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CASE HISTORY COMPILATION OF ENGINEERING PROPERTIES OF COMMON ROCKS IN MAHARASHTRA, INDIA, FOR DATABASE (1982-2002)

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ABSTRACT

Rock samples are received from various project sites for testing at MERI. These rock samples were tested and test results were communicated to the project in charge from time to time. After carrying out tests to determine different engineering properties of various types of commonly available rocks, mostly for irrigation structures in Maharashtra, lot of historical data is available. It was felt that, this data of results may be compiled digitally in database software (M. S. Access) and analyzed suitably for use in design and construction of irrigation and other important structures in future. The results of about **1920** Rock samples tested during the period from 1982 to 2002 have been compiled in the database. Mainly the following test results are required by the construction agencies

- 1) % Water Absorption
- 2) Specific Gravity and Density of Rock
- 3) Compressive strength (Kg/cm²)

General standards of acceptance of these rock properties are also discussed in this paper. Abstracts of results indicating Average, Minimum and Maximum values of laboratory test results on rocks are presented. Database presented in this paper is basin and sub-basin-wise, region-wise, district-wise and geological class-wise.

INTRODUCTION

Maharashtra Engineering Research Institute, (MERI) is functioning at Nashik, Maharashtra state of India, since 1959 to provide guidance and update technical know how in applied and fundamental research on matter pertaining to River valley projects and Civil Engineering research in general. Rock Mechanics cell was established in the year 1971 in MERI to cope up with the latest developments in the field of Rock Mechanics. This cell is equipped for the testing of the rocks in the laboratory as well as in field which are widely used in design and construction of field structures. Facilities to carry out laboratory tests like % Water Absorption, Specific Gravity and Density, Compressive Strength, Durability, Young's Modulus and Poisson's Ratio, Split Tensile Strength, etc. are available in this cell. In addition to laboratory tests, field tests on rocks like shear, Pull Out, Flat Jack, Plate Bearing, Strain Measurement are also carried out.

Rock samples are received at MERI from various project sites for testing. These rock samples were tested and test results were communicated to the project in charge from time to time. After carrying out tests to determine different engineering properties of various types of commonly available rocks, mostly for irrigation structures in Maharashtra, lot of data is

available. It was felt that this data of results may be compiled digitally in database software (M. S. Access) and analysed suitably for use in design and construction of irrigation and other structures.

TEST SPECIMEN

Rock samples are received from various construction sites for testing. They are of the size of 30cmX30cmX30cm (1'x1'x1') in general as prescribed by MERI. Cores are drilled out from these samples for testing at MERI lab. 50mm diameter and 100mm length samples are used for testing.

Test Specimen

Cores of 50 mm diameter and 100 mm length are drilled out from the rock samples and tested as per Indian Standards **I.S.-9143-1979** (Reaffirmed 1987) and **ASTM-C 97-47 Part 12-1964** procedure

Mainly following test results are required by the construction agencies for design and construction purpose.

- 1) % Water Absorption

- 2) Specific Gravity and Density of Rock
- 3) Compressive strength

Unconfined Compressive strength test
(as per I.S.- 9143-1979)

This test is primarily an index test for strength classification of rock material. The sample should be in the form of specimens of regular geometry. A suitable loading machine (Universal Testing Machine at MERI) for applying and measuring the axial load to the specimen is used. It shall be of sufficient capacity and capable of applying load at the rate such that failure will take place in about 5 to 15 minutes. (Stress rate 0.5 Mpa /s to 1.0 Mpa /s) Maximum load on the specimen shall be recorded in N within 1% accuracy.

No. of specimen to be tested should be determined from practical consideration. At least 5 specimens are required to obtain a representative value.

$$\text{Unconfined Compressive strength} = \frac{\text{Maximum load}}{\text{Av original cross sectional area}}$$

% Water Absorption and Specific Gravity tests
(as per I.S. or ASTM-C97-47 Part 12-1964)

For these tests at MERI, mostly ASTM procedure is followed.

