Experimental Study on Flexural Strength of Basalt Fiber Concrete with Phosphogypsum

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Abstract— Most of the research investigations were carried out by purifying phosphogypsum for the impurities present in it, Concrete had a good future and is unlikely to get replaced by any other material on account of its ease to produce , infinite variability , uniformity, durability and economy with using of basalt fiber in high strength concrete then its utilization were suggested. In another research approach phosphogypsum and Basalt fiber could be utilized without any treatment and therefore it may be entitled as untreated and impure form. The main aim of the investigation program is first to prepare the strength of concrete of grade M25 with locally available ingredient and then to study the effect of different proportion of basalt fiber in the mix and to find optimum range of basalt fiber and phosphogypsum content in the mix. The concrete specimens were tested on flexural properties of concrete and other test were conducted for cement, chemical admixture, coarse aggregate & fine aggregate. 10% and 15% of phosphogypsum has been fixed and basalt fiber is being varying on 0.3%, 0.6%, 0.9%. The properties of such cement, cement mortar and concrete mixes produced compared with conventional mixes. The conventional concrete mixes have been modified to accommodate raw phosphogypsum and basalt fiber as a part of cement to be suitable for the concrete for workability and 28 days compressive strength varying from 20 N/ mm2 to 30 N/ mm2.

Key words: Concrete, Basalt Fiber, Phosphogypsum

I. Introduction

With the advancement of technology and increased field application of concrete and mortars the strength, workability, durability and other characteristics of the ordinary concrete is continually undergoing modifications to make it more suitable for any situation. The growth in infrastructure sector led to scarcity of cement because of which the cost of cement increased inclemently. In India, the cost of cement during 1995 was around Rs. 1.25/kg and in 2014 the price increased approximately three times. In order to combat the scarcity of cement and the increase in cost of concrete under these circumstances the use of recycled solid wastes, agricultural wastes, and industrial by-products like fly ash, blast furnace slag, phosphogypsum, silica fume, rise husk, basalt fiber etc. came into use. The use of particular waste product will be economically advantageous usually at the place of abundant availability and production. Much of the literature is available on the use of fly ash, blast furnace slag, silica fume, rise husk, etc. in manufacture of cement concrete. However, the literature on the use of phosphogypsum with basalt fiber in construction industry is in the budding stage. So we try to focus on the use of phosphogypsum with basalt fiber in partial replacement of cement in concrete.

A. Basalt Fiber

Basalt rock is a volcanic rock and can be divided into small particles then formed into continues or chopped fibers.

Basalt fiber has a higher working temperature and has a good resistance to chemical attack, impact load, and fire with less poisonous fumes. Some of the potential applications of these basalt composites are: plastic polymer reinforcement, soil strengthening, bridges and highways, industrial floors, heat and sound insulation for residential and industrial buildings, bullet proof vests and retrofitting and rehabilitation of structures. Basalt is fine-grained, extrusive, igneous rock composed of plagioclase, feldspar, pyroxene and magnetite, with or without olivine and containing not more than 53 wt% SiO_2 and less than 5 wt% total alkalis. Many types of basalt contain phenocrysts of olivine, clinopyroxene (augite) and plagioclase feldspar. Basalt is divided into two main types, alkali basalt and tholeiites. They have a similar concentration of SiO_2, but alkali basalts have higher content of NA_2O and K_2O than tholeiites. The production of basalt fibers is similar to the production of glass fibers. Basalt is quarried, crushed and washed and then melted at 1500° C. The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fiber.

B. Phosphogypsum

Current worldwide production of phosphoric acid yields over 100 million tons of phosphogypsum per year In India, about 6 million tons of waste gypsum such as phosphogypsum, flourogypsum etc. are being generated annually. Phosphogypsum is a by-product in the wet process for manufacture of phosphoric acid (ammonium phosphate fertilizer) by the action of sulphuric acid on the rock phosphate. It is produced by various processes such as dehydrate, hemihydrates or anhydrite processes. In India the majority of phosphogypsum is produced by the dehydrate process due to its simplicity in operation and lower maintenance as compared to other processes. The other sources of phosphogypsum are by-products of hydrofluoric acid and boric acid industries. While most of the rest of the world looked at phosphogypsum as a valuable raw material and developed process to utilize it in chemical manufacture and building products, India blessed with abundant low-cost natural gypsum piled the phosphogypsum up rather than bear the additional expense of utilizing it as a raw material [3, 4]. It should be noted that during most of this time period the primary reason phosphogypsum was not used for construction products in India was because it contained small quantities of silica, fluorine and phosphate (P205) as impurities and fuel was required to dry it before it could be processed for some applications as a substitute for natural gypsum, which is a material of higher purity. However, these impurities impair the strength development of calcined products. It has only been in recent years that the question of radioactivity has been raised and this question now influences every decision relative to potential use in building products in this country.

