Precast Masonry Blocks using Basalt Fines and Coarse Aggregates

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ABSTRACT

Basalts are the major source of construction material in Maharashtra and Madhya Pradesh rigions of India. Quarried basalts are crushed to various sizes at the quarry sites for obtaining aggregates for road making, railway tracks and concrete. As a result of crushing a lot of fines is produced which is considered as waste. A systematic study was undertaken to assess the suitability of basalt fines and coarse aggregates with respect to the durability of concrete. Studies also included the tests on the masonry blocks made by using basalt fines and coarse aggregates. These results are presented in this paper.

Introduction

Basalts or trap rocks of India consist of several volcanic flows and form one of the most predominant and widely spread rock formations in the peninsular shield extending from the sea cost of Bombay in the West to the temples of Amarkantak (Lat. 22°50'N; Long. 81°31'E) at the head of Narmada river in the east and Guna (Lat. 24° 40'; Long. 77°22'E) in the north to Beglaum (Lat. 15°50'; Long. 74°25'E) in the South. These rocks indicate considerable difference in structure, texture and mineralogical constituents. Texture varies from homogeneous cryptocyystalline mass to a coarsely crystalline dolerite. Petrographically, the common types are normal augite basalt consisting predominantly of plagioclases and augites often with ophitic or sub-ophitic texture. At places the rock is vesicular or amygdoloidal wherein the cavities are filled up by secondary minerals like calcite, quartz and zeolites. Dark coloured basalts are known to be rich in glass while the light coloured grey or greenish grey basalts are generally poor in glassy matter. The secondary minerals commonly found are palagonite, chlorophaeite, serpentine, chlorites, calcite and quartz.

The studies carried out by Shkarupa[1] on the effects of composition of aggregates on the strength of structural concrete and bond strength have shown that basalts have better adhesion with cement than granite. The disintegration of concrete specimens having granite aggregates were found at cement aggregate contact whereas concretes having basalt aggregate showed cracking of cement stone. According to Soloman[2] the use of basalt dusts in place of natural sand increases the compressive and tensile strength of the concrete. He, however, suggested the use of some additives to overcome the problems of high water content. There have also been a fear[3,4] by using some varieties of basalt stones as aggregates in concrete due to alkali-aggregate reaction.

In India, basalt is generally used as building stones and its gravels are used as road ballast, on railway tracks and concreting work. During crushing of basalts a huge amount of dust or fines is produced which is considered as waste. So far no significant use of these wastes have been found. In view of the above, an investigation was carried out to study the suitability of basalt coarse and fine aggregates for use in concrete and precast stone masonry blocks. The results obtained on samples collected from Panjim, Bhopal, Indore and Nagpur areas are described in this paper.

Experimental Procedure

Basalt coarse and fine aggregates were evaluated for various physico-chemical and engineering properties, according to 'Indian Standard Methods of Test for Natural Aggregates for Mortar and Concrete', IS : 2386 (Part I-VIII)-1963. Physical properties viz. bulk density, water absorption, specific gravity and voids were determined as per IS : 2386 (Part III)-1963; particle size analysis and fineness modulus of fine aggregate samples according to IS : 2386 (Part I)-1963; presence of deleterious matters and organic impurities as per IS : 2386 (Part II)-1963 and soundness and presence of reactive minerals (alkali-aggregate reactivity) as per IS : 2386 (Part V) and (Part VII)-1963.

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Mechanical properties of coarse aggregate samples like crushing value in terms of percentage of fines −(2.36 mm) obtained on the application of 40 tonnes load, the load in tonnes required for 10 percent fines (−2.36 mm) and impact value in terms of % fines (−2.36 mm) were determined according to IS : 2386 (Part IV)—1963.

Mortar making properties of the basalt fine aggregates were studied on the basis of their requirements for mortar having 2 kg cement and at 110 ± 5 percent flow with 0.6 W/C ratio as given in IS : 2386 (Part VI)—1963. The cubes of size 7.06X7.06X7.06cm of 1 : 3 cement-fine aggregate mortar at 110 ± 5 per cent flow were cast and tested at the age of 7 and 28 days of water curing.

The cubes of size 10X10X10 cm of 1 : 2:4 concrete mixes of cement, basalt fine and basalt coarse aggregates (−20 mm) were also cast at 0.80—0.82 compaction factor and tested at the age of 7.28 and 90 days of water curing. A few cubes after 28 days of water curing were subjected to 100 cycles of alternate wetting in water for 6—8 hours and drying in oven at 110°C for 16 hours as well as to natural exposure for one year to assess their durability.