Utilization of Test Results

Rock samples are received from various projects and construction sites for testing. After testing these test results are communicated to the project authorities.

In the case of Water Resources department's projects these test results are sent to Central Designs Organization (CDO) either by the project authority or by MERI itself as CDO is a sister organization of MERI. Then CDO utilizes these results for the design of the project structures and its components. Other project authorities also use their data for design purposes as well as for construction purposes.

In the case of quarry rock sample testing, the test results are utilized for deciding whether the quality of the quarry is useful for the project purpose or not. Accordingly the quarry is opened or rejected and banned.

The General standards of acceptance are also communicated along with these results.

DATA BASE PREPARATION

The work of preparation of this database was taken in hand in year 2001 and completed in 2002. The results of about **1920** Rock samples tested during the period from 1982 to 2002 (March) have been compiled in the database. Searching of the old data was itself a great job. The old record available was hand written, manuscript or typed on type writer.

Following fields for each sample are created.

- (1) Sr. No.
- (2) Name of Project
- (3) District
- (4) Region
- (5) Year of Testing
- (6) Laboratory No.
- (7) Geological Classification
- (8) % Water Absorption
- (9) Porosity
- (10) Density
- (11) Specific Gravity
- (12) Compressive strength.
- (13) River Basin
- (14) River Sub Basin

For presentation of this database River-basin and sub-basin wise, use of basins prescribed in the Government of Maharashtra Water and Irrigation Commission's 2nd report (June 1999) has been made.

The topography of Maharashtra is divided in 5 main River basins. These are Godavari River, Krishna River, Tapi River, Kokan group of Rivers and Narmada River.

Initially the database is prepared Project wise covering all above fields. (Table 3) These are off course arranged year wise or even date wise in the data base. Some of the fields were required to search for the project area such as River basin, River Sub Basin, Region etc. and the data was placed appropriately in to these fields.

Abstracts of results indicating Average, minimum and maximum values of laboratory test results on rocks are presented in the beginning. There after these results have been presented Basinwise, Sub-basinwise, Projectwise, Districtwise, Regionwise and Geological classification wise.

This database is also presented Region wise and District wise. The Region means the Revenue region of Maharashtra state. There are overall 6 regions. These regions are further divided in to Districts.

The geological classification of the Rock sample was done at the time of testing from time to time. As a very long period of 20 years is lapsed there may not be the similarity in the terminology of Rock samples.

GENERAL STANDARDS OF ACCEPTANCE OF ROCK PROPERTIES

Uniaxial Compressive Strength –

Handbook of Quality Control is silent about the permissible value of compressive strength. However, the manual on Rock Mechanics published by C.B.I.P., New Delhi (1979) has

classified the Rock on the basis of compressive strengths as given below in Table 1.

Table 1: Rock Strength Classification

CLASS	DESCRIPTION	UNIAXIAL COMP. STRENGTH kg / cm ²
A	Very High	Over 2300
B	High	1150 -2300
C	Medium	570 -1150
D	Low	285 - 570
E	Very Low	Less than 285

% Water Absorption (% W)

- For Building Stone % W Shall not be more than **5 %** as per the Standard Specifications (Red Book).
- For Water Retaining Structures As per provision stipulated in the handbook of Quality Control (1990) the permissible % water absorption for stone is usually specified as **1 %** of Dry Weight.

Specific Gravity

No mention about the permissible value of Specific Gravity of Stone is available either in I.S. or Quality Control Handbook or Manual of Rock Mechanics.

It is usual practice in MERI that these standards of acceptance are communicated to the clients along with the test results.

DISCUSSION OF RESULTS

1. The database presented in this paper is basin and sub-basinwise, it is also manipulated for presentation, district wise, project wise, geological class wise or date wise.
2. Basin wise abstract reveals that average compressive strength of rocks in each basin is almost identical around 600kg/cm².

