Laboratory Studies on Filter Materials Placed at Ramganga Main Dam

by

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1. Introduction

THE Ramganga River Project envisages the creation of a reservoir in Ramganga Valley adjacent to Corbett National Park in Uttar Pradesh providing for an annual irrigation of 7·46 lakh hectares of land in the Ganga-Yamuna Doab and for generation of 451·8 million units of power. The spillway has been designed for a flood discharge (1 in 750 yrs. frequency) of 9374 cumecs. The storage is being created by construction of two zoned earth and boulder fill dams, 126 m high on the main river and 72 m high on a tributary to close the saddle.

1.0 The design of dam is based upon maximum utilisation of the readily obtainable materials. A typical cross-section of the main dam is shown in Figure 1. The hearting (Core) will be made up of three zones of impervious material, inner core containing crushed clay shales. The clay zone is encased both on upstream and downstream side by crushed sand rock. The upstream shell will be a pervious zone built up of the natural river bed material, with a transition filter between the pervious and impervious zones. The downstream shell consists of crushed sand rock. A filter drain, flanked on either side by transition layers, has been provided between the core and downstream outer shell and is connected to a horizontal drain underneath the downstream shell. The soil parameters of the materials of each zone are given below :—

Soil Parameter	Clay	Sand Rock	River Bed Material
(i) Angle of internal friction (ϕ)	22°	33°	38°
(ii) Cohesion (c)	1 kg/cm²	0·35 kg/cm²	—
(iii) Plasticity Index	5 to 10	Nil	—

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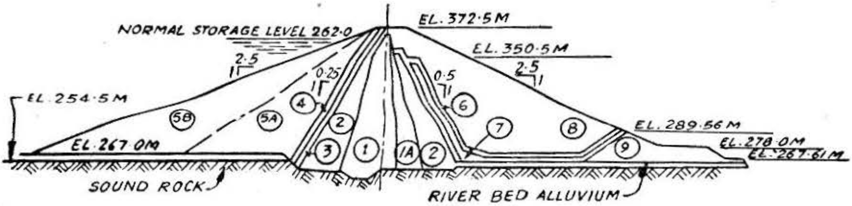


TYPICAL SECTION OF MAIN DAM – EMBANKMENT ZONES

1-CRUSHED CLAY SHALE
1A-MIXTURE OF CRUSHED CLAY SHALE & SAND ROCK
2,8-CRUSHED SAND ROCK
3,6-RIVER BED MATERIAL # 15 I.S SIEVE TO 20 MM.
4 - RIVER BED MATERIAL (–) 150 MM
5A - RIVER BED MATERIAL (–) 450 MM
5B, 9-RIVER BED MATERIAL 20 MM. TO 450 MM
7 - RIVER BED MATERIAL # 240 I.S. SIEVE TO 75 MM.

FIGURE 1.

1.1 The chimney filters downstream of the core have to perform the function of preventing the movement of core materials while permitting seepage moisture to drain off. The specified gradations for the proposed filter materials together with gradation for crushed sand rock are shown in Figure 2. These specifications have been selected on the basis of Terzaghi and U.S.B.R. criteria. Ranges of filter requirements according to these two criteria have also been shown in this figure.

