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Petrographic evaluation of natural aggregates as construction material from Bhogavo river basins, Surendranagar district, Gujarat

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Abstract

Petrographically analyzed data of natural fine aggregate (sand) around Wadhwan Bhogavo (from Muli to Gedi villages) and Limdi Bhogavo (from Sudamada to Panshina villages) river basins in Surendranagar district of Gujarat, were studied for evaluating the quality of aggregate as construction material. Geologically the area is occupied with Wadhwan, Dhrangadhra and trap formations from Cretaceous to recent age. Major constituents of the natural aggregates comprise of quartz, basalt and sandstone which are easily available in good quantum. A small proportion of amygdaloidal basalt, moderately weathered basalt and sandstone are also found to be present. Weathered amygdaloidal basalt, moderately weathered sandstone and carbonates are also present as physically poor materials throughout the basin, though in lesser quantity. Cryptocrystalline silica with very little percentage of shell fragments at one or two places is found to be the deleterious materials constituting the natural aggregates but well within the prescribed limit of BIS.

1. Introduction:

Surendranagar district in Gujarat is situated around the Wadhwan Bhogavo and Limdi Bhogavo (popularly known as Bhogavo) river basins. Wadhwan Bhogavo river originates near Muli and passes through sedimentary terrain & meets Arabian sea in Bay of Khambhat. Its length is 107 km with 1570 sq km catchment area. Limdi Bhogavo river originates from Chotila ridge & also joins Bay of Khambhat. Its length is 120 km with 1116 sq km catchment area. Bhogavo river is a major right tributary of Sabarmati river.

A variety of rock types right from Cretaceous to Recent age are available as construction material in Surendranagar. These rocks are the main source for deposition of natural aggregates all along the river course. The sediments of rocks are carried away into streams and rivers by rain waters to form shoals to river course. Palaeo flood plains/ river banks are also a source for such river aggregates apart from existing river beds. These natural aggregates are the source of construction material which is being used in large quantities for civil engineering works like roads, bridges, dams, canals, buildings, water supply and drainage, ports etc. Therefore, knowledge of quality of construction material is of vital importance along with its availability.

Topographically the study region is almost flat (excluding Chotila ridge and its surrounding area) with gentle slope towards East. The drainage is moderate with ‘dendritic’ pattern.

Petrographic analysis provides information of constituents present in aggregate with their physical and chemical characteristics as well as the relative amounts of the aggregate's constituents, including deleterious material. Some of the rocks and minerals in aggregates, which are chemically reactive (reacts with the alkalis of cement and forming the gel which expands leading to development of cracks and thus making the structure weak) and thus harmful (deleterious) when used in concrete. As prescribed in IS: 383-1970- "Specification for coarse and fine aggregates from natural sources for concrete", the deleterious constituents should not exceed 5 percent.

An attempt is made in this paper to study the petrographic properties of naturally occurring fine aggregates in the rivers- Wadhwan Bhogavo and Limdi Bhogavo. Petrographic study of samples from various locations along these rivers is carried out in the Petrological Laboratory at GERI, Vadodara. Different constituents are separated out based on its physical and chemical properties. Quantitative analysis is carried out to find the quality of these aggregates as construction material. The testing results provide the presence of various rocks/minerals including deleterious material and physically poor constituents, in the samples.

2. Geology:

Geologically the region studied is occupied by variety of rocks. The general geological succession of the rock formations occurring in the Surendranagar district is given in table-1 below.