3. As regards the average % Water Absorption, rock in Tapi basin has the lowest, viz. 1.5 % and that for a rock in Krishna basin, the highest viz. 2.89 %.
4. If compared to the permissible range of % Water Absorption provided in handbook of Quality Control laid down at 1%, it reveals that average rocks in all the basins have these properties higher than the permissible values.
5. Although the Quality Control handbook has specified the limit range of permissible % Water Absorption of 1%, it is silent on the limit range of permissible Compressive Strength. However, the analysis of the results in this database reveals that Compressive Strength of stones having % Water Absorption up to 1% is higher than 700 kg/cm². If this empirical value is to be assumed as permissible limit, then Average Compressive Strengths of all the river basins fall short of this limit. This is suggestive of revision in the permissible values of % Water Absorption and Compressive Strength.

6. The nature of failure of Rock samples is not seen recorded during laboratory testing of compressive strength and tensile strength of the rocks and hence could not be mentioned in the database.

FUTURE SCOPE OF THE STUDY

This study can be extended beyond 2002 March as lot of testing work is done after 2002.

It is planned that all this data will be placed in Geographical Information System (GIS) for which a GIS map of Maharashtra will be prepared River basin wise. All the spatial and non spatial properties will be placed on these maps.

REFERENCES

Maharashtra Water and Irrigation Commission's 2nd report (June1999)

Table 2. RIVER BASINS AND SUB BASINS IN MAHARASHTRA

Sr. No.	RIVER BASIN	RIVER SUB BASIN	SUB BASIN NO.
1	GODAVARI BASIN	UPPER GODAVARI (UP TO JAYAKWADI DAM) 1-A :EXCL. MULA PRAVARA 1-AA:MULA PRAVARA GROUP	1
		LOWER GODAVARI	2
		PURNA (INCL. DUDHANA)	3
		MANJARA	4
		REST OF GODAVARI	5
		PAINGANGA	6
		WARDHA	7
		MIDDLE VAINGANGA	8
		LOWER VAINGANGA 9-A:VAINGANGA-PRANAHITA 9-B:INCHAMPALLI AREA 9-C:INDRAVATI AREA	9
2	TAPI BASIN	PURNA TAPI	10
		GIRNA	11
		PANZARA	12
		MIDDLE TAPI GROUP 13-A :TAPI (SATPUDA) AREA 13-AA:TAPI (SOUTH) AREA	13
3	NARMADA BASIN	NARMADA	14
4	KRISHNA BASIN	UPPER KRISHNA (WEST) 15-A:WEST NORTH AREA 15-AA:WEST SOUTH AREA	15
		UPPER KRISHNA (EAST) 16-A:YERALA AREA 16-AA:AGRANI AREA	16
		UPPER BHIMA (UP TO UJJANI)	17
		REST OF BHIMA	18
		SINA-BORI-BENETURA	19
5	KOKAN BASIN GROUP	DAMANGANGA-PAR	20
		NORTH KOKAN GROUP	21
		MIDDLE KOKAN GROUP	22
		WASISHTI GROUP	23
		SOUTH KOKAN GROUP	24
		TEREKHOL-TILLARI GROUP	25