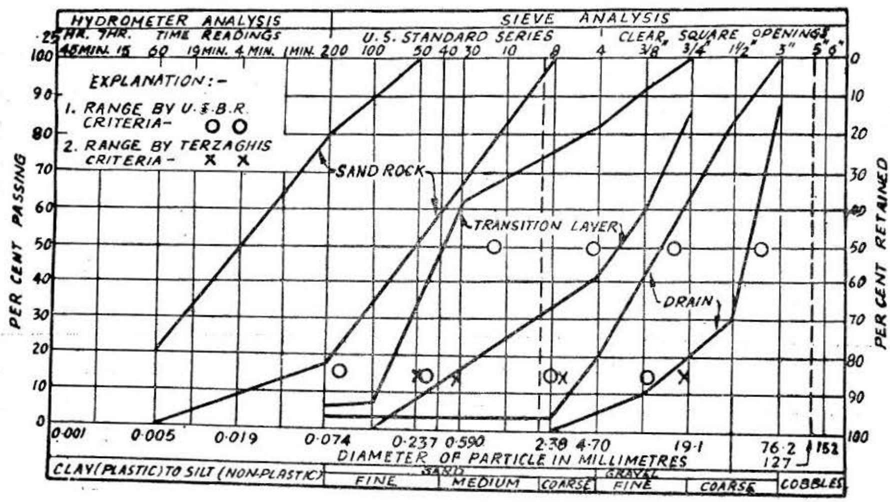


FIGURE 2.

1.2 From a study of filter materials manufactured at the Processing Plant and laid during the last season (1969-70) in the filter chimney, it was observed that gradation curves of fine filter were on the finer side and in some cases even outside the finest specified range, while those of coarse filter were on the coarser side, as shown in Figure 3.

1.3 The fine filter being on the finer side there was no apprehension of movement of crushed sand rock fine particles. The capacity of fine filter to provide free drainage was also not affected, as it remained much more pervious than the crushed sand rock (soil being filtered), the ratio of permeabilities being 40 to 1. The ratio $\frac{D\ 15-FF}{D\ 85-SR}$ (Terzaghi criterion—not more than 4) and $\frac{D\ 50-FF}{D\ 50-SR}$ (U.S.B.R. criterion—12 to 58) works out to 0.65 and 20 respectively. The ratio $\frac{D\ 15-FF}{D\ 15-SR}$ works out to 27, which fully satisfies both Terzaghi and U.S.B.R. criteria for free drainage (Terzaghi criterion being $\frac{D\ 15-FF}{D\ 15-SR}$ to be more than 4 while that of U.S.B.R. provides it to be between 12 to 40).

1.4 But the coarse filter being on coarser side, there could be a possibility of failure of the filter system. The U.S.B.R. criterion of ratio $\frac{D\ 50-CF}{D\ 50-FF}$ was not satisfied being 71 against 12 to 58 specified, though the Terzaghi criterion of $\frac{D\ 15-CF}{D\ 85-FF}$ ($\not> 4$) was satisfied, the ratio being 1.35.

1.5 It was therefore decided to carry out an experimental programme to study the suitablity of the filter material.

2. Selection of Various Grades of Filters for Testing

The tests were conducted for filter materials after dividing them into various grades conforming to the finest, coarsest and mean grade as produced last year (1969-70). An enveloping zone was marked in such a way that 80 percent of gradation curves of filter materials actually produced fell in this zone. The enveloping curve on finest range was termed as 80 percent finest filter and on coarser range as 80 percent coarsest filter (See Figure 3). These grades have been denoted by A 1,2,3 & B in figures.