Concrete blocks of size 30X20X15 cms using basalt coarse and fine aggregates of nominal mixes 1 : 3 : 6 and 1 : 4 : 8 were made using a plate vibrator and tested at 28 days of water curing. The blocks containing a coarse sand (Badarpur sand) and locally available coarse aggregates of the same mix compositions were also made for comparative study.

Results & Discussion

The particle size analysis of basalt fines collected from Panjim (Goa), Bhopal, Indore and Nagpur given in Table 1 and Fig. 1 indicate that these samples fall in the grading zone II except in the case of sample from Nagpur which fall under the grading zone I according to IS : 383—1970. The fineness modulus of these fine aggregates varied from 2.36 to 3.07 and therefore on the basis of the grading they are suitable for making mortar or concrete as per IS : 2116—1965. The data given in Table 2 indicate that water absorption values of these aggregates vary from 0.50 to 1.10 percent whereas bulk density, specific gravity and void values vary from 1.65 to 1.82 kg/litre, 2.51 to 3.03 and 26.1 to 40.0 percent respectively. These data further confirm the suitability of the aggregates examined for making mortar or concrete.

The results given in Table 3 show that basalt stone aggregates pass the IS specification 383—1970 for soundness as the percent losses obtained in these aggregates treated with sodium sulphate solution are 4.06 to 11.76 percent against the standard values of 12.0 percent. The amount of deleterious materials, which affect the bonding of aggregate with cement as well as strength and workability of cement mortar are given in Table 3. The data show that all the deleterious materials except clay lumps, coal and lignite are of higher order as compared to the IS specification. Organic impurities in these samples were found to be absent. The silt and clay content in the samples from Bhopal and Indore is higher as compared to the standard values, which may cause excessive drying shrinkage in mortar or concrete. The material finer than 75 microns (more than 3.0 percent) may affect the quality of mortar or concrete due to higher requirement of water for the same workability.

The presence of reactive minerals in basalt aggregates determined in terms of reduction in alkalinity (Rc) and soluble silica (Sc) in millimoles—litre are given in Table 3. Rc and Sc vary from 112.3 to 270.0 and 97.1 to 180.6 millimoles/litre respectively against the specified limits of not more than 75 and 70 millimoles/litre. The higher values may be ascribed to the reaction between NaOH used and amorphous silica of the aggregate. The mortar bar tests were carried out using a cement of 0.62% alkalies as per IS : 2386 (Part II (VII)—1963) for alkali aggregate reactivity. The results did not show any appreciable expansion. The accelerated test (5) on mortar bars too did not show any expansion. Above results clearly indicate that the cement of low alkali content (0.62%) was responsible for the soundness of the bars. Hence, the basalt aggregates can be used for mortar or concrete only if the cement of lower alkali content is used.

The mechanical properties of basalt coarse aggregates like crushing values in terms of percent fines obtained on applying 40 tonnes load for 10 percent fines and impact value in terms of percent fines are given in Table 4. The results obtained satisfy the requirements laid down in IS : 383—1970. The data further show that these aggregates are quite strong and can safely be used in concrete work.

The mortar making properties of basalt fine aggregates (Table 5) show that the consumption of these saturated and surface dried aggregates for mortar having 2 kg cement and 110 ± 5 percent flow with W/C 0.6 vary between 4.0 to 4.8 kg as compared to the standard limits of 3.3 to 5.2 kg. as per IS : 383—1970. This shows that the consumption of these samples for a fixed quantity of cement are within specified limits. The compressive strength of these aggregates mixes at the age of 7 and 28 days of water curing vary between 72 to 102 and 150 to 194 kg/cm^2 respectively. The 1 : 3 mortars having these aggregates as fine aggregate and 110 ± 5 percent flow show 7 and 28 days compressive strength values in the range of 55 to 82 and 95 to 129 $kg./cm^2$ as compared to 56 and 102 $kg./cm^2$ with Badarpur sand of fineness modulus 2.89. Hence these stone dusts can be used as fine aggregate for making mortars.

The concrete making properties of baalt stones fine and coarse aggregates as given in Table 6 show that the C.S. at 28 days of concrete cubes (10X10X10 cm) having 1 : 2 : 4 mix by volume vary between 120 to 136 kg/cm² while with Badarpur sand the compressive strength was found to be 103kg./cm. due to coarser nature of Badarpur sand deficient in fines. This data show that basalt stone aggregates as fine and coarse aggregates can be used in concrete. The durability studies carried out on the 28 days cured concrete cubes made from these aggregates (by putting concrete cubes for 100 cycles of alternate wetting and drying) did not indicate any reduction in the compressive strength of the cubes as compared to their 28 days strength. Further, the compressive strengths of the concrete cubes after one year natural exposure was found to be 263—337 kg/cm² as compared to 120—135 kg./cm² (28 days compressive strength). These results confirm the durability of these aggregates for making concrete.