Table 1
Geological succession in Surendranagar district, Gujarat

Age	Formation	Lithology
Pleistocene to Recent	Soil/ Alluvium	Black cotton soil and clay, sandy soil, clay, silt, brown sand and gravel
--Unconformity--		
Upper Cretaceous to Lower Miocene	Deccan Traps and related intrusive	Basalts, volcanic tuff , pocellanites, dolerite dykes & related volcanic rocks
Middle Cretaceous	*Wadhwan Group*	
	1.Khamisara Formations	White to Red coloured sandstone
	2.Malachimata Formations	Sandstone and Fossiliferous cherty limestone
	3.Kukda Formations	Ferruginous sandstone with conglomerate
--Unconformity--		
Upper Jurassic to Cretaceous	*Dhrangadhra Group*	
	1.Ranipat Formations	Gritty hard quartzite sandstone
	2.Surajdeval Formations	White sandstone with thin bands of white and grey shale
	3.Than Formations	Ferruginous sandstone, carbonaceous shale with coal seams

2.1 Wadhwan group:

The Wadhwan Group, which overlies the Dhrangadhra group, is about 80 m thick and represents Middle Cretaceous sedimentation. It comprises three formations. The Kukda formation mainly consisting of highly ferruginous, semi-consolidated sandstone with bands of conglomerate and shale overlies the Ranipat formation. The Malachimata formation consists of sandstone and fossiliferous limestone pointing to a marine environment of deposition. Bryozoa, corals, gastropods, echinoids and algae are reported from this formation. The overlying Khamisara formation was deposited in shallow-water deltaic basins developed after marine regression. The rock types are mainly white to light coloured sandstone with thin bands of white shale.