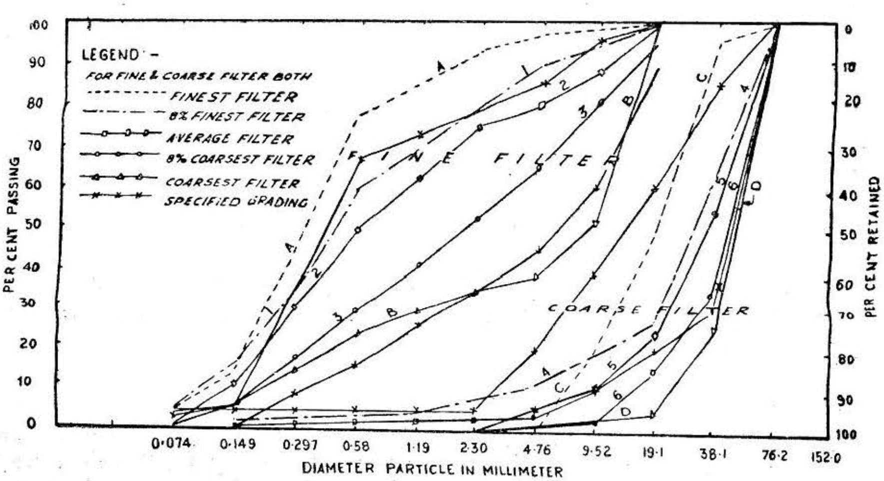


FIGURE 3 : **Various grades of filter produced in year 1969-70.**

3. Programme of Testing

As has been explained in para 1.4, there was apprehension of the coarse filter not being able to perform its basic function of holding fine filter particles in place, consequently causing the progressive seepage erosion of fine filter and clogging of the drain. Therefore the basic objective of this testing programme was to ascertain the capacity of coarse filter to perform this function and also to assess the extent of progressive damage of filter which may affect its stability.

The testing programme was therefore conducted in two series.

3.1 FIRST SERIES OF TESTS

3.1.1 *In this phase of testing, the fine filter was placed* on a sieve (having opening size equal to effective void diameter of the coarse filter) and the test was run under maximum head of 9 m of water. According to Terzaghi criterion, the effective void diameter ranges from 1/4 to 1/5th, the diameter of the smallest 15 percent size of the soil. It was observed that *D*-15 size of coarse filter conforming to various grades as detailed in para 2.0, varied from 6.7 mm (80 percent finest) to 20 mm (80 percent coarsest). Therefore, the effective void diameter of coarse filter would range from 1.7 mm to 5 mm. I.S. Sieve size No. 480 (opening size 4.76 mm) was therefore selected for this series of test to depict the worst conditions.

3.1.2 An effective assessment about internal stability of filter can also be made by these tests. For example if after testing, it is observed that certain fine particle sizes of fine filter have been substantially washed out, it would show that there were voids within the filter zone, permitting migration of its own finer particle sizes. Such filter would be termed as unstable as the gradation would change materially due to substantial washing out of certain finer particle sizes. If, such fine filter is placed against an impervious layer, the fine sizes of the filter itself would be moving into the drain and choking it, consequently permitting fine sizes of the impervious zone to move into the filter and eventually result in choking it.

In case the gradation after testing shows no material change in it the filter can be termed as stable.

3.2 SECOND SERIES OF TESTS

3.2.1 In the second series of tests, the fine filter was placed over coarse filter to check the extent of clogging of coarse filter by fine filter particles and to observe the process of re-adjustment of both the filters after penetration of fine filter particles into the latter. The different combinations of fine filter and coarse filter of various grades are shown in para 5.2.1.

The tests were run at a maximum head of 9 m only. The U.S.B.R. criterion has been established after running tests at maximum head of 9 m only.

4. Details of Experiments

4.1.1 The general arrangement is shown in Figure 4. Two octogonal containers (275 mm internal distance between parallel sides) were selected for placing specimen filter into it. Height of each container was 300 mm. These containers were bolted to each other in such a way that no leakage occurred during testing. Below the containers 9.52 mm sieve was attached. The top of the container was closed by 9.52 mm thick M.S.

