CHAPTER : IX

BARODA'S ROADS

INTRODUCTION :

The major source of road construction material for the city of Baroda comes from quarries situated near the historic, volcanic Pavagadh hill in the Panchmahals district. The main rocks occurring in these quarries are basalts, agglomerates and volcanic tuffs. During crushing of the quarried rock, if mixing of all the three rock types is done, then the product becomes inconducive for use as a road building material since it fails to achieve the requisite quality parameters laid down by the Indian Road Congress [1978]. Pure basalts are ideal for road making. The crushed aggregates used in road making in Baroda, are usually purplish-red in colour and agglomeratic in nature. During the monsoon, such material, when used in road making would disintegrate due to its inability to adhere to the bitumen, resulting in the formation of pot-holes of various shapes and sizes [Plate : 30 and 31]. Even a leaking underground water pipe is sufficient to cause the surficial disintegration of a tarmac road.

A field study, of the major quarries and sampling of the finished products i.e. crushed aggregates, followed by laboratory investigations, have revealed that though basalt is available, the high demand for road building material has forced the usage of sub-standard material.

BRIEF GEOLOGY OF PAVAGADH HILL :

Pavagadh hill volcanic suite [820 m high] [Longitude 73° 34'30" E,

POT-HOLES DEVELOPED ON TAR ROADS DURING THE MONSOON.

PLATE 30 :

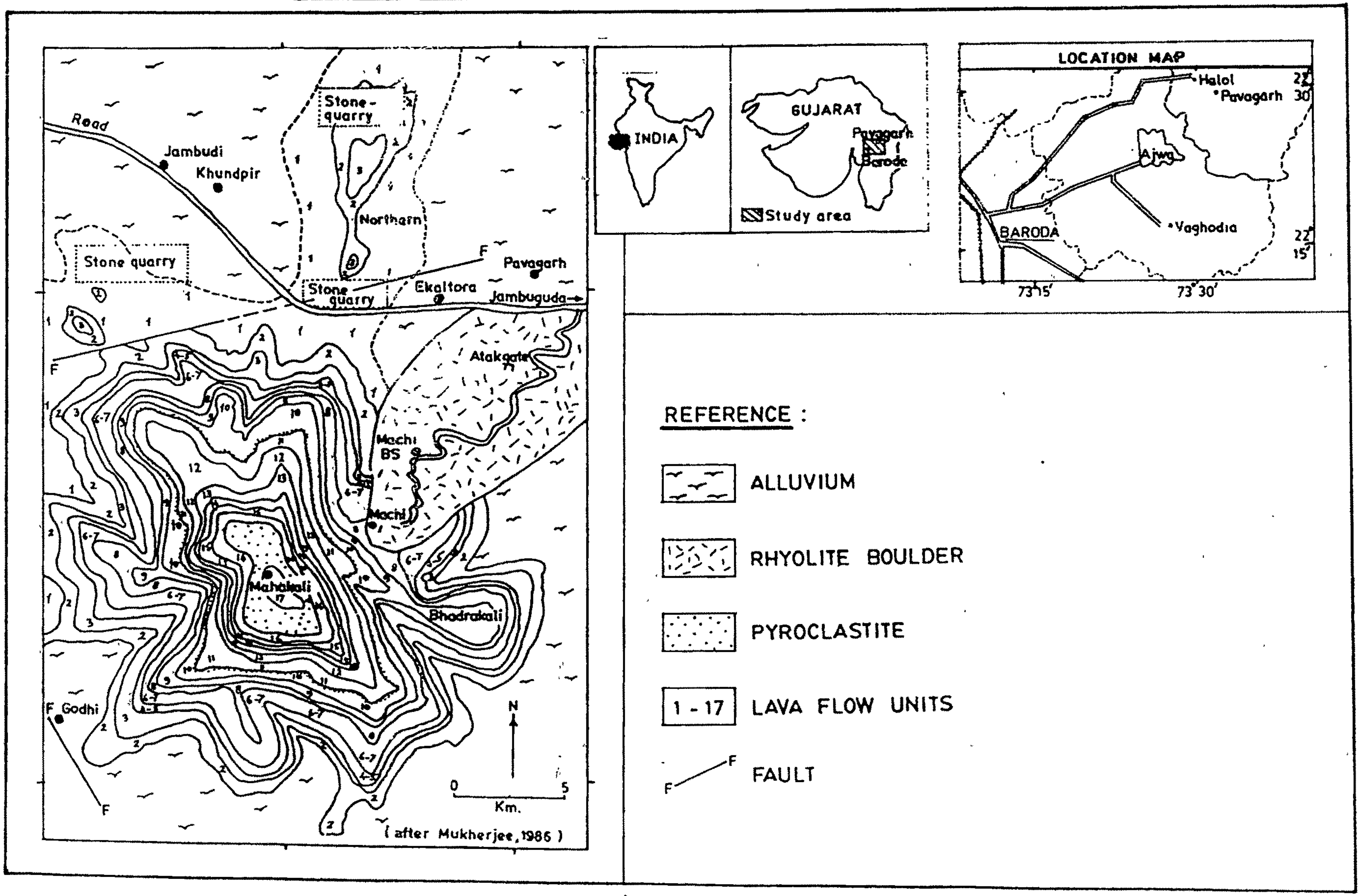
PLATE 31 :