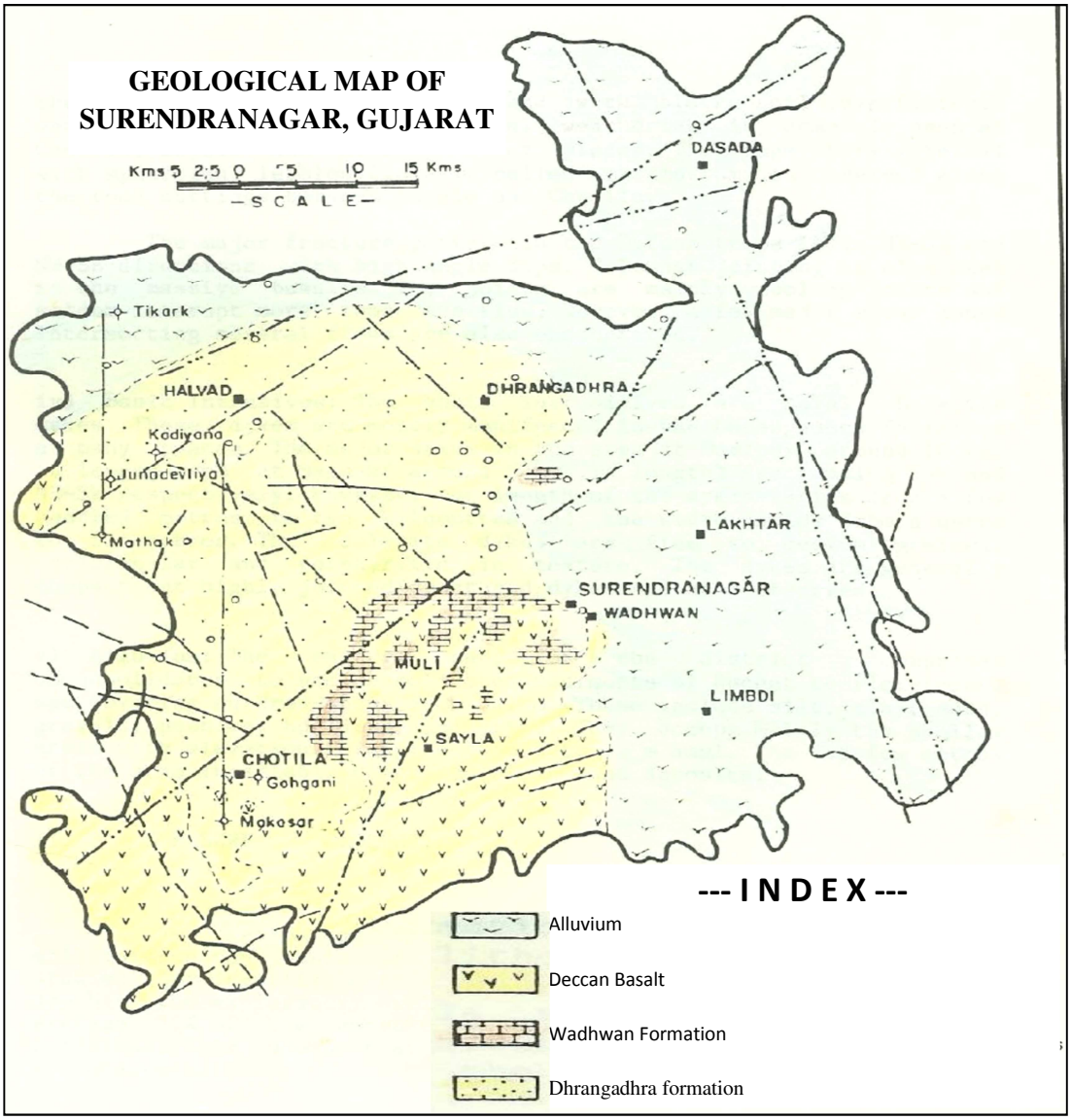

Figure 1 Geological Map of Surendranagar (Ref: CGWB, 2014)

2.2 Dhrangadhra group:

Early Cretaceous sediments are represented by the Dhrangadhra group comprising three formations. The oldest- 'Than formation' consists mainly of current-bedded, ferruginous sandstone and carbonaceous shale with thin coal seams.

The overlying Surajdeval formation consists of white sandstone (glass sand variety) with specks of kaolinised feldspar and thin bands of white to grey shale.

The youngest- Ranipat formation is composed of gritty, hard, purple to brown, highly ferruginous, occasionally quartzitic, sandstone. There are thin bands of white, grey, ferruginous shale and conglomerate. This formation has the widest areal extent among the Mesozoics of Saurashtra.

3. Methodology of the study:

The analyzed data along these two rivers Wadhwan Bhogavo and Limdi Bhogavo was studied, for its various constituents since last 10 years (from 2008 to 2018). In total 38 tested sample data along Limdi Bhogavo river (from Sudamada village to Panshina village) and 31 sample data along Wadhwan Bhogavo river (from Muli village to Gedi village) was available for the study. The locations of villages from where samples were collected are shown in figure 2.

