Evaluation of fine and coarse basalt aggregates for mortar and concrete

Mohan Rai, G. S. Mehrotra and Dinesh Chandra

The paper gives results of an investigation carried out to study the suitability of using basalt coarse as well as fine aggregate, in the form of stone dust, for making mortar and concrete. A detailed study of physico-chemical and mechanical properties of the aggregates have shown that these aggregates can suitably be used in mortar and concrete.

Basalt or trap rock covers about 520,000km² in India. Their composition varies considerably from area to area, both in mineral content and crystallinity which can vary from homogeneous crypto-crystalline mass to a coarsely crystalline dolerite. The rock can also be vesicular and scoriaceous with cavities filled up by secondary minerals like calcite, quartz and zeolites.

The effects of composition and physico-mechanical properties of aggregates on the strength of structural concrete and bond strength between the binder and the aggregate have been studied by Shkarupa by measuring the tensile strength of concrete specimen made from Portland cement, sand and aggregate (grey granite, basalt, blast furnace slags etc)[1]. The adhesion of cement to granite has been found lower than to basalt or slag. Further, concrete specimens made with granite as aggregate were found to disintegrate at the cement-aggregate contact while those with basalt disintegrate by cracking of cement stone. The properties of aggregates for structural concrete have been specified in terms of Washington degradational factor, secondary mineral content, Los Angel's abrasion loss, flakiness index and contents of unsound rock for basalt aggregates[2]. On the basis of these properties the use of green basalt is restricted whereas, that of grey basalt is permitted.

The methods of determining the secondary mineral contents of basalts have been mentioned by Cole[3]. The use of stone dust from basalt quarries in place of natural sand in concrete mixes has been studied by Solomon who compared the properties of concrete specimens made with basalt stone dusts of different proportions[4]. If such stone dust is used in the normal proportions as fine aggregates some additives are required to overcome certain problems of high water content. There have also been some apprehensions in using few varieties of basalt as aggregate due to the alkali-aggregate reaction [5, 6].

In India, basalts are extensively used as building stones and crushed to various sizes for use as road bases, railway ballast and in concreting work. During crushing a lot of fine dust is produced which is considered as a waste material. So far no concerted efforts have been made to utilize the fine dust. A systematic study was carried out at the Central Building Research Institute to determine the suitability of coarse as well as fine basalt aggregate (stone dust) for making mortar and concrete from the samples collected from Indore, Bhopal and Nagpur.

Dr Mohan Rai, MSc (Tech), PhD, FIE, Scientist Coordinator, Building Materials Division, Central Building Research Institute, Roorkee, UP

Dr G. S. Mehrotra, MSc, PhD, Scientist, Building Materials Division, Central Building Research Institute, Roorkee, UP

Dr Dinesh Chandra, MSc, PhD, Scientist, Building Materials Division, Central Building Research Institute, Roorkee, UP

Experimental

Basalt stone dust and coarse aggregates were evaluated for bulk density, specific gravity, water absorption and voids according to IS: 2386 (part I)-1963, presence of deleterious and organic impurities according to IS: 2386 (part II)-1963; soundness and presence of reactive minerals (alkali aggregate reactivity) according to IS: 2386 (part V) and (part VII)- 1963, respectively.

Crushing value in terms of percentage of fines (—2.36mm obtained on the application of 40-t load; the load required in tonnes for 10 percent fines, (—2.36 mm) and impact value in terms of fines (—2.36mm) were determined as in accordance with IS: 2386 (part IV)-1963.

The mortar making properties of basalt stone dust samples were determined according to IS: 2386 (part VI)-1963. Specimens for compressive strength test 7.06×7.06×7.06-cm cubes were cast with a water-cement ratio of 0.6 and flow at 110± 5 percent for the mortar containing 2kg cement and required amount of stone dust. These cubes were immersed in water after 24 hours of casting till their testing at the age of 7 and 28 days. 7.06-cm cubes of 1:3 cement-basalt dust mortar at 110± 5 percent flow were also cast and tested after 7 and 28 days curing. Control specimens with cement and sand were also cast for comparison.