II. EXPERIMENTAL PROGRAM

A. Materials Used

In this the various materials used for the study, their properties, test conducted and results are discussed. This section also explains the mix proportions used for the study.

B. Cement

Although all materials that go into concrete mix are essential, cement is very often the most important because it is usually the delicate link in the chain. The function of cement is first of all to bind the sand and stone together and second to fill up the voids in between sand and stone particles to form a compact mass. Portland cement referred as ordinary and also they offer many hidden benefits. One of the most important benefits is a fine powder produced by grinding Portland cement clinker. The OPC is classified into three grades, namely 33 Grade, 43 Grade, 53 Grade depending upon the strength of 28 days. It has been possible to upgrade the qualities of cement by using high quality limestone, modern equipment, maintaining better particle size distribution, finer grinding and better packing. Ordinary Portland Cement (OPC) of 43 Grade (JK cement) from a single lot was used throughout the course of the investigation. The physical properties of the cement as determined from various tests conforming to Indian Standard IS: 8112:1989 are listed in Table 3.1.The various tests conducted on cement are initial and final setting time, specific gravity, fineness and compressive strength.

Fig. 1: Cement in pan for testing purpose

1) Normal Consistency

The percentage amount of water which is required to prepare standard cement paste when vicat plunger penetrate under 10±1mm reading is known as standard consistency or normal consistency cement paste.

2) Setting Time

The setting time was conducted as per IS: 4031(Part 5)–1988. The water content observed by normal or standard consistency was used for measuring initial setting time. It was observed that even for ten percent replacement of cement with raw or impure phosphogypsum the initial and final time was increased beyond standard value for ordinary Portland cement as specified in IS: 12269-1987. The initial setting time results are presented in Table 1.1.

S. No.	Name of Test	Details of relevant code	Test Result
1	Consistency	IS :4031 (Part 4)-1988	31%
2	Initial Setting Time	IS : 4031 (Part 5)-1988	30 minutes
3	Final Setting Time	IS : 4031 (Part 5)-1988	310 minutes
4	Specific Gravity	IS : 4031 (Part 11)-1988	3.15

Table 1: Setting time of cement and cement – phosphogypsum mixes

Further compression test on cement was performed to verify the grade of cement which is going to be used. The test was performed using the IS: 4031 (Part 6)-1988 procedure. The test result and standard values are tabulated in Table 2.

No of Days	Compressive Strength (MPa)	
	As Per IS 8112-	Test Result 1989
03	23	24.8
07	33	37.5
28	43	47.6

Table 2: Compressive Strength of cement

C. Aggregate

Aggregates constitute the bulk of a concrete mixture and give dimensional stability to concrete. To increase the density of resulting mix, the aggregates are frequently used in two or more sizes. The most important function of the fine aggregate is to assist in producing workability and uniformity in mixture. The fine aggregate assist the cement paste to hold the coarse aggregate particles in suspension. This action promotes plasticity in the mixture and prevents the possible segregation of paste and coarse aggregate, particularly when it is necessary to transport the concrete some distance from the mixing plant to placement. The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important. They should therefore meet certain requirements if the concrete is to be workable, strong, durable and economical. The aggregates must be proper shape, clean, hard, strong and well graded.

1) Coarse Aggregates

The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. The coarse aggregates may be of following types:

Crushed graves or stone obtained by crushing of gravel or hard stone.

Uncrushed gravel or stone resulting from the natural disintegration of rocks. The normal maximum size is gradually 10-20 mm; however particle sizes up to 40 mm or more have been used in Self Compacting Concrete. Gap graded aggregates are frequently better than those continuously graded, which might expensive grader internal friction and give reduced flow. Regarding the characteristics of different types of aggregate, crushed aggregates tend to improve the strength because of interlocking of angular particles, while rounded aggregates improved the flow because of lower internal friction.