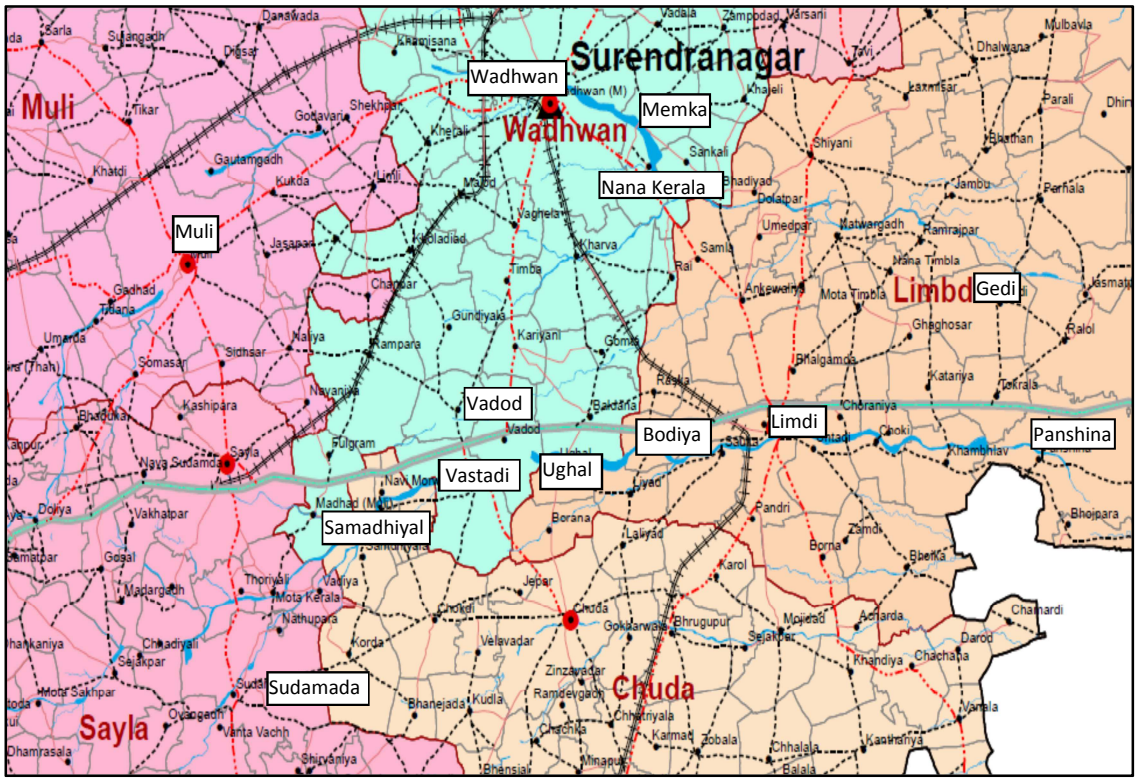

Figure 2 Map showing the locations of villages from where the samples were brought by the project authorities for petrographic analysis

The results obtained from average calculation of observed 'deleterious material' as well as 'physically poor materials' in the samples brought from villages along the rivers Limdi Bhogavo and Wadhwan Bhogavo are tabulated in Tables 2 and 4, respectively. These tables also show the number of samples from respective villages. The averages for both types of materials are calculated on the basis of their percentage presence by weight. Similarly, the percentage of other (major & minor) constituents viz., quartz, basalt, sandstone etc. along the rivers Limdi Bhogavo and Wadhwan Bhogavo are tabulated in Tables 3 and 5 respectively.

Table 2
Average percentage of deleterious materials and physically poor materials along Limdi Bhogavo river

SNo.	Village	No. of Samples	Average of Deleterious Material		Physically poor constituent	
			Mineral	% by Weight	Mineral	% by Weight
1	2	3	4	5	6	7
1	Sudamada	2	Cryptocrystalline silica	0.41	Carbonate, weathered amygdaloidal basalt and weathered sandstone	5.57
2	Samadhiyala	1		0.25		5.93
3	Vastadi	7		0.53		5.92
4	Vadod	5		0.54		9.91
5	Ughal	2		0.75		5.68
6	Bodiya	5		0.79		8.93
7	Limdi	9		0.78		13.10
8	Panshina	7		0.94		12.22

Table 3
Average percentage of other (major & minor) constituents along Limdi Bhogavo river

SN.	Village	Average percentage (By weight) for various rock/mineral					
		Amygdaloidal Basalt	Basalt	Basalt (Weathered)	Quartz	Sandstone	Zeolite
1	2	3	4	5	6	7	8
1	Sudamada	0	13.2	0	61.35	10.6	0
2	Samadhiyala	0.91	23.58	4.82	61.16	0.46	0.05
3	Vastadi	4.33	28.33	0.33	59.96	2.94	0.23
4	Vadod	3.54	29.86	0	55.62	3.62	0.68
5	Ughal	2.16	35.25	0	52.96	5.52	0.21
6	Bodiya	2.16	28.25	0	59.28	2.53	0
7	Limdi	4.79	14.35	0	56.36	5.95	1.82
8	Panshina	0	22.97	0	61.06	3.14	0.25

Table 4
Average percentage of deleterious material and physically poor constituent along Wadhwan Bhogavo river

SNo.	Village	No. of Samples	Average of Deleterious Material		Physically poor constituent	
			Mineral	% by Weight	Mineral	% by Weight
1	2	3	4	5	6	7
1	Muli	4	Cryptocrystalline silica and organic shell	0.56	Carbonate and organic shell	11.2
2	Wadhwan	2		1.00		20.85
3	Memka	22		0.59		16.87
4	Nana Kerala	2		0.30		18.67
5	Gedi	1		0.92		20.79