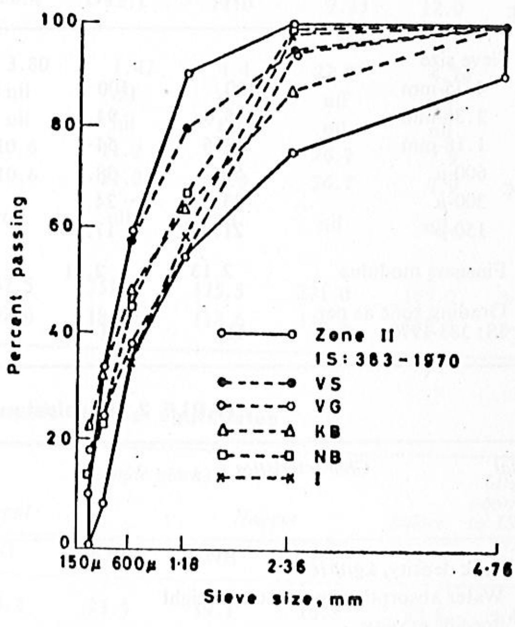

Fig 1 Sieve analysis of basalt stone dust samples marked VS VG, KB, NB and I

1:2:4 concrete cubes of size 10×10×10 cm were cast using either stone dust or Badarpur sand as fine aggregate and basalt stone as coarse aggregate. The compaction factor was kept to 0.80 with vibration time one minute. These cubes were cured in water till their age of testing at 7, 28 and 90 days.

To study the effect of basalt fines and coarse aggregates on the performance of concrete made from them, a few specimens after 28 days curing were subjected to alternate heating for (16 hours) and wetting for (8 hours) for 100 cycles, after which the compressive strength was determined.

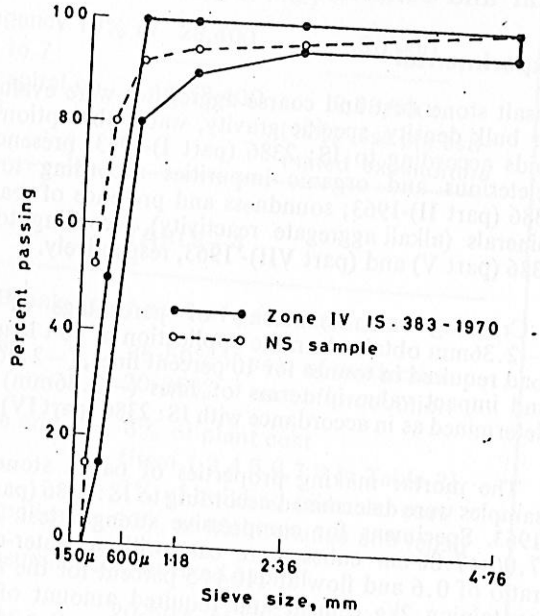

Fig 2 Sieve analysis of basalt stone dust sample marked NS

Results and discussions

The particle size analysis of basalt stone dust samples are given in *Table* 1 and *Figs* 1 and 2 which indicate that these samples mostly fall under the grading zone II of IS: 383-1970 except in the case of sample NS (from Nagpur), which comes under the grading zone IV. The fineness modulus of basalt fines varies between 1.19 to 2.81. This shows that these aggregates can be suitably used for making mortar according to IS:2116-1965. The sieve analyses of the samples indicates that these can be used in mortar or concrete although in the case of sample NS, the requirement of water was more. The water absorption, bulk density, specific gravity and voids values given in *Table* 2 indicate that the bulk density values vary from 1.52 to 1.82 kg/litre, while water absorption, specific gravity and voids values vary from 0.40 to 1.60 percent, 2.5 to 3.12 and 26.1 to 48.9 percent, respectively. All these results confirm the suitability of the basalt fine aggregates for mortar or concrete.