Latitude 22° 29' W] in Halol taluka of Panchmahals district, is situated about 40 km NE of Vadodara city in Gujarat [Fig. 36]. It has associated small hillocks ranging in height from 213 to 279 m. The whole suite comprises of 17 horizontal lava flows and is considered to be an outlier of Deccan Traps. This volcanic massif overlies Nimar sandstone belonging to Bagh Series of Middle Cretaceous age. Nimar sandstones are in turn underlaid by Champaner Group of rocks [Middle Proterozoic] and are intruded by Godhra granites. Champaner rocks consist of phyllites, slates and quartzites. Both Nimar sandstone and Champaner rocks crop out only in the surrounding vicinity of the hill and not within. Morphologically the hill shows the typical flat topped features with steep escarpments and several flat terraces. The traps of the Pavagadh have been minimally affected by post-magmatic disturbances, except for a major caldera collapse towards the northern portion, evidenced by scarce exposure and rhyolite boulders occurring between the northern hill and Machi [Fig. 36]. The only insitu rhyolite that occurs on the top of the main hill, is the remnant southern edge of the collapsed caldera [Mukherjee and Gupta, 1989]. The geological sequence as given by Mukherjee [1986] for Pavagadh and its close surroundings is as follows :

Generalised Strafigraphic succession of Pavagadh and its vicinity [after Mukherjee, 1986].

Alluvium	:	[Cretaceous - Eocene]
Rhyolite boulder	:	[Cretaceous - Eocene]
Pyroclastic	:	[Cretaceous - Eocene]
1-17 lava flow units	:	[Cretaceous - Eocene]
Nimar Sandstone [Bagh]	:	[Middle Cretaceous]
Godhra Granite	:	[Intrusive into Champaner group]
Quartzites, phyllites, slates	:	[Champaner group [Middle Proterozoic]

FIG. 36-LOCATION / GEOLOGICAL MAP OF STUDY AREA



The seventeen flows constituting Pavagadh have been classified by Mukherjee [1986] as follows [Fig. 36].

Flow No.	Rock Type
1	Tholeiitic Picrite
2	Olivine Tholeiite
3	Oligoclase bearing Tholeiite
4	Tholeiitic Basalt
5	Tholeiitic Basalt
6	Tholeiitic Basalt
7	Tholeiitic Basalt
8	Olivine Tholeiite
9	Tholeiitic Basalt
10	Tholeiitic Basalt
11	Tholeiitic Basalt
12	Tholeiitic Basalt
13	Olivine Tholeiite
14	Tholeiitic Basalt
15	Tholeiitic Basalt
16	Tholeiitic Andesite
17a	Pitchstone
17b	Rhyolites
17c	Rhyolites

DESCRIPTION OF VARIOUS QUARRIES AND LABORATORY INVESTIGATIONS OF CRUSHED AGGREGATES :

Depending upon their locality, the numerous quarries have been divided into 2 groups :

[1] Quarries around Ekaltora near Pavagadh village
[2] Quarries around Jambudi village near Halol.

