 90 days and 180 days and is indicating that compressive strength is increasing as age progresses as vermiculite when replacing natural sand at 10% filled the air voids. When air voids are decreased this in turn increases the compressive strength.

| e-ISSN: 2319-8753, p-ISSN: 2320-6710| www.ijirset.com | Impact Factor: 7.512|

||Volume 9, Issue 12, December 2020||

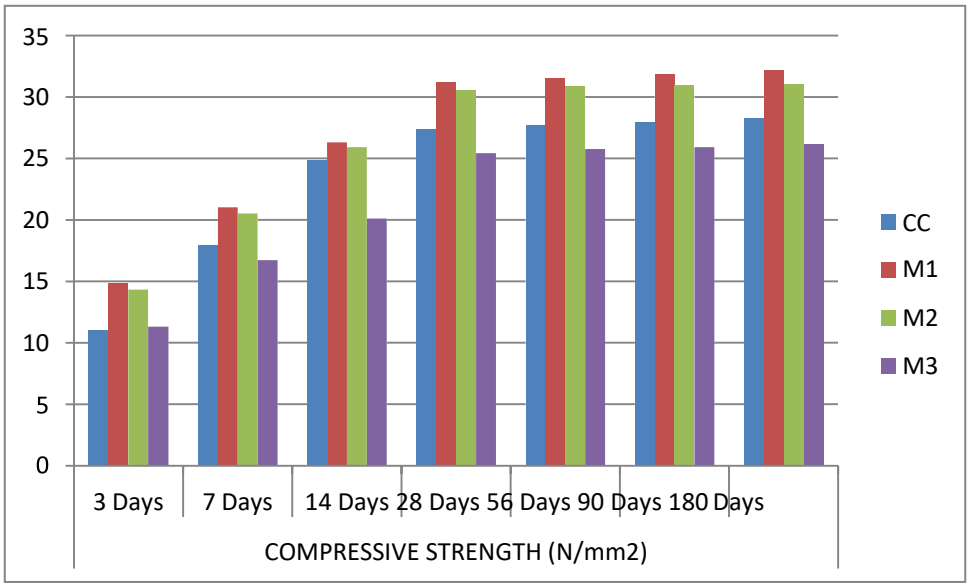

Fig1: Compressive Strength of cubes

Table.9 Split Tensile strength after 28 days

S.No	Design Mix	Split Tensile Strength (N/mm^2)
1	CC	2.4
2	M1	2.5
3	M2	2.1
4	M3	1.8

The M1 mix is giving slightly better split tensile strength values when compared with conventional concrete mixand other mixes.The reason may be attributed to vermiculite acting like a filler materialand thus reducing air voids and increasing the split tensile strength values.

Table.10 Water Absorption Test

S.No	Description	Conventional Concrete	10% Replacement(M1)	20% Replacement(M2)	30% Replacement(M3)
1	Fresh cube weight	8.121	8.034	7.5	7.094
2	Dry cube weight	8.080	7.994	7.45	7.034
3	Water absorbed	0.505	0.497	0.667	0.846

Table 11: Durability of Concrete Cubes (Resistance to Acid Penetration)

Mix	Weight after 28 days		% Loss	Compressive Strength after 28 days		% Loss
	before Acid immersion (KG)	After Acid immersion (KG)		before Acid immersion (KG)	After Acid immersion (KG)	
Conventional Concrete (CC)	7.71	7.02	8.9	27.33	25.62	6.2
M1	7.20	6.33	12.1	31.20	27.25	12.67
M2	6.94	5.98	13.8	30.50	25.53	16.3
M3	6.68	5.67	15.1	25.40	20.64	18.74

The water absorbed by M1 mix is slightly lesser than conventional sample, M2 and M3 mix. The reason may be attributed to the filling of voids by vermiculite and preventing the entry of water and thus reducing the content of water absorbed. The results are depicted in Table 10.

| e-ISSN: 2319-8753, p-ISSN: 2320-6710| www.ijirset.com | Impact Factor: 7.512|

||Volume 9, Issue 12, December 2020||

When tested for resistance of concrete towards acid attack, percentage of loss of Compressive strength of concrete specimens recorded 12.67 for M1 specimen which is almost double the value of 6.2 of conventional concrete specimens. Other specimens M2 and M3 mix samples register higher percentage of loss of compressive strength when compared to M1 mix. Weight of concrete cube specimen is taken before and after subjecting the specimen to acid attack. The percentage of loss of weight of specimen recorded 12.1 for M1 mix almost 1.5 times more than that recorded for that of conventional concrete specimens.The results are depicted in Table 11.