The data in terms of percentage loss as given in *Table* 3 indicate that basalt aggregates from Bhopal region marked VS, VG and KB do not pass the specifications laid down in IS: 383-1970 for soundness test as the percentage loss with sodium sulphate solution after 10 cycles was found to be 22.1 to 30.4 percent as compared to the specified 12.0 percent (maximum). The higher values of soundness may be due to the porous nature of these samples. Other samples from Nagpur, (NB) and Indore (I) which are comparatively less porous show

TABLE 1 Sieve analysis of basalt stone dust sample

Serial no	Sieve analysis	*Percent of material passing in sample marked* Bhopal VS	VG	KB	Nagpur NB	NS	Indore I	According to IS: 383-1970 zone II	zone IV
1.	Sieve size								
	4.75-mm	100	100	100	100	100	100	90 to 100	95 to 100
	2.36-mm	95.0	94.6	87.0	98.9	98.6	98.2	75 to 100	95 to 100
	1.18-mm	79.6	54·6	63.7	66.2	94.8	58.2	55 to 90	90 to 100
	600-µ	57.3	38.1	48.1	44.9	92.0	34.0	35 to 60	80 to 100
	300-µ	33.5	24.2	31.8	22.7	80.0	17.1	7.5 to 30	15 to 50
	150-µ	21.3	17.9	22.6	13.5	52.4	11.1	0 to 10	0 to 15
2.	Fineness modulus	2.13	2.71	2.47	2.54	1.19	2.81	—	—
3.	Grading zone as per IS: 383-1970	II	II	II	II	below IV	II	—	—

TABLE 2 Physical properties of basalt stone dust samples

Serial no	Characteristics	Bhopal VS	VG	KB	Nagpur NB	NS	Indore I
1.	Bulk density, kg/litre	1.52	1.60	1.72	1.55	1.47	1.58
2.	Water absorption, percent by weight	1.60	1.00	0.80	0.40	1.00	0.40
3.	Specific gravity	2.84	2.96	3.12	2.86	2.87	2.94
4.	Voids, percent	46.8	46.0	44.8	45.8	48.9	46.2
5.	Suitability for mortar according to IS:2116-1965	yes	yes	yes	yes	yes	yes

soundness values well within the limits specified. Since the tests carried out for soundness of aggregates by using sodium sulphate or magnesium sulphate indicate the resistance of aggregates against freezing and thawing, the use of such basalts can be restricted in very cold climate whereas, in tropical to subtropical regions, as in peninsular India, such aggregates can be considered suitable for making concrete. This inference is confirmed by the durability results obtained on alternate wetting and drying cycles of concrete described later.

The presence of deleterious materials like clay plus silt, clay lumps, coal and lignite and material finer than 75-microns sieve in these samples as shown in *Table* 3 are more than the specified limit in the case of samples VS, VG, KB, NS and I. The presence of material finer than 75-microns more than 3 percent may affect the quality of concrete due to higher water requirement for the desired workability.

The amount of organic impurities evaluated according to IS:2386 (part II)-1963 was found to be in harmless quantities.

The alkali-aggregate reactivity of basalt samples in terms of reduction in alkalinity and soluble silica content in millimoles/litre as given in *Table* 3 was found to be very high; *i.e.* 169.0 to 357.5 and 115.5 to 192.6 millimoles/litre, respectively. In case of the Bhopal sample (VG) these values reach even 357.5 and 192.6 millimoles/litre, although these values should not be more than 75 or 70 millimoles/litre. Theoretically higher values may be attributed to the reaction between alkalies leached out from hydrated cement and microcrystalline phases of silica from the aggregates. Another test on alkali-aggregate reactivity based on mortar bar method as given in IS: 2386 (part VII)-1963 does not indicate any appreciable expansion. The accelerated tests carried out also did not show any expansion in bars[7, 8]. This variable behaviour may be assumed to be due to lower alkali content of the cement used. Thus the aggregates which showed high values of alkali reduction and Silica content but failed to show any appreciable expansion in mortar bars can be used for making mortar or concrete. In practice, if the cement of lower alkali content is used, there should be no problem concerning the durability of concrete.

The mechanical properties of coarse basalt aggregates determined according to IS: 2386 (part IV)-1963 and shown in *Table* 4 indicate that these aggregates offer strong impact resistant and hence can be safely used in concrete work. All the values are well within the specified limits of IS: 383-1970.