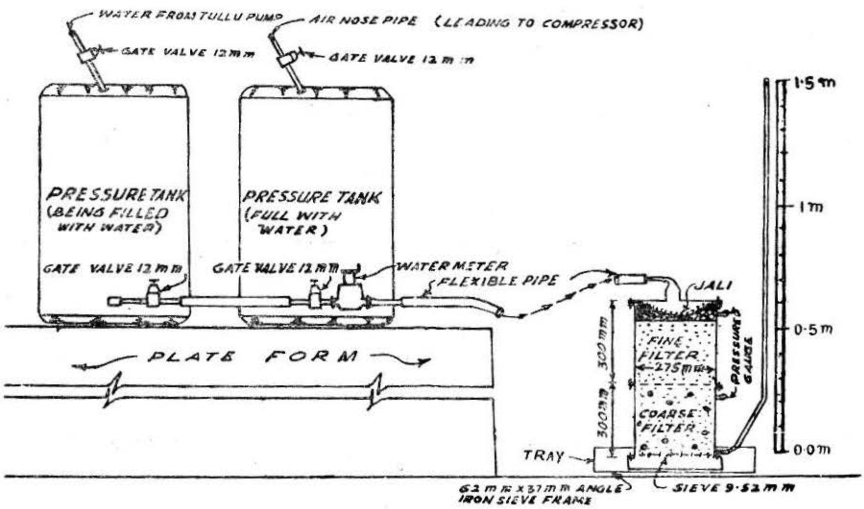


FIGURE 4 : Details of experiment.

Plate (bolted to the container) which contained a 50 mm. diameter hole in the centre. To this hole, 12 mm diameter pipe connections were made leading to twin pressure tanks of 200 litre capacity. A water meter (Least count—0.1 gals.) was also placed in this 12 mm diameter G.I. feeder pipe, to measure the discharge of water passing through. These pressure tanks were used in such a way that while one was being filled with water the other tank was supplying water under pressure for the experiment. When the filled tank was about to get empty, the lead from the compressor was attached to the other tank.

4.1.2 For the second series of tests, the coarse filter was placed in the container above 9.52 mm sieve (the drain is flanked on downstream by a zone of processing plant rejects, 19 mm to 450 mm size, the effective voids of which range about 9 mm) and was suitably compacted to the desired density in 250 mm layer. The fine filter was placed above it and compacted in 275 mm thickness to the 70 percent relative density. A layer of + 38 mm material was placed and hand packed at the top of fine filter to prevent erosion of fine filter from water jet. A sieve having holes of 2.5 mm diameter was then placed at the top of the container to eliminate the effect of entry of water and the top plate with gasket was then fitted to it.

4.1.3 The sample was saturated under a head of 0.6 to 1.2 m for half to one hour. Thereafter the test was run for half hour each under 3 and 6 m head respectively. The readings of discharge were noted down. Then the test was run under 9 m head for twelve hours. After this testing the fine filter and coarse filter were sun-dried and then sieved to determine the gradation of the filters after testing.

4.2.1 To check the internal stability of fine filter the experiment was slightly modified. The 9.52 mm sieve at the bottom was replaced by I.S. Sieve size No. 480. In this phase of testing, a 400 mm thick fine filter conforming to various grades was placed directly on the sieve. The tests were then conducted in the same way as described above.

4.2.2 Fine filter and coarse filter conforming to a particular gradation were prepared in the laboratory by mixing the different particle size in the required proportions.

4.2.3 The gradation of the top half layer and bottom half layers of fine filter after testing were also determined separately in some cases.

5. Test Results

5.1 TEST RESULTS OF FIRST SERIES OF TESTS

5.1.1 Five specimens of fine filter conforming to various grades as explained in para 2 were tested, under heads of 0.6 to 9 m by stages for about 24 hours. The results of this testing are shown in Figures 5 and 6 & Table I.