Table 12: Durability of Concrete Cubes (Resistance to Alkali Penetration)

Mix	Weight of Cubes after 28 days		% Loss	Compressive Strength of Cubes		% Loss
	before immersing in Alkali (KG)	After immersing in Alkali (KG)		after 28 days before immersing in Alkali	after 28 days before immersing in Alkali	
CC	7.71	7.23	7.6	27.33	26.57	3.5
M1	7.20	6.45	10.4	31.20	29.74	4.67
M2	6.94	6.15	11.3	30.50	28.87	5.34
M3	6.68	5.87	12.12	25.40	23.93	5.78

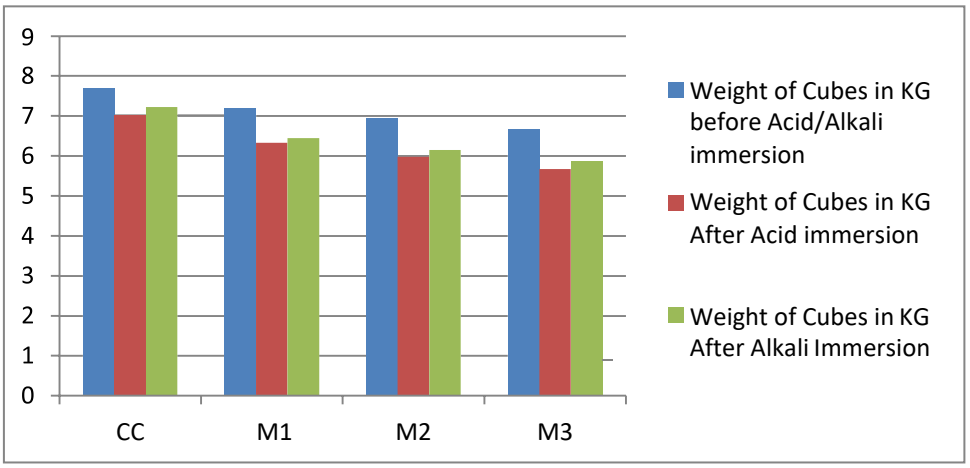

Fig.2 Comparison of weight of cubes before and after acid/alkali immersion

When tested for resistance of concrete towards alkali attack, the percentage of loss of Compressive strength of concrete specimens recorded 4.67 for M1 specimen which is almost 1.5 times the value of 3.5 of conventional concrete specimens. Other specimens M2 and M3 mix samples register higher percentage of loss of compressive strength when compared to M1 mix. Weight of concrete cube specimen is taken before and after subjecting the specimen to alkali attack. The percentage of loss of weight of specimen recorded 10.4 for M1 mix almost 1.5 times more than that recorded for that of conventional concrete specimens

Table.13 Chlorination Depth for different mixes of concrete specimens

Design Mix	Chlorination Depth (mm)
CC	**6.80**
M1	**6.9**
M2	**7.95**
M3	**8.53**
M4	**8.94**

| e-ISSN: 2319-8753, p-ISSN: 2320-6710| www.ijirset.com | Impact Factor: 7.512|

||Volume 9, Issue 12, December 2020||

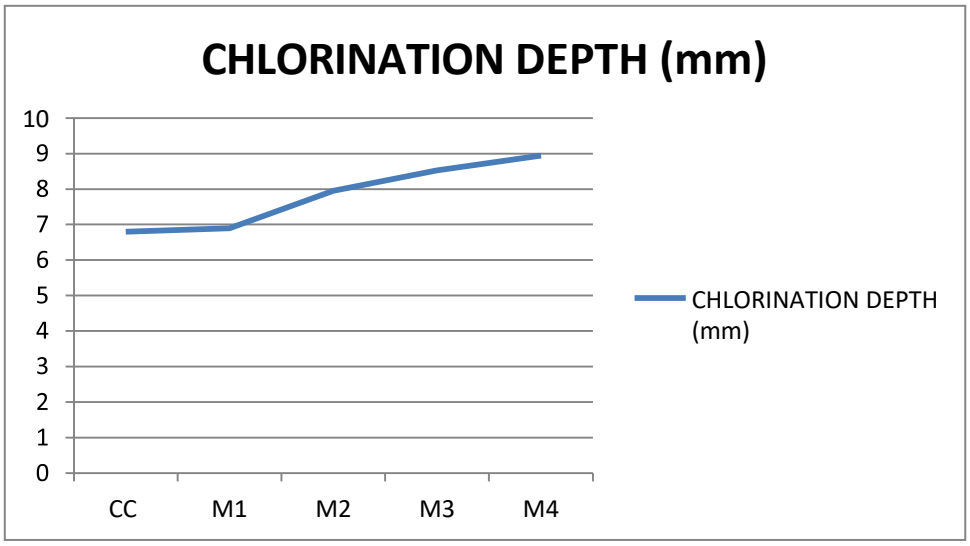

Fig.3 Chlorination Depth for different mixes of concrete specimens

For M1 Mix Chlorination depth values are almost same as that of conventional sample. The reason may be attributed that void is filled effectively at that mix proportion and is able to resist Chloride effectively when compared with other mixes.