The mortar making properties of basalt stone dust as given in *Table* 5 show that the consumption of saturated and surface dried fine aggregates for every 2kg of cement varies between 2.27 to 4.5 kg. However, according to IS: 383-1970 it should be between 3.3 to 5.2kg. As the sample NS was the finest among all samples, only 2.27kg of fine aggregate was required for 2kg of cement at 110± 5 percent flow and water-cement ratio 0.6. Thus, it is on the lower side as compared to the specified limits. On the basis of these data the order of water requirement can be found out for a particular fineness of each sample for 1:3 mortar as well as the respective compressive

TABLE 3 Physico-chemical properties of basalt stone dust samples

Serial no	Characteristics	Sample marked						Limits according IS:383-1970
		Bhopal			Nagpur		Indore	
		VS	VG	KB	NB	NS	I	
1.	Soundness, percent loss	28.1	30.4	22.1	11.0	7.35	12.0	$\ngtr$12.0
2.	Deleterious, matters							
	clay silt, percent	0.48	3.80	1.42	4.4	22.9	4.74	
	clay lumps, percent	nil	nil	nil	nil	nil	nil	
	coal lignite, percent	nil	nil	nil	nil	nil	nil	
	material passing 75-μ sieve	10.2	10.6	11.2	5.0	26.7	7.9	
	Total deleterious materials, percent	10.2	10.6	11.2	5.0	26.7	7.9	$\ngtr$ 5.0
3.	Organic impurities	nil	nil	nil	nil	nil	nil	
4.	Reactive minerals							
	reduction in alkalinity, millimoles/litre	286.0	357.5	351.0	175.5	221.0	169.0	$\ngtr$75
	soluble silica content, millimoles/litre	162.4	192.6	184.9	118.6	136.4	115.5	$\ngtr$70

TABLE 4 Mechanical properties of basalt coarse aggregates

Serial no	Properties	Sample marked						Limits according to IS:383-1970
		Bhopal			Nagpur		Indore	
		VS	VG	KB	NB	NS	I	
1.	Aggregate crushing value at 40-t load, percent fines	26.1	24.2	23.4	19.1	16.5	20.8	$\ngtr$45
2	Aggregate crushing value for 10 percent fines	14.0	16.7	17.1	21.0	21.4	19.8	—
3.	Aggregate impact value, percent fines	10.4	9.5	9.9	8.1	7.2	6.7	$\ngtr$45

strengths at 110±5 percent flow of this mortar. The compressive strengths of 1:3 mortar at the curing age of 7, 28 and 90 days were found to be more than the control specimen in all cases except for the mortar containing aggregate NS which could be attributed to its finer grading. The higher or better values of compressive strength of the basalt containing specimen mortar cubes as compared to the control mortar samples may be due to better gradings as well.

The concrete making properties of basalt fine and coarse aggregates, Badarpur sand and basalt coarse aggregates and that of the control samples are given in *Table* 6. The data indicate that 28 days compressive strengths of 1:2:4 concrete cubes (10 × 10 × 10-cm) containing basalt aggregate vary between 68 to 109kg/cm² as compared to 74kg/cm² of the control sample. The highest values of compressive strength of the concrete made by using sample VS could be explained on the basis of vesicular surface of the aggregate resulting into better bonding. The tensile strengths data of similar samples confirm the trend of compressive strength data.

The concrete cubes after 28 days water curing were subjected to 100 cycles of alternate wetting and drying. The results did not indicate any reduction in compressive strength as compared to their 28 days strengths and no sign of cracking or deterioration was observed, *Table* 6. This would predict the good durability of concrete made from these basalt samples.