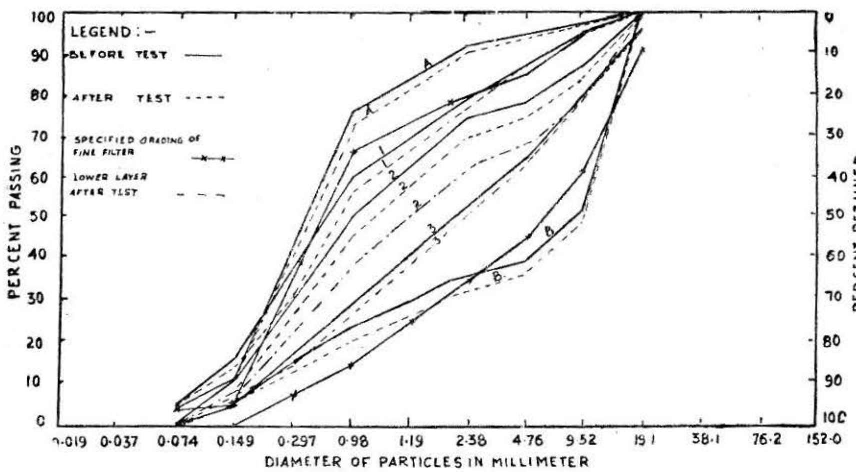


FIGURE 5 : Grades of fine filter specimen before and after test when placed over I.S. Sieve No. 480 (For data see Table I).

From these the main findings can be summed up as under :—

1. As expected the percentage of migration of particles through I.S. Sieve No. 480 was greatest in the finest fine filter. The percentage migration showed a decrease in the coarser filters.

2. After about 3 to 6 hours of testing the migration of particles from fine filter stopped completely and clear water discharged out, showing that the filter had attained stability.

3. There was no wash out of any particular particle size predominantly. All the particle sizes smaller than Sieve No. 480 migrated in varying proportions, though the variation was not significant. In the begining of the test, particles finer than I.S. Sieve No. 480 were ejected from the bottom layer of filter only and thereafter the filters started attaining stability by migration of the finer

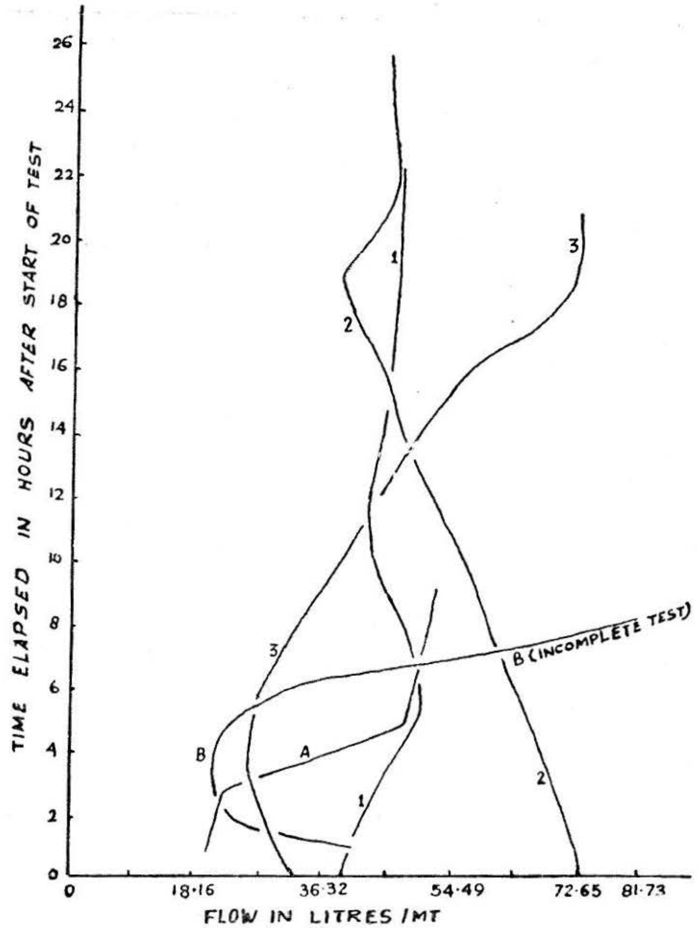


FIGURE 6 : Discharge versus time for fine filter specimen placed on I.S. Sieve No. 480.

particle sizes. In the process, the voids at the top of this bottom layer got much reduced and consequently only much smaller sizes moved down. This process continued upwards until complete stability was achieved.

4. Migration of particles from fine filter took place mainly from the bottom half layer, there was almost no migration of particles from top half layer of filter specimen (As shown in Table I).