TABLE : 41

DESCRIPTION OF VARIOUS QUARRY SECTION

SR. NO.	NAME OF QUARRY	DEPTH [mts]	ROCK TYPE	OTHER GEOLOGIC FEATURES
1	2	3	4	5
	Quarries around Ekaltora near Pavagadh village :			
1.	C.C. Patel Quarry	0 to 12	Moderately weathered massive basalt	Well developed columnar joints
2.	Giriraj Quarry	0 to 5	Thin layer of over-burden underlain by highly weathered basalt	
		5 to 36	Moderately weathered porphyritic & amygdaloidal basalt	
3.	Goverdhan Quarry	0 to 1	Over-burden	
		1 to 17	Moderately weathered massive and amygdaloidal basalt	At few places, basalt shows spheriodal weathering
4.	Kamlesh Quarry	0 to 6	Highly weathered basalt	
		6 to 36	Different flows of moderately weathered basalt	
		36 to 50	Weathered volcanic material consisting of angular pieces of porphyritic amygdaloidal basalt	A 4 mt wide dyke of porphyritic basalt cuts through quarry, trending N-S/73° due NW. Joints trending N 21°W - S 21°E/ 84° to 71° due NW direction

Table : 41 contd.

1	2	3	4	5
5.	Prabhat Quarry	0 to 3	Over-burden with pieces of basalt	Joints trending N 62°E/21° to 27° due NW and also well developed columnar joints
		3 to 35	Moderately weathered to fresh massive basalt	
6.	Somnath Quarry	0 to 1.5	Over-burden with rock pieces	
		1.5 to 38	Moderately to highly weathered porphyritic and amygdaloidal basalt	Staining of iron oxide is observed along joints
7.	Tulsi Quarry	0 to 10	Highly weathered basalt	
		10 to 55	Fresh to moderately weathered basalt	
	Quarries around Jambudi Area near Halol :			
1.	Aditya Quarry	0 to 16	Highly to moderately weathered basalt and agglomerates	Crystals of calcite and zeolites are seen along joint planes
		16 to 45	Fresh, massive and porphyritic basalt	
2.	Janta Quarry	0 to 22	Moderately weathered basalt with patches of agglomerates	Reddish brown coloured skin is developed along joint planes due to weathering
		22 to 46	Fresh massive basalt	
3.	Krishna Quarry	0 to 2	Over-burden	
		2 to 16	Highly weathered basalt	
		16 to 37	Fresh to moderately weathered purphyritic basalt underlain by amygdaloidal basalt	Spheroidal weathering is seen

Table : 41 contd.

1	2	3	4	5
4.	Manhar Quarry	0 to 6	Highly weathered basalt	Staining of joints by iron oxide is seen
		6 to 25	Moderately weathered massive basalt	
5.	Navrang Quarry	0 to 6	Highly weathered basalt with thin cover of over-burden	
		6 to 22	Moderately weathered basalt underlain by fresh basalt	
6.	Parul Quarry	0 to 3.5	Over-burden	Joints, associated with volcanic tuffs, trending NE-SW/71° to 79° due NW
		3.5 to 16	Highly weathered basalt	
		16 to 33	Moderately weathered basalt with patches of agglomerates	
7.	Sarvodaya Quarry	0 to 2	Over-burden	Joints trending N 21°E - 20°W/76° due N 70°W. Phenocryst of augite are clearly seen
		2 to 22	Moderately weathered basalt with patches of agglomerates	
		22 to 34	Fresh porphyritic basalt	
8.	Shreeji Quarry	0 to 3	Highly weathered basalt overlain by a thin over-burden	Joints trending N 71°E - S 71°W/45° due NW. Chloritised material is seen along the joint planes.
		3 to 16	Moderately weathered massive basalt	
		16 to 27	Moderately weathered amygdaloidal basalt	

Most of the quarries have a thin overburden of soil, but in some cases the rock is exposed at the surface, with the overburden completely missing. The main rocks found in the quarries are massive, porphyritic and amygdaloidal varieties of basalts, agglomerates and occasional volcanic tuffs. The colour varies from grey to greenish-black to purplish-brown. Well developed columer and sheet jointing is seen, along which, occasionally, iron oxide staining is observed at various depths. Secondary infilling of joint operings with weathered material is common near the surface. Surficial weathering along joint planes is common, but at deeper levels fresh rock is encountered [Table : 41].