Locally available coarse aggregate having the maximum size of 20 mm was used in this work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per IS: 383-1970. Specific gravity and other properties of coarse aggregates are given in Table 3.5. The sieve analysis of coarse aggregate was done.

Table 4 & 5 shows the result of sieve analysis. Proportioning of coarse aggregates was done and fineness modulus was obtained.

Sr. No	IS-Sieve (mm)	Wt. Retained	%age retained	%age Passing	Cumulative % retained
1	12.5	290	9.67	90.33	9.67
2	10	580	19.33	80.67	29
3	4.75	1800	60	40	89
4	2.36	270	9	91	98
5	Pan	60	2	98	

Table 3: Sieve Analysis of Coarse Aggregate

Characteristics	Value
Colour	Grey
Shape	Angular
Nominal Size	20 mm
Specific Gravity	2.68 (20mm), 2.74 (10mm)
Fineness modulus	6.98 (20mm), 6.26 (10mm)

Table 4: Properties of Coarse Aggregates

Fig. 2: 20mm Coarse Aggregate Fine Aggregates

The aggregates most of which pass through 4.75 mm IS sieve are termed as fine aggregates. The fine aggregate may be of following types:

1) Natural sand, i.e. fine aggregate resulting from natural disintegration of rocks.
2) Crushed stone sand, i.e. Fine aggregate produced by crushing hard stone.
3) Crushed gravel sand, i.e. Fine aggregate produced by crushing natural gravel.

According to size, the fine aggregate may be described as coarse, medium and fine sands. Depending upon the particle size distribution IS: 383-1970 has divided the fine aggregate into four grading zones (Grade I to IV). The grading zones become progressively finer from grading zone I to IV.

In this experimental program, fine aggregate was locally procured and conformed to Indian Standard Specifications IS: 383-1970. The sand was sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and conforming to grading zone II. It was coarse sand light brown in colour. Sieve analysis and physical properties of fine aggregate are tested as per IS: 383-1970 and results are shown in Table 5 and Table 6.

Sr. No.	IS-Sieve (mm)	Wt. Retained	%age retained	%age Passing	Cumulative % retained
1	4.75	3	0.30	99.70	0.30
2	2.36	21	2.10	97.90	2.40
3	1.18	156	15.60	84.40	18.00
4	600g	240	24.00	76.00	42.00
5	300g	375	37.50	62.50	79.50
6	150g	184	18.40	81.60	97.90
7	Pan	21	2.10		

Table 5: Sieve Analysis of Fine Aggregate

Characteristics	Value
Specific gravity	2.56
Bulk density(kg/m^3)	1.3
Fineness modulus	2.43
Water absorption, %	0.89

Table 6: Physical Properties of fine aggregates

D. Concrete Mix Proportions

The mixture proportioning was done according the Indian Standard Recommended Method IS 10262-2009. The target mean strength was 31.6 MPa for the control mixture, the total cement content was 420 kg/m3, fine aggregate is taken 828 kg/m3 and coarse aggregate is taken 1123kg/m3, the water to cement ratio was kept as 0.45. The total mixing time was 2 minutes, the samples were then casted and left for 24 hrs before de-moulding. They were then placed in the curing tank until the day of testing Cement, sand, Basalt fiber, Phosphogypsum and fine and coarse aggregate were properly mixed together in accordance with IS code before water was added and was properly mixed together to achieve homogenous material. Water absorption capacity and moisture content were taken into consideration and appropriately subtracted from the water/cement ratio used for mixing.150 × 150 × 150mm 3 cubes, 500 × 100 × 100mm 3 beams were used for casting. The concrete specimens were cured in the tank for 28 days.

III. EXPERIMENTAL TEST RESULTS

A. Workability

The result shows that partial replacement of cement from phosphogypsum and basalt fiber has different slump value for concrete as the concrete collapse when the mould of frustum of cone is raised vertically. The slump value for M-25 grade of concrete it is between 71 mm to 75 mm. The variation of slump value according to grade of concrete is shown in fig.