Conclusions

The present study has shown that basalt coarse as well as fine aggregates can suitably be used for making mortar and concrete in tropical to subtropical regions having temperate climate provided the cement to be used does

TABLE 5 Mortar making properties of basalt stone dust samples

Serial no	Characteristic	Bhopal VS	Bhopal VG	Bhopal KB	Nagpur NB	Nagpur NS	Indore I	Badarpur sand	Limit according to IS:383-1970
1.	Consumption of fine aggregate for 2-kg cement, kg	4.3	3.8	4.0	3.7	2.27	4.5	3.75	3.3 to 5 2
2.	Compressive strength of above mixes, kg/cm²								
	7 days	50	60	40	68	70	61	65	—
	28 days	78	92	64	108	110	100	127	—
	90 days	140	170	128	200	208	178	206	—
3.	Compressive strength of 1:3 mortar cubes, kg/cm²								
	7 days	30	25	24	31	12	41	28	—
	28 days	52	46	46	55	23	62	42	—
	90 days	84	74	76	112	54	122	80	—

TABLE 6 Concrete making properties of basalt work aggregate with basalt stone dust or Badarpur sand

Serial no	Sample marked	Mix proportions, by weight	Water-cement ratio	CF	Compressive strength, kg/cm² 7 days	28 days	90 days	after 100 cycles of durability
1.	Bhopal VS*	1:2.76:4.62	0.75	0.81	62	109	170	220
2.	Bhopal VS†	1:2.27:4.62	0.71	0.77	60	88	122	138
3.	Bhopal VG*	1:2.77:4.98	0.79	0.80	48	85	106	150
4.	Bhopal VG†	1:2.23:4.98	0.75	0.78	53	73	94	112
5.	Bhopal KB*	1:2.91:4.95	0.80	0.81	47	78	100	172
6.	Bhopal KB†	1:2.23:4.98	0.77	0.81	44	87	113	115
7.	Nagpur NB*	1:2.66:5.10	0.75	0.77	52	94	123	147
8.	Nagpur NB†	1:2.26:5.10	0.78	0.80	40	72	124	135
9.	Nagpur NS*	1:2.66:5.00	0.75	0.80	40	68	115	185
10.	Nagpur NS†	1:2.26:5.00	0.76	0.78	50	78	122	95
11.	Indore I*	1:2.80:5.12	0.83	0.84	50	87	163	180
12.	Indore I†	1:2.26:5.12	0.77	0.78	54	83	150	125
13.	Control C*	1:2.23:4.83	0.80	0.82	38	74	112	135
14.	Control C†	1:2.74:4.83	0.80	0.82	52	80	105	128

Note: *using basalt stone dust as fine aggregate
†using Badarpur sand as fine aggregate

not contain alkalies more than 0.6 percent. The substitution of basalt stone dust for natural sand in concrete increases the compressive and tensile strengths of the concrete.

Acknowledgement

This paper forms a part of the regular research programme of the Central Building Research Institute, Roorkee and it is published with the kind permission of the Director.

References

1. SHKARUPA, S.S. Effect of the characteristics of binder aggregate adhesion on the properties of structural concrete. *Strait Mater. Detali Izdelhya.* 1975, Vol 19, pp. 114-120.

2. COLE, W. F. Testing of basalt aggregates for concrete, *Conf Prod Prop Test Aggregate.* 1976, pp. 93-109.

3. COLE, W. F. Dimensionally unstable grey basalt. *Cement and Concrete Research,* 1979, Vol 9, pp. 425-430.

4. SOLOMON, K. T. The substitution of stone dust for natural sand in concrete mixes. *Australian Road Research,* March 1977. Vol 7, pp. 27-30.

5. GOGATE, B. S. An evaluation of some common Indian rocks with special reference to alkali-aggregate reaction. *Engineering Geology,* 1973 Vol 7. p.

6. JAGUS, P. J. and BAWA, N. S. Alkali-aggregate reaction in concrete construction, *Road Research Bulletin,* 1957. No. 3.

7. JOHN, BROTSCHI and MEHTA, P. K. Test methods for determining potential alkali-silica reactivity in cements. *Cement and Concrete Research,* 1978, Vol 8, pp. 191-200.

8. CHATTERJI, S. An accelerated metl od for the detection of alkali-aggregate reactivities of aggregates. *Cement and Concrete Research,* 1978. Vol 8(5), pp. 647-9.