5. The gradation curves of filter before and after test remained quite close and parallel to each other.

5.2 TEST RESULTS OF SECOND SERIES OF PROGRAMME

5.2.1 The second phase of testing included placing the fine filter over coarse filter. The following combination of grades of fine and coarse filters were adopted (Table II).

TABLE-I.

SIZE OF SCREEN	PERCENTAGE / WT. IN Kg. OF EACH PARTICLE BEFORE TEST					WT. OF PARTICLE AFTER TEST						PARTICLES MIGRATED FROM FINE FILTER				
						TOTAL LAYER	TOTAL LAYER	UPPER LAYER	LOWER LAYER	TATAL LAYER	TOTAL LAYER					
SET. NO.	A	1	2	3	B	A	1	2		3	B	A	1	2	3	B
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
76.2–38.1 mm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38.1–19.1 mm	-	-	1.0 / 0.51	5.0 / 2.85	2.0 / 1.14	-	-	0.24	0.27	2.85	1.14	-	-	-	-	-
19.1–9.52 mm	2.5 / 1.425	5.0 / 2.55	12.0 / 6.12	15.0 / 8.55	47.0 / 26.79	1.425	2.55	2.58	3.54	8.55	26.79	-	-	-	-	-
9.52–4 No mm	2.5 / 1.425	7.0 / 3.57	8.0 / 4.08	15.0 / 8.55	12.0 / 6.84	1.425	3.57	1.94	2.14	8.55	6.84	-	-	-	-	-
4 – 8 No.	3.0 / 1.710	9.0 / 4.59	4.0 / 2.04	12.0 / 6.84	4.0 / 2.28	1.540	4.40	1.0	0.85	6.35	2.20	0.17	0.19	0.19	0.49	0.08
8–16 No.	8.0 / 4.560	10.0 / 5.10	12.0 / 6.12	12.0 / 6.84	6.0 / 3.42	3.90	4.79	3.0	2.28	6.29	3.18	0.66	0.31	0.84	0.55	0.24
16–30 No.	8.0 / 4.560	10.0 / 5.10	14.0 / 7.14	12.0 / 6.84	6.0 / 3.42	4.01	4.65	3.56	2.27	6.20	3.02	0.55	0.45	1.31	0.64	0.40
30–50 No.	35.0 / 18.81	26.0 / 13.26	19.0 / 9.69	12.0 / 6.84	9.0 / 5.13	14.90	11.25	4.46	2.85	6.28	4.23	3.91	2.01	2.38	0.56	0.90
50–100 No.	32.0 / 18.24	19.0 / 9.69	20.0 / 10.20	12.0 / 6.84	9.0 / 5.13	13.10	8.02	5.02	2.87	6.35	4.10	5.14	1.67	2.31	0.49	1.03
100–200 No.	8.0 / 4.560	11.0 / 5.61	9.0 / 4.59	5.0 / 2.85	5.0 / 2.85	3.45	4.24	2.10	1.10	2.44	2.55	1.11	1.37	1.39	0.41	0.30
–200 No.	3.0 / 1.710	3.0 / 1.53	1.0 / 0.51	-	-	1.18	1.02	0.24	0.15	-	-	0.53	0.51	0.12	-	-
TOTAL.	100.00 / 57.00	100.0 / 51.0	100.0 / 51.00	100.0 / 57.0	100.0 / 57.0	44.93	44.49	24.14	18.32	53.86	54.05	12.07	6.51	8.54	3.14	2.95