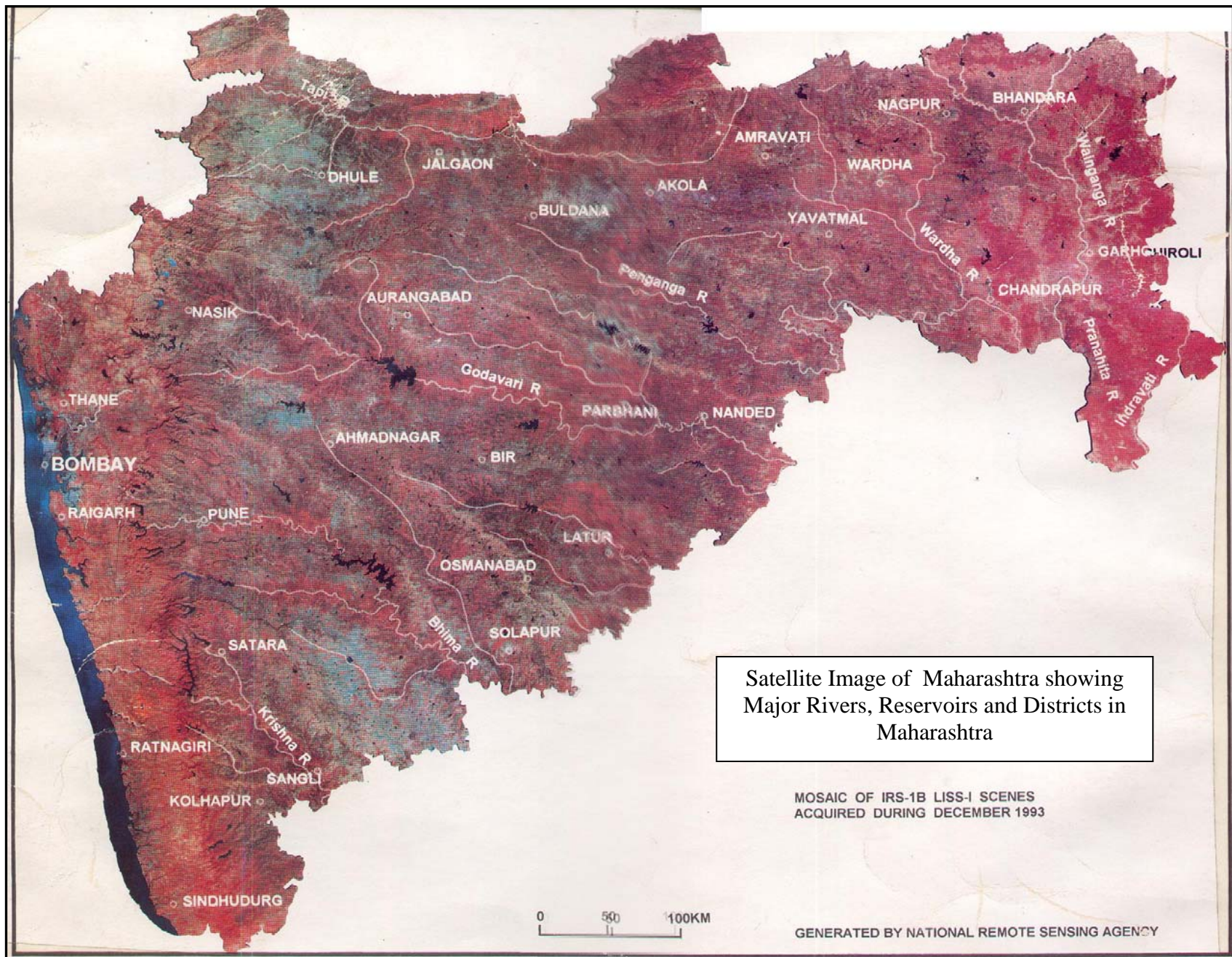


Fig. 1 Maharashtra Map

Table3 **YEAR WISE ROCK DATA BASE**

ID	Project_name	Region	District	Year of Testing	Lab No.	Geo logy Class	%Water Ab	Sp Gravity	Comp. Strength Kg/cm2	(No.) Sub Basin	River Basin
1	KANHER PROJECT	PUNE	SATARA	1982	K 1	A.B.	0.50	3.00	660.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
2	KANHER PROJECT	PUNE	SATARA	1982	K 2	A.B.	0.50	3.00	660.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
3	KANHER PROJECT	PUNE	SATARA	1982	K 3	A.B.	0.60	2.90	560.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
4	KANHER PROJECT	PUNE	SATARA	1982	K 4	A.B.	0.40	3.00	1530.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
5	KANHER PROJECT	PUNE	SATARA	1982	K 5	A.B.	0.70	3.00	1320.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
6	KANHER PROJECT	PUNE	SATARA	1982	K 6	A.B.	0.60	2.90	1320.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
7	KANHER PROJECT	PUNE	SATARA	1982	K 7	A.B.	0.50	2.90	1070.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
8	KANHER PROJECT	PUNE	SATARA	1982	K 8	A.B.	0.70	2.90	1220.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
9	KANHER PROJECT	PUNE	SATARA	1982	K 9	A.B.	0.70	2.80	1070.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
10	KANHER PROJECT	PUNE	SATARA	1982	K10	A.B.	0.60	2.90	970.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
11	KANHER PROJECT	PUNE	SATARA	1983	K 1	A.B.	0.50	3.00	660.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
12	KANHER PROJECT	PUNE	SATARA	1983	K 8	A.B.	0.70	2.90	1220.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
13	KANHER PROJECT	PUNE	SATARA	1983	K 9	A.B.	0.70	2.80	1070.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
14	KANHER PROJECT	PUNE	SATARA	1983	K10	A.B.	0.60	2.90	970.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
15	KANHER PROJECT	PUNE	SATARA	1983	K11	A.B.	0.60	2.90	1070.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
16	KANHER PROJECT	PUNE	SATARA	1983	K12	A.B.	0.50	2.90	1470.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
17	KANHER PROJECT	PUNE	SATARA	1983	K13	A.B.	0.90	2.90	710.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
18	KANHER PROJECT	PUNE	SATARA	1983	K14	A.B.	0.80	2.80	920.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