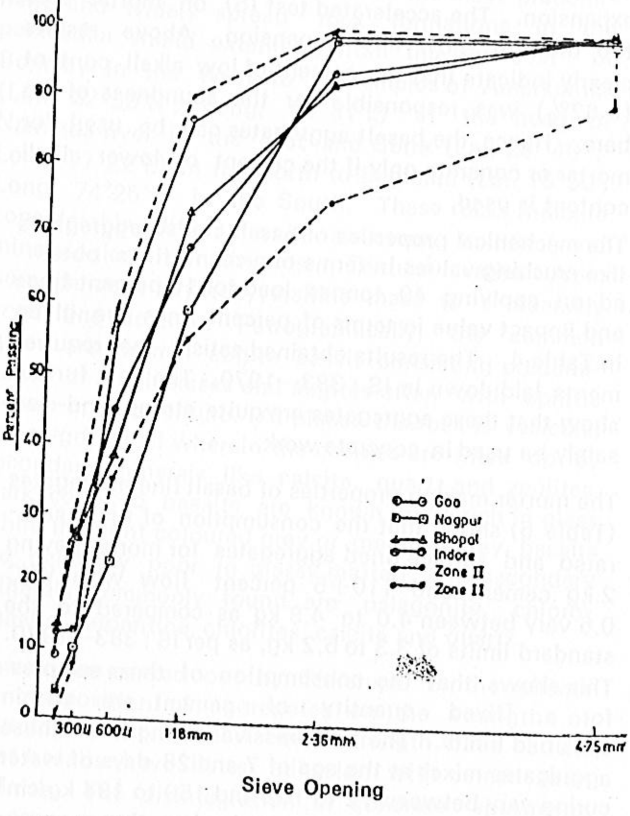

Fig. 1. Sieve Analysis of Basalt Stone Dust Samples from Goa, Nagpur, Bhopal and Indore .

On the basis of above results concrete masonry blocks of 1 : 3 : 6 and 1 : 4 : 8 (by volume) mixes made with basalt coarse and fine aggregates from Bhopal and Indore ; Badarpur sand and basalt coarse aggregate and the control samples using local coarse aggregate and Badarpur sand were made and tested after curing for 28 days. The results (Table 7) show that the compressive strength of the blocks containing 1 : 3 : 6 and 1 : 4 : 8 mixes vary between 76 to 121 kg/cm² and 42 to 90 kg./cm² respectively as compared to 88 kg./cm² and 44 kg/cm² with conventional aggregates. It is significant to note that the compressive strengths of the blocks having basalt fines as fine aggregate are higher when compared to those of the corresponding samples using Badarpur sand.

Conclusions

A study on the suitability of the basalt stone as fine and coarse aggregates available as a waste from the quarry and crusher sites has shown that these can be used for making mortar as well as concrete masonry blocks. However, the cement to be used with basalt aggregates should preferably be low in alkali content. The use of basalt fines as fine aggregate in place of coarse sand increases the compressive strength of concrete masonry blocks.

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TABLE 1 : Sieve Analysis of Basalt Stone Dust Samples from Goa, Nagpur, Bhopal & Indore :

Sl. No.	Sieve Size	Samples Collected from (Material % Passing)				Badarpur Sand (%Passing)	Limits for Grading Zone-II (%Passing)
		Goa	Nagpur	Bhopal	Indore		
1.	4.75 mm	100	98.8	100	100	99.8	90—100
	2.36 mm	99.6	98.3	91.8	93.5	92.0	75—100
	1.18 mm	86.8	59.0	73.2	68.1	68.8	55—90
	600 Microns	56.9	23.0	38.5	45.1	38.9	35—59
	300 Microns	12.9	10.0	26.6	25.8	8.7	8—30
	150 Microns	12.7	4.1	13.6	9.0	2.5	0—10
2.	Fineness Modulus	2.31	3.07	2.57	2.60	2.89	—
3.	Grading Zone As per IS : 383-1970	II	I	II	II	II	

TABLE 2 : Physical Characteristics of basalt stone aggregates :

Sl. No.	Characteristics	Samples collected from				IS : 383—1970 Limits
		Goa	Nagpur	Bhopal	Indore	
1.	Bulk density (kg. litre)	1.75	1.82	1.80	1.65	—
2.	Water absorption (%)	0.60	1.10	0.50	0.68	1.0
3.	Specific Gravity	2.70	3.03	2.85	2.51	—
4.	Voids (%)	26.1	40.0	36.8	32.7	—
5.	Suitability for mortar making as per IS:2116/1965	Yes	Yes	Yes	Yes	—

TABLE 3 : Physico/Chemical Properties of Basalt Stone Aggregate :