Fifteen quarries were selected for investigations which included quarry section study, [Table : 42] random sampling of the crushed aggregates followed by laboratory investigations as per standards set down by ISI:6579:1972, with permissible limits as per Indian Road Congress [1978], to assess the suitability of the aggregates for roads and buildings. [Table : 42].

The laboratory investigations were carried out in the Highway Research Unit of the Gujarat Engineering Research Institute, Baroda.

DISCUSSION :

Laboratory investigations of crushed aggregates from the fiteen quarries selected revealed that nearly all of them fail to meet one or the other requirement as per the specifications laid down by IRC [1978]. If any one of the quality parameters of the crushed aggreage fails to meet the requirements set down by IRC, then it is deemed unsuitable for road making.

Abrasion test is carried out to test the hardness property of stones and to decide whether the stones are suitable for road construction works. Road stones should be hard enough to resist the abrasion due to the traffic. The Los Angeles abrasion value of good aggregates acceptable

TABLE : 42

LABORATORY TEST RESULTS OF AGGREGATE

[INVESTIGATIONS CARRIED OUT AS PER THE SPECIFICATIONS LAID DOWN BY ISI:6579:1972]

Sr. No.	Name of Quarry	Aggregate	Impact Value %	Abrasion Value %	Flakiness %	Stripping Value %	Water Absorption %	Sp.Gr.	Subbase Caurse	Base Caurse	Bituminous Work
	Permissible limit as per IRC [1978]		<35	<30	<25	<2.5	<0.6	2.6 to 2.9			
	A - Ekaltora Area										
1.	C.C. Patel Quarry	Kapachi	16.4	20.8	7.9	>25	2.670	2.679	Suitable	Suitable	Unsuitable
2.	Giriraj Quarry	Kapachi	13.2	23.0	19.4	>25	1.200	2.630	Suitable	Suitable	Unsuitable
3.	Goverdhan Quarry	Kapachi	17.7	19.0	20.6	>25	3.367	2.789	Suitable	Suitable	Unsuitable
4.	Kamlesh Quarry	Kapachi	12.8	17.4	5.5	>25	2.525	2.900	Suitable	Suitable	Unsuitable
5.	Prabhat Quarry	Kapachi	16.3	15.8	56.8	<25	1.720	2.932	Suitable	Suitable	Unsuitable
6.	Somnath Quarry	Kapachi	14.1	21.8	11.1	>25	1.910	2.804	Suitable	Suitable	Unsuitable
7.	Tulsi Quarry	Kapachi	12.3	17.0	13.4	>25	2.314	2.709	Suitable	Suitable	Unsuitable
	B - Jambudi Area										
1.	Aditya Quarry	Kapachi	17.3	13.4	25.7	>25	2.308	2.961	Suitable	Suitable	Unsuitable
2.	Janta Quarry	Kapachi	15.0	14.1	23.9	>25	1.946	2.713	Suitable	Suitable	Unsuitable
3.	Krishna Quarry	Kapachi	22.2	21.2	36.9	>25	4.020	2.704	Suitable	Suitable	Unsuitable
4.	Manhar Quarry	Kapachi	16.6	13.4	6.9	>25	1.132	2.765	Suitable	Suitable	Unsuitable
5.	Navrang Quarry	Kapachi	12.9	22.4	20.6	>25	2.441	2.765	Suitable	Suitable	Unsuitable
6.	Parul Quarry	Kapachi	17.0	16.9	8.4	>25	1.622	2.739	Suitable	Suitable	Unsuitable
7.	Sarvodaya Quarry	Kapachi	21.2	20.7	9.5	>25	1.945	2.981	Suitable	Suitable	Unsuitable
8.	Shreeji Quarry	Kapachi	15.7	13.6	16.1	>25	1.627	2.770	Suitable	Suitable	Unsuitable

for road making should be less than 30 percent. It is seen that aggregates of all fifteen quarries falls under the permissible limit set down by IRC.

Flakiness test evaluate the shape of the aggregates. The flakiness index of aggregate is the percentage by weight of aggregate particles whose least dimension/thickness is less than three fifth or 0.6 of their mean dimension. It is seen that out of fifteen quarries, three quarries show flakiness index value above the permissible limit.