19	KANHER PROJECT	PUNE	SATARA	1983	K15	A.B.	0.40	2.90	890.00	(15 -A) UPPER KRISHNA (W)	KRISHNA
20	KANHER PROJECT	PUNE	SATARA	1983	K16	A.B.	1.30	2.90	610.00	(15 -A) UPPER KRISHNA (W)	KRISHNA

Table 4 BASIN / SUB BASINWISE ABSTRACT OF ROCK PROPERTIES IN MAHARASHTRA (1982-2002)

River Basin	GODAVARI	Av %W	Min % W	Max % W	Av Sp_Gr	Min Sp_Gr	Max Sp_Gr	AvComp kg/cm²	MinComp kg/cm²	MaxComp kg/cm²	No.of Samples
(1-A)	UPPER GODAVARI	1.85	0.02	13.35	2.75	2.05	3.06	532.86	30	2040	231
(1-AA)	UPPER GODAVARI	1.91	0.08	9.38	2.74	2.32	3.05	522.87	50	1320	341
(2)	LOWER GODAVARI	3.62	0.18	17.46	2.89	2.47	3.24	420.43	40	970	47
(3)	PURNA (DUDHANA)	0.84	0.36	5.28	2.92	2.54	3.03	870.00	200	1270	38
(4)	MANJARA	0.47	0.16	1.20	2.93	2.78	2.99	869.37	252	1730	27
(6)	PAINGANGA	0.49	0.16	1.48	2.93	2.65	2.99	950.64	150	1730	47
(7)	WARDHA	0.65	0.09	3.00	2.86	2.30	3.00	1096.84	360	1810	38
(9-A)	LOWER VAINGANGA	0.34	0.14	0.50	2.74	2.67	2.78	807.62	170	1470	51
River Basin	KOKAN GROUP										
(21)	NORTH KOKAN GROUP	2.11	0.18	9.08	2.69	2.26	3.00	681.20	90	2290	183
(22)	MIDDLE KOKAN GROUP	2.22	1.02	4.23	2.67	2.56	2.72	367.33	200	510	15
(24-AA)	SOUTH KOKAN GROUP							736.67	610	970	6
(25)	TEREKHOL-TILLARI GROUP				2.82	2.76	2.92				6
River Basin	KRISHNA										
(15-A)	UPPER KRISHNA (WEST)	0.60	0.20	2.70	2.89	0.90	3.00	929.50	250	2390	122
(15-AA)	UPPER KRISHNA (WEST)	0.62	0.28	0.77	2.94	2.93	2.94	745.00	560	970	6
(17)	UPPER BHIMA	1.48	0.68	2.70	2.69	2.61	2.82	428.46	250	600	13
(18-A)	REST OF BHIMA	1.63	0.07	7.72	2.91	1.90	3.20	458.29	40	1290	73
(19-A)	SINA-BORI-BENITURA	0.69	0.08	2.15	2.86	2.50	3.00	311.74	70	880	46
(19-AA)	SINA-BORI-BENITURA	10.59	0.44	18.39	2.18	1.87	2.96	182.60	40	1170	53
River Basin	TAPI										
(10)	PURNA (TAPI)	2.27	0.05	11.61	2.86	2.09	2.99	401.32	30	1750	198
(11)	GIRNA	1.17	0.10	5.27	2.85	2.57	3.00	867.46	101	1780	54
(12)	PANZARA	0.57	0.27	1.08	2.83	2.60	2.98	588.57	250	1320	14
(13)	MIDDLE TAPI GROUP	0.59	0.46	0.83	2.90	2.80	2.95	398.52	50	1020	67
(13-A)	MIDDLE TAPI GROUP	1.47	0.05	6.12	2.82	2.51	3.01	598.55	50	1680	55
(13-AA)	MIDDLE TAPI GROUP	0.89	0.05	6.42	2.85	2.38	3.02	826.88	150	1780	189
Total Samples 1920											