Table 5
Average percentage of other (major & minor) constituents along Wadhwan Bhogavo river

SN0.	Village	Average percentage (by weight) for various rock/mineral			
		Amygdaloidal Basalt	Basalt	Quartz	Sandstone
1	2	3	4	5	6
1	Muli	1.29	9.05	73.88	0.46
2	Wadhwan	0	4.05	68.77	5.18
3	Memka	0	6.94	67.39	5.63
4	Nana Kerala	0	4.24	66.59	10.27
5	Gedi	0	2.51	59.33	3.58

4. Discussion:

a) The locations of shoals from where the samples are picked up are shown in figure 2.

b) The aggregate materials in Limdi Bhogavo and Wadhwan Bhogavo river basins are mainly comprised of basalt, sandstone, quartz, cryptocrystalline silica and carbonate. More than 80% of the constituents are comprised of quartz and basalt wherein the occurrence of quartz is maximum followed by basalt.

c) Cryptocrystalline silica is found to be the main chemically reactive deleterious material while carbonates, weathered amygdaloidal basalt and weathered sandstone are found to be physically poor materials in the samples. A very little quantity of organic shell is also found at one or two places which may be considered as deleterious as well as physically poor material both.

d) Average percentage variation of deleterious material (cryptocrystalline silica and shell fragments) in different samples, for the respective villages, are shown in

tables 2 & 4 for Limdi Bhogavo and Wadhwan Bhogavo rivers, respectively. It varies between 0.25% - 0.94% along Limdi Bhogavo river while it is between 0.30% - 1.00% along Wadhwan Bhogavo river.

e) Similarly, average percentage presence of physically poor materials including carbonates, weathered amygdaloidal basalt and weathered sandstone, in different samples, for the various villages, are shown in tables 2 & 4 for Limdi Bhogavo and Wadhwan Bhogavo rivers, respectively. It varies between 5.57% - 13.10% and 11.2% - 20.85% along the rivers Limdi Bhogavo and Wadhwan Bhogavo, respectively.

f) Tables 3 and 5 show the average percentage of major constituents viz. basalt, quartz and sandstone present in different samples, for the respective villages along the rivers Limdi Bhogavo and Wadhwan Bhogavo, respectively.

g) Plot of locations of shoals from upstream to downstream along Limdi Bhogavo river (on X- axis) and average percentage of deleterious material present (on Y-axis) is shown in figure 3. The graph shows that there is gradual increase in deleterious material from west to east along the river flow direction.