Water absorption is expressed as the percent water absorbed in terms of overdried weight of the aggregate. Stones having higher water absorption value are porous and thus weak. They are generally unsuitable unless found acceptable based on crushing and hardness test. Aggregates more than 0.6 percent water absorption are considered unsatisfactory. From [Table : 42] it is seen that all of them fail in the water absorption test.

The stripping value test determines the degree of cohesiveness of bitumen with the crushed aggregate. If the surface of the crushed aggregate is fresh, then maximum cohesion is seen, while on the other hand, weathered or pyroclastic ejecta aggregates show minimum cohesion. The theory behind this is that bitumen will only adhere to surface which are impervious to water e.g. fresh basalt. Pervious, like those seen in weathered basalt, agglomerates and tuffs, afford little cohesion to the bitumen. This is especially important during the monsoon months, when the disintegration of the road surface occurs with the first showers. This process is diagramatically described in Fig. 37.

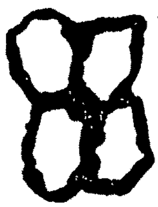
The stripping of bitumen is due to the fact that some aggregates have a greater affinity towards water then with bituminous binders, and this displacement depends on the physiochemical forces acting on the system. Most road aggregates have surfaces that are electrically charged. For example, secondary silica, a common constituent of igneous rocks possess a weak negative charge and hence have greater attraction wit the polar

FIG : 37 SKETCH SHOWING DISINTEGRATION OF ROCK AGGREGATE AND DISRUPTION OF ROAD SURFACE

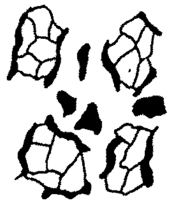
ROCK PIECE PRIOR TO MIXING WITH TAR

SAME ROCK PIECE HAVING A COATING OF TAR [THICK BOUNDARY] ON MIXING.

FIGURATIVE DEPICTION OF BONDING ACTION OF TAR ON ROCK METAL AND FINER FRACTIONS USED IN THE MAKING OF TARMAC ROADS. THIS BOND IS RETAINED OVER A LONG PERIOD OF TIME ONLY IF THE ROCK IS FRESH.

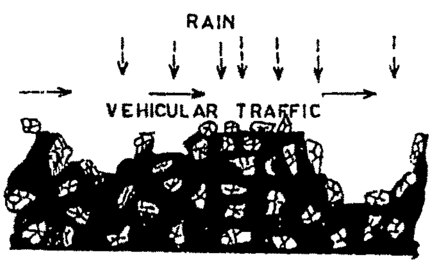


RUPTURED BONDING DUE TO STRIPPING OF THE TAR COATING ON WEATHERED ROCK PIECE IN CONTACT WITH WATER AND DUE TO HEAVY VEHICULAR TRAFFIC PHYSICAL DISINTEGRATION OF ROCK MATERIAL ALSO TAKES PLACE.



SKETCH OF THE TOP PORTION OF THE ROAD SHOWING THE BONDING OF ROCK PIECES DUE TO TAR AND THE STRUCTURE DUE TO ROLLING OF THE ROAD AFTER SPREADING OF THE TAR MIXED ROCK MATERIAL BY A GRADER.

FIGURATIVE DEPICTION OF THE DISRUPTION OF ROAD SURFACE AND THE FORMATION OF DEPRESSIONS DUE TO COMBINED ACTION OF RAIN AND VEHICULAR TRAFFIC ON TAR COATED WEATHERED ROCK MATERIAL ALSO TAKES PLACE.



liquid water then with bituminous binders having little polar activity. These aggregates which are electronegative are water liking and are termed hydrophyillic. Basic aggregates like fresh basalt have a dislike for water and greater attraction for bitumen, as they have a positive surface charge. These aggregates are called hydrophobic. The static immersion test is very commonly used in arbitrarily determining the adhesion of bituminous binder on as an aggregate in presence of water. The principle of this type of test is by immersing the aggregate fully coated with the binder in water maintained at a specific temperature, and by estimating the degree of stripping. The result is reported as the percentage of stone surface that is stripped off after a specified time period. The Indian Road Congress have specified that the stripping values of aggregates should not exceed 25% for use in a bituminous surfaces dressing, penetration macadam and bituminous macadam.

Low quality crushed aggregates lead to low quality roads, which in turn are a cause of inconvenience to the citizens of Baroda and their vehicles.