Table 5 **BASINWISE ABSTRACT OF ROCK PROPERTIES IN MAHARASHTRA (1982-2002)**

RIVER BASIN	AvD	MinD	MaxD	Av% W	Min%W	Max%W	Av	Min	Max	AvComp	MinComp	MaxComp	No.of
	Density			% Water	Absorption		Specific	Gravity		kg/cm²	kg/cm²	kg/cm²	Samples
NARMADA	-			-			-			-			-
GODAVARI				1.72	0.02	17.46	2.79	2.05	3.24	614	30	2040	820
KOKAN GROUP				2.12	0.18	9.08	2.69	2.26	3.00	660	90	2290	210
KRISHNA				2.89	0.07	18.39	2.73	0.90	3.20	582	40	2390	313
TAPI	2.789	2.3	3.02	1.50	0.05	11.61	2.85	2.09	3.02	608	30	1780	577
Total Samples												1920	

Table 6. **REGIONWISE ABSTRACT OF ROCK PROPERTIES IN MAHARASHTRA (1982-2002)**

REGION	Av% W	Min%W	Max%W	Av	Min	Max	Av Comp.	Min Comp.	Max Comp.	No. of
				Sp_Gr	Sp_Gr	Sp_Gr	kg/cm²	kg/cm²	kg/cm²	Samples
AMRAVATI	1.76	0.05	11.61	2.88	2.09	3.03	560.24	30	1750	288
KOKAN	2.12	0.18	9.08	2.69	2.26	3.00	602.34	90	1950	198
MARATHWADA	5.17	0.04	18.39	2.61	1.87	3.24	466.46	40	1730	163
NAGPUR	0.63	0.09	3.00	2.82	2.30	2.98	954.80	170	1810	84
NASHIK	1.58	0.02	13.35	2.78	2.05	3.06	597.02	30	2290	967
PUNE	0.89	0.07	7.72	2.88	0.90	3.20	740.75	40	2390	220
Total Samples										1920