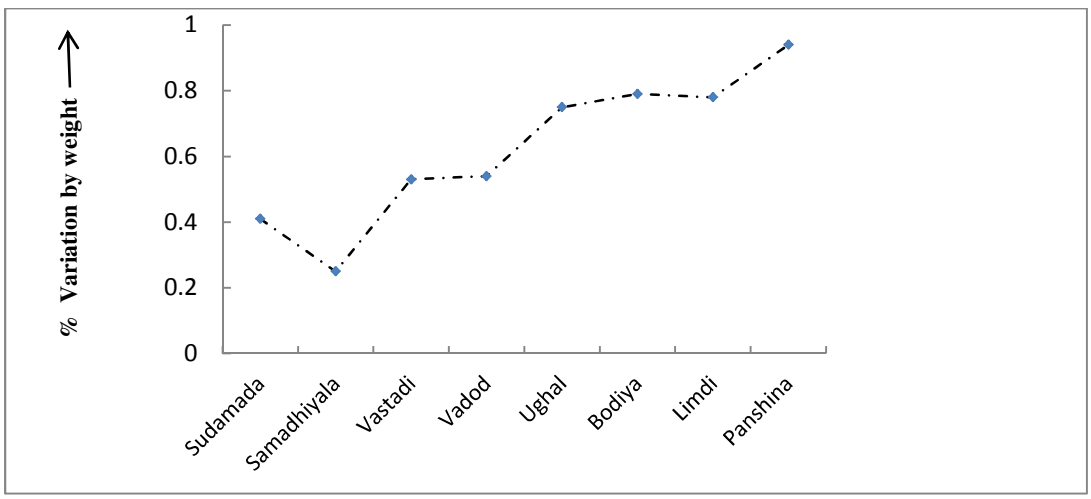

Figure 3 Average percentage of deleterious material along Limdi Bhogavo river

h) Figure 4 is the graph between villages from West (upstream side) to East (downstream side) and average percentage of physically poor materials present viz. carbonates, weathered amygdaloidal basalt and weathered sandstone along Limdi Bhogavo river. Here also, in general, there is increasing trend in percentage of physically poor materials mainly carbonates from west to east along the river flow except at Ughal village where there is a downward fluctuation.

i) The fluctuations in average percentage of deleterious materials (cryptocrystalline silica and shell fragment) present at various villages from upstream to downstream side along Wadhwan Bhogavo river is shown in figure 5. The sudden increase at Wadhwan can be understand by the fact that in this region, the river

flows through the Kukda formations comprising of Ferruginous sandstone with Conglomerate beds mainly composed of Cryptocrystalline Silica.

j) Figure 6 represents the percentage of physically poor materials (carbonates and shell fragments) present at various villages along Wadhwan Bhogavo river from upstream to downstream side. The graph shows that there is increase in percentage of carbonates from west to east along the river flow, in general.

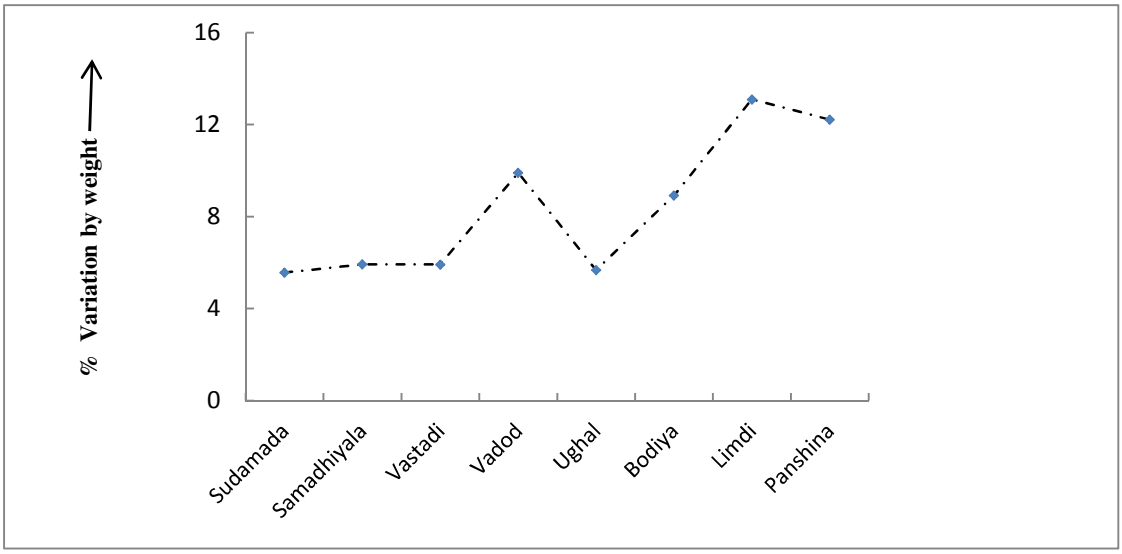

Figure 4 Average Percentage of physically poor materials along Limdi Bhogavo river