Table.15 Sulphate Resistance Test

S.No	Replacement (Sample Number)	Spilt Tensile Strength (N/mm2) Before sulphate resistance test			Spilt Tensile Strength (N/mm2) After sulphate resistance test		
		7 Days (N/mm2)	14 Days (N/mm2)	28 Days (N/mm2)	7 Days (N/mm2)	14 Days (N/mm2)	28 Days (N/mm2)
1	CC	1.35	1.98	2.4	1.23	1.87	2.18
2	M1	1.57	2.09	2.5	1.45	1.95	2.07
3	M2	1.21	1.74	2.1	1.09	1.59	1.75
4	M3	1.03	1.51	1.8	0.97	1.38	1.43

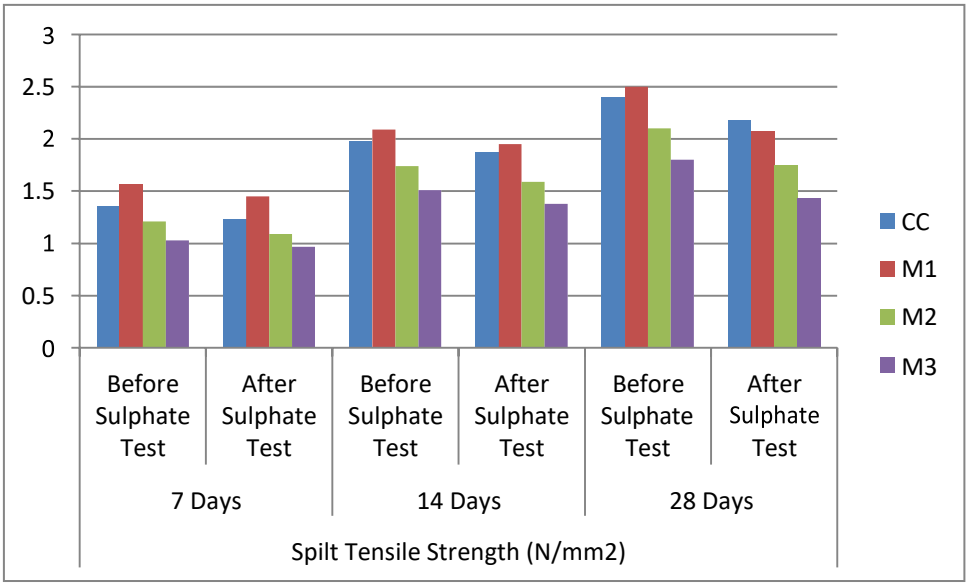

Fig.4 Split Tensile Strength of cubes

| e-ISSN: 2319-8753, p-ISSN: 2320-6710| www.ijirset.com | Impact Factor: 7.512|

||Volume 9, Issue 12, December 2020||

Split tensile strength values of M1 mix, before subjecting the specimen to sulphate attack test are slightly better than Conventional concrete. However split tensile strength values for M2 mix and M3 mix recorded lesser values than conventional sample. When the split tensile strength test was conducted initially for 7 days and 14 days, sulphate resistance test results of M1 sample were slightly better than conventional concrete sample. But for 28 days the split strength values corresponding to conventional concrete sample are better than M1, M2 and M3 mixes.

Table.16 Cost comparison of various Mixes

M	SC (%)	SW (kg)	CS (RS)	V %	VW (kg)	CV (Rs)	T=CS+CCGF (RS)	TC-C+G (RS)	TFC (RS)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=(4)+(7)	(9)	(8)+(9)
CC	100	620	**89**	**0**	**0**	**0**	**89**	**3913**	**4002**
M1	90	558	**80**	**10**	**62**	**1612**	**1692**	**3913**	**5605**
M2	80	496	**72**	**20**	**124**	**3224**	**3296**	**3913**	**7209**
M3	70	434	**64**	**30**	**186**	**4836**	**4900**	**3913**	**8813**