Grade of concrete	Phosphogypsum	% of Basalt Fiber	Slump Value (mm)	Avg. value (mm)
M25	0%	0.0	78	
M25	10%	0.3	76	
M25	10%	0.6	75	75
M25	10%	0.9	74	
M25	15%	0.3	72	
M25	15%	0.6	70	
M25	15%	0.9	73	71

Table 7: Result

B. Flexural Strength Test

The flexural strength is the capacity of a beam to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Flexural strength were measured at 28 day of testing. The test results are shown in the following table 7: the beam specimen was placed in the machine, of 2000 kN capacity. The load was applied at a rate of approximately 180 kg/sq.cm/min until the resistance of the specimen to the increasing load can be sustained.

The flexure strength of concrete is found to increase with the addition of phosphogypsum up to 10% replacement of cement with phosphogypsum and 0.3%, 0.6%0.9% replacement of cement with basalt fiber. The increase in flexure strength is more at a water cement ratio of 0.47. The percentage increase in flexure strength (at water-cement ratio 0.47) at 10% phosphogypsum content. There is a significant reduction in the flexure strength at 15% phosphogypsum content. Thus the optimum amount of phosphogypsum in concrete is found to be 10%.The specimen was placed in the machine in such a manner that the load was applied to the uppermost surface as cast in the mould, along two lines spaced 13.33cm apart. The axis of the specimen was carefully aligned with the axis of the loading device. The load was applied through two similar steel rollers, 38mm in diameter, mounted at the third points of the supporting span that is spaced at 13.33cm centre to centre. The load was applied without shock and increasing continuously at a rate of 180 kg/min until the specimen filed. Test results are presented in Table.

Fig. 3: Beam on Universal Testing Machine

Phosphogypsum	% of Basalt Fiber	Flexural Strength (28 days) in N/mm^2	Average Strength in N/mm^2
0%	0.0	2.90	
10%	0.3	3.28	
10%	0.6	3.55	3.37
10%	0.9	3.75	
15%	0.3	2.76	
15%	0.6	3.10	3.14
15%	0.9	3.56	

Table 8: Results

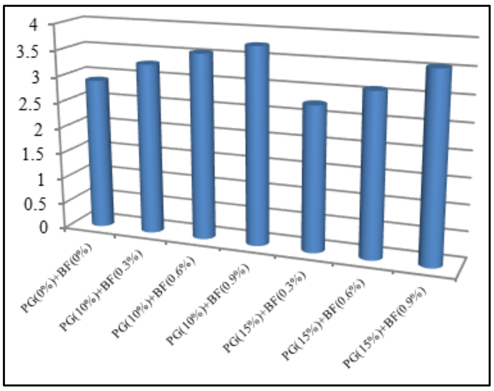

Fig. 4: Graph of Flexural Strength

IV. Conclusion

Conclusions lead to drastic reduction not only in the compressive strength but also in the flexural strength on increasing the percentage of phosphogypsum with basalt fiber. Based on the limited experimental investigation conducted and the analysis of test results, the following conclusions are drawn:

1) An industrial waste like phosphogypsum impairs the strength development of calcined products and hence it can be used in construction industry for preparation of concrete replacing some quantity of cement, which is a valuable ingredient of concrete, to achieve Economy. Thus, the cost of basalt fibre is considerable lower than that of similar materials.
2) With 10% replacement of cement with phosphogypsum not only the compressive strength increased marginally/ significantly with age but also the flexural strength at 28 days increased commendably.
3) Phosphogypsum can be economically used up to ten percent as an ingredient or admixture of cement-mortar mix, both for stone and brick masonry work. As well as the benefit of using basalt fiber is that it is non-corrosive. The strength is very good. The heat resistance power is very good which is extremely important for every building.
4) The degree of workability of concrete mix with ten percent phosphogypsum decreases as compared to conventional concrete, but it improves cohesiveness of the concrete mix and thus reduction in segregation and bleeding. It also has been observed that the workability of concrete decreases with the addition of Basalt Fibre.
5) The compressive strength of phosphogypsum cement concrete (with ten percent PG) is improved indicates that phosphogypsum has immense potential to be utilised in concrete applications especially mass concrete work. It shows that the presence of fibers in the concrete acts as the crack arrestors. The ductility characteristics have improved with the addition of basalt fibers. The failure of fiber concrete is gradual as compared to that of brittle failure of plain concrete.

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