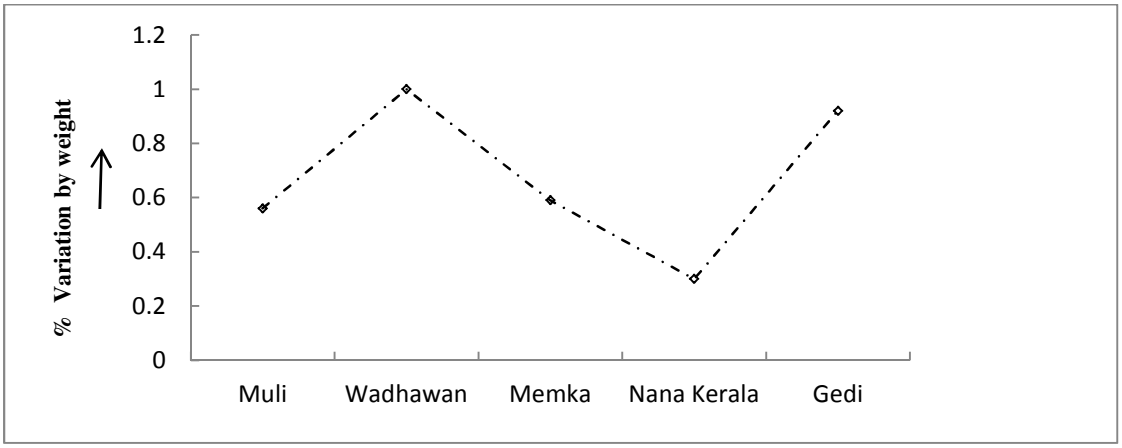

Figure 5 Average percentage of deleterious materials along Wadhwan Bhogavo river

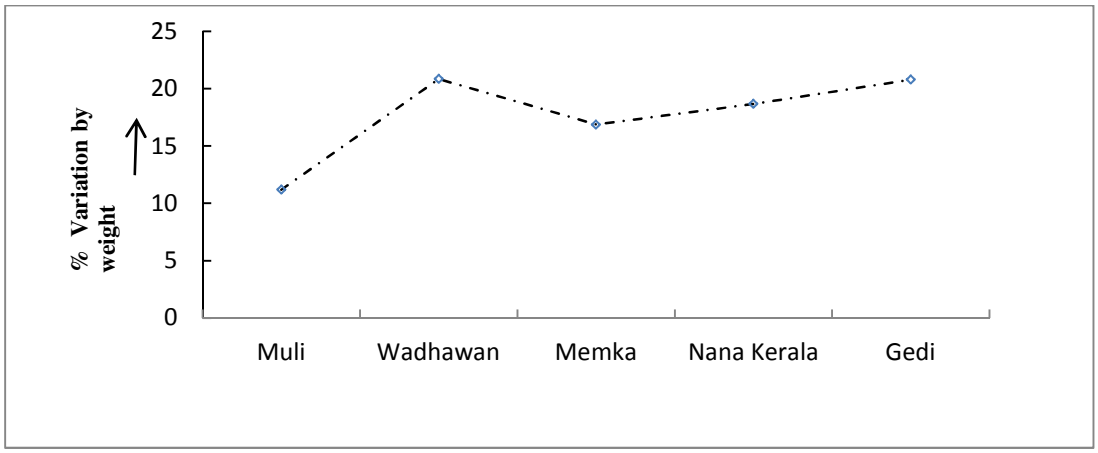

Figure 6 Average percentage of physically poor materials along Wadhwan Bhogavo river.

k) The variation in percentage of major constituents (basalt, quartz and sandstone) present in the natural aggregate along the river Limdi Bhogavo is shown in figure 7. Quartz is the major constituent here. The natural aggregate constitutes more than 50 % of quartz throughout the river basin. This is followed by basalt (nearly 20%). Sandstone vary around 5%. From Sudamada to Ughal, quartz follows a decreasing trend while basalt follows an increasing trend. Beyond Ughal up to Panshina, the trend reverses.