Here M=Combination
SC=Sand Content in %
SW= Weight of Sand in Kg per cubic meter of Concrete CS=Cost of Sand @ Rs 0.143 Rs/Kg
V=Vermiculite content in %
VW= Vermiculite Weight in Kg
CV=Cost of Vermiculite @Rs 26/Kg
T-C S+CCGF=Total Cost of Sand +Crushed Granite Fine in Rupees
TC-C+G= Total Cost of Cement @ Rs 7.1/ kg and Gravel @ Rs 0.7107/kg in Rupees
TFC=Total Final Cost in Rupees

Here when the cost of M1 mix is compared with that of conventional concrete, it is 40% more, but because of its superior split tensile strength when compared to conventional concrete and also because of its superior properties like Thermal insulation and better acoustic properties. M1 mix may be adopted in keeping durability point of View.

V. CONCLUSION

In this study, because of limited availability of sand, vermiculite in exfoliated form is used to partially replace natural sand by 10%, 20%, and 30% at the water cement ratio of 0.45 for the M20. Plain normal aggregate is used as coarse aggregate. The test conducted on concrete specimens cast includes, compressive strength test, split tensile strength test, Sulfate resistance test, Acid attack test, alkali attack test, and carbonation chloride test and cost analysis.On comparing the test results, the following conclusions are arrived at:

1. Workability of the concrete with plain normal gravel is satisfactory and within limits. When vermiculite replaced natural sand at 10%, air voids decreased. This resulted in an increase of compressive strength and split tensile strength. Compressive strength increased with age.
2. When durability tests are conducted, resistance to acid attack and alkali attack. Vermiculite was used to partially replace the sand. Concrete specimen to acid attack, by soaking it in acid solution for 28 days. The concrete specimen with vermiculite showed lesser compressive strength when compared with conventional concrete specimens. The similar results were noticed for alkali attack on concrete with vermiculite.
3. The M1 mix of concrete exhibited lesser water absorption than Conventional sample. The reason may be attributed to the filling of voids by vermiculite and preventing the entry of water and thus reducing the content of water absorbed. The similar results were found for carbonated chlorination test and sulphate resistance test. Here when the cost of M1 mix is compared with that of conventional concrete, it is 40% more.

Considering above results we can conclude that when vermiculite can be used to partially replace natural sand at 10%.

.

| e-ISSN: 2319-8753, p-ISSN: 2320-6710| www.ijirset.com | Impact Factor: 7.512|

||Volume 9, Issue 12, December 2020||

REFERENCES

1. S.K.Kim, and W.K. Hong, "High Sulfate Attack Resistance of Reinforced Concrete Flumes Containing Liquid Crystal Display (LCD) Waste Glass Powder". Materials, 12-2031, **2019**
2. K.Bhuvaneswari, Dr.G.Dhanalakshmi, and G.Kaleeswari."Experimental Study on Light weight concrete using Perlite" International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 04, pp 2451-2455,2017.
3. A.V.V.Sairam, and K.Sailaja,"An Experimental Study of strength Properties of vermiculite concrete using Fly ash as partial replacement of cement and silica fume as mineral amixture", International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 05, pp 659-664,2017.
4. S.Sharmila, and L.Vijayan,"Investigation on Thermo Proof Construction using Vermiplast", wjert, Vol. 2, Issue 3, 96 -101, 2016.
5. S Syed Abdul Rahman, and Gijo K Babu, "An Experimental investigation on light weight cement concrete using vermiculite minerals", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 2, 2016.
6. M.R.Divya, Prof.M.Rajalingam, and Dr.Sunilaa George, "Study on Concrete with Replacement of Fine Aggregates by Vermiculite", International Journal of New Technology and Research (IJNTR), Vol 2, Issue-5, pp 87-89, 2016,
7. E.Praveen Kumar, C. Manoj kumar, K.B. Prakash, and Siddesh K Pai, "Experimental study of vermiculite insulated samples with conventional samples in construction industry" IJRET , 2015.
8. P. Santhosh Murugan, Dr. M.Devasena, Dr.R. Venkatasubramani, " Experimental Study On Strength Properties Of Diaphanous Concrete with Vermiculite", International Journal of Applied Engineering Research, Volume 10, pp 13968-13970, 2015.
9. Indian standard recommended guidelines for concrete mix design, IS 10262-1982.
10. "Plain and reinforced concrete code ofpractice", IS 456- 2000.
11. "Recommended guidelines for concrete mixdesign", IS 10262 – 2009.

| e-ISSN: 2319-8753, p-ISSN: 2320-6710| www.ijirset.com | Impact Factor: 7.512|

||Volume 9, Issue 12, December 2020||