Sl. No.	Characteristics	Samples collected from				IS : 383—1970 Limits (Maximum)
		Goa	Nagpur	Bhopal	Indore	
1.	Soundness (% loss)	4.06	8.70	11.76	4.65	12.0
2.	Presence of deleterious Materials					
	—Clay+Silt (%)	0.23	0.47	2.16	1.53	1.0
	—Clay lumps (%)	Nil	Nil	Nil	Nil	1.0
	—Coal+Lignite (%)	Nil	Nil	Nil	Nil	1.0
	—Material passing 75 micron	3.8	5.1	6.51	5.60	3.0 (15% for crushed stone dust).
	Total deleterious Material (%)	3.8	5.1	6.51	5.60	5.00
3.	Organic Impurities	Absent	Absent	Absent	Absent	Absent
4.	Reactive Minerals					
	Reduction in Alkalinity (RC) (Millimoles/Litre)	112.3	131.6	270.0	150.0	75.0
	Soluble Silica Content (Sc) (Millimoles/litre)	97.1	113.9	180.6	135.0	70.0

TABLE 4 : Mechanical Properties of Basalt Stone Aggregate :

Sl. No.	Properties	Samples collected from Nagpur	Bhopal	Indore	IS : 383—1970 Limits (Maximum)
1.	Aggregate crushing value at 40 tonnes load (% fines)	18.5	17.0	16.0	45
2.	Aggregate crushing value for 10 percent fines.	20.9	24.3	25.8	...
3.	Aggregate Impact Value (% fines)	10.3	9.4	8.2	45

TABLE 5 : Mortar Making Properties of Basalt Fine Aggregate :

Sl. No.	Properties		Samples collected from Goa	Nagpur	Bhopal	Indore	Badarpur Sand
1.	Consumption of saturated and surface dried fine aggregate for mortar having 2 Kg. cement and 110 ± 5 % flow (Kg.)		4.04	4.7	4.8	4.0	3.75
2.	Compressive strength of the above mixes at the age of (kg./cm. sq.)	7d	98	86	72	102	87
		28d	180	166	150	194	158
3.	Compressive strength of 1:3 mortar cubes at the age of (kg/cm. sq.)	7d	55	72	70	82	56
		28d	95	112	102	129	102

TABLE 6 : Concrete Making Properties of Basalt Fine or Badarpur Sand with Basalt-Coarse Aggregate (1 : 2 : 4 by Volume).

Sl. No.	Samples from	W/C	C.F.	Compressive Strength (kg./cm sq.) at the age of 7d	28d	90d	After 100 Cycles of durability	After one year natural exposure
1.	Goa*	0.60	0.82	82	136	185	—	—
2.	Bhopal*	0.60	0.81	87	135	182	175	337
3.	Bhopal**	0.61	0.82	86	127	176	140	267
4.	Indore*	0.62	0.81	78	125	173	164	293
5.	Indore**	0.65	0.82	76	120	165	152	281
6.	Crushed Stone** Aggregate	0.70	0.78	66	103	151	—	—

* With Basalt Fine Aggregate.
** With Badarpur Sand.

TABLE 7 : Compressive Strengths Data of Precast Masonry Blocks after curing for 28 days :

Sl. No.	Mix composition (by volume)	Average crushing Load (Tons)	Average compressive Strength (kg./cm.sq.)
1.	Cement : Bhopal basalt fine aggregate; Bhopal basalt coarse aggregate (—40 mm) (1:3:6)	70.0	117.0
2.	Cement : Bhopal basalt fine aggregate; Bhopal basalt coarse aggregate (—40 mm) (1:4:8)	54.0	90.0
3.	Cement : Badarpur sand : Bhopal basalt coarse aggregate (—40 mm) (1:3:6)	46.0	76.7
4.	Cement : Badarpur sand : Bhopal basalt coarse aggregate (—40 mm) (1:4:8)	35.0	58.3
5.	Cement : Indore basalt fine aggregate : Indore basalt coarse aggregate (—40 mm) (1:3:6)	73.0	121.0
6.	Cement : Indore Basalt fine aggregate : Indore Basalt coarse aggregate (40 mm) (—1:4:8)	36.0	60.0
7.	Cement : Badarpur sand : Indore basalt coarse aggregate (—40 mm) (1:3:6)	45.0	75.0
8.	Cement : Badarpur sand : Indore basalt coarse aggregate (—mm) (1:4:8)	25.0	42.0
9.	Cement : Badarpur sand : Local coarse aggregate (—40 mm) (1:3:6)	48.0	80.0
10.	Cement : Badarpur sand : Local coarse aggregate (—40 mm) (1:4:8)	26.3	44.0