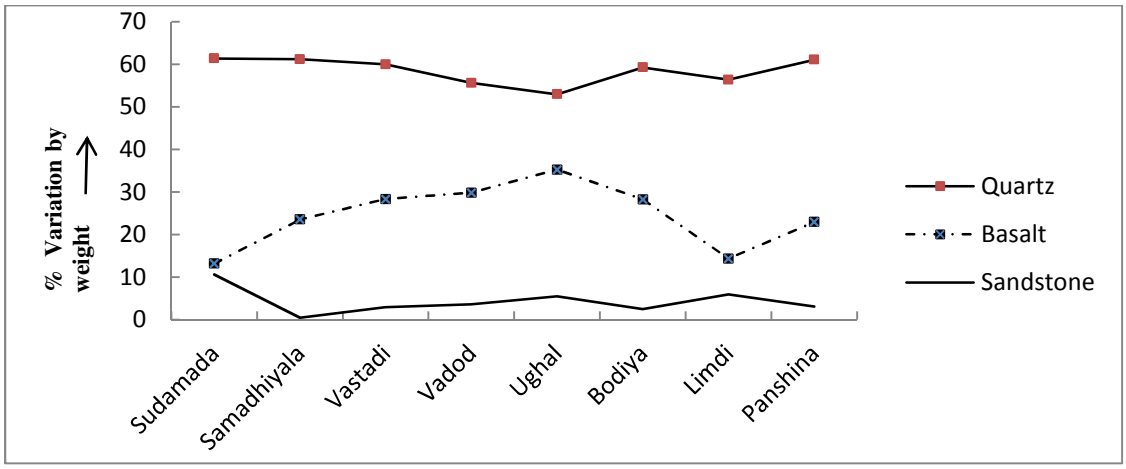

Figure 7 Average percentage of major constituents (quartz, basalt and sandstone) along Limdi Bhogavo river

l) Similarly, along Wadhwan Bhogavo river basin, quartz constitute the major parts (67.2%) of the aggregate followed by basalt (around 5.4%) and sandstone (around 5.04%, figure 8).

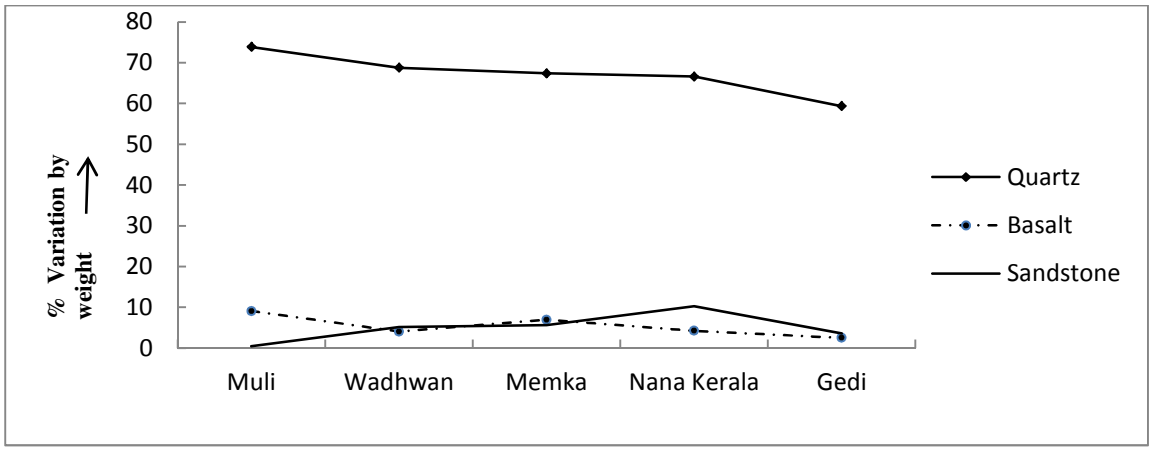

Figure 8 Average percentage for major constituents along Wadhwan Bhogavo river

5. Conclusions:

1. In the study region of both the river basins, the percentage presence of deleterious material is well below the maximum prescribed limit (by IS: 383-1970) of 5%.
2. Other major constituents viz. quartz, basalt and sandstone, which are good constituents in the natural aggregate, are abundantly present in the samples.
3. Looking to the above two criteria it may be concluded that the fine aggregate (sand) in this region is good enough to be used as construction material.
4. This is an overall assessment based on petrographic analysis, however, before use from particular site, necessary tests as per IS codes may be carried out.

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