Table 7. **DISTRICTWISE ABSTRACT OF ROCK PROPERTIES IN MAHARASHTRA. (MERI-NASHIK) (1982-2002)**

District	Density			% Water Absorption			Sp_Gr Av			Compression			No.of
	Avg	Min	Max	Av %W	Min%W	Max%W	Av	Min	Max	Av	Min	Max	Samples
AHMEDNAGAR				1.85	0.08	9.38	2.75	2.32	3.05	500	50	1320	391
AMRAVATI				2.80	0.34	11.61	2.85	2.09	2.99	277	30	1530	131
AURANGABAD				0.88	0.04	3.09	2.82	2.65	2.99	675	250	1170	42
BEED				3.62	0.18	17.46	2.89	2.47	3.24	420	40	970	47
BULDHANA	2.965	2.84	3.02	0.91	0.05	8.01	2.91	2.54	3.03	796	150	1750	147
CHANDRAPUR				2.54	2.19	3.00	2.33	2.30	2.37	662	360	810	6
DHULE				1.10	0.05	6.42	2.82	2.38	3.02	615	50	1780	224
GADCHIROLI				0.34	0.14	0.50	2.74	2.67	2.78	808	170	1470	51
JALGAON	2.578	2.3	2.85	1.01	0.10	5.27	2.87	2.51	3.01	930	50	1780	90
KOLHAPUR				0.62	0.28	0.77	2.94	2.93	2.94	745	560	970	6
NANDED				0.47	0.16	1.20	2.93	2.78	2.99	1312	870	1730	13
NANDURBAR				0.68	0.18	1.76	2.88	2.77	2.94	703	150	1430	38
NASHIK				1.95	0.02	13.35	2.75	2.05	3.06	597	30	2290	224
PUNE				1.48	0.68	2.70	2.69	2.61	2.82	252	40	600	44
RAIGAD				2.22	1.02	4.23	2.67	2.56	2.72	367	200	510	15
RATNAGIRI				2.82	2.76	2.92	6						
SATARA				0.86	0.07	7.72	2.89	0.90	3.20	862	45	2390	164
SINDHUDURGA										737	610	970	6
SOLAPUR				0.46	0.44	0.49	2.96	2.95	2.96	1012	870	1170	6
THANE				2.11	0.18	9.08	2.69	2.26	3.00	618	90	1950	171
USMANABAD				11.94	3.10	18.39	2.08	1.87	2.62	163	40	831	61
WARDHA				0.29	0.09	1.13	2.95	2.88	2.98	1249	710	1810	27
YAWATMAL				0.42	0.24	0.93	2.94	2.65	3.00	775	510	1100	10
Total Samples												1920	

Table 8. GEOLOGICAL ABSTRACT OF ROCK PROPERTIS IN MAHARASHTRA (MERI NASHIK) 1982-2002

Geological Description	Min Density	Max Density	Min % W	Max % W	Min Sp. Gr.	Max Sp. Gr.	Min Comp. kg/cm2	MaxComp kg/cm2	No.of Samples
Amegdoloidal Basalt	2.3	2.85	0.08	11.61	0.90	3.24	30.00	2390.00	577
Black Basalt							150.00	380.00	7
Black Compact Basalt			0.02	0.68	2.81	3.00	170.00	710.00	9
Basalt with Plagioclage laths							50.00	1020.00	54
Basalt	2.84	3.02	0.04	9.08	2.26	3.06	50.00	2040.00	855
Breccia							40.00	390.00	23
Compact Basalt			0.07	7.72	1.90	3.20	45.00	1470.00	134
Dense Compact Basalt (D.C.B.)			0.19	0.49	2.92	2.98	710.00	1530.00	12
Fine Grained Compact Basalt (F.G.C.B.)			0.08	1.75	2.60	3.01	200.00	2290.00	99
Granite							610.00	970.00	6
Gray A.B.			0.08	2.63	2.50	3.00	390.00	880.00	18
Pink A.B.			0.35	1.66	2.59	2.75	300.00	415.00	3
Pink Weak Basalt			0.17	2.15	2.90	2.99	310.00	720.00	4
Sand Stone			2.19	3.00	2.30	2.37	360.00	810.00	6
Volcanic Braccia			2.52	18.39	1.87	2.62	40.00	220.00	65
Weak Basalt			0.23	17.46	2.36	3.05	40.00	1680.00	48
Total Samples									1920