TABLE II

Sl. No.	Particulars	Value of *R*-15 before test	Value of *R*-50 before test	Value of $\frac{D\ 15\text{—}CF}{D\ 85\text{—}FF}$ before test.	Denoted in figures & tables as
1	2	3	4	5	6
1.	80% finest fine filter placed over 80% coarsest coarse filter.	133.2	95.6	5.3	1–6
2.	80% finest fine filter placed over average coarse filter.	83.4	75.0	3.38	1–5
3.	80% finest fine filter placed over 80% finest coarse filter.	44.6	62.0	1.81	1–4
4.	80% coarsest fine filter placed over 80% coarsest coarse filter.	77.0	22.0	1.61	3–6
5.	80% coarsest fine filter placed over 80% finest coarse filter.	25.2	14.5	0.54	3–4
6.	Average fine filter placed over 80% coarsest coarse filter.	114.1	73.4	2.47	2–6
7.	Average fine filter placed over 80% finest coarse filter.	38.3	48.3	0.83	2–4
8.	Average fine filter placed over average coarse filter.	57.5	45.2	1.35	2–5

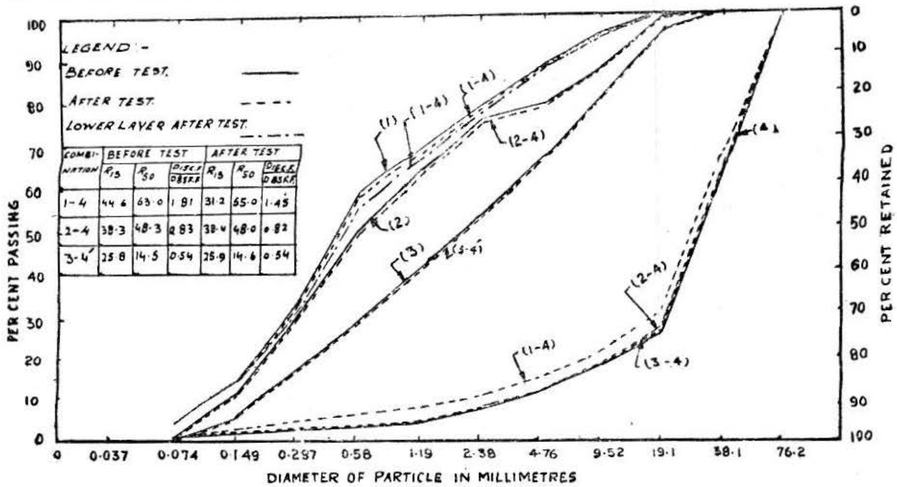


FIGURE 7 : Grades of combination Nos. (3), (5) & (7) of the Report (For data see Table III).

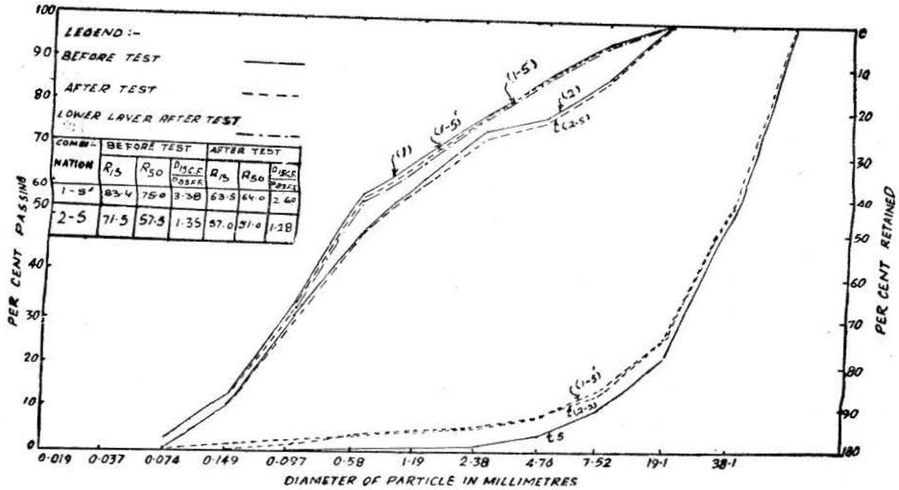


FIGURE 8 : Grades of combination Nos. (2) & (8) of the Report (For data see Table IV).

Combination Nos. (3), (4) & (8) represented average condition of the combination of filter materials as actually laid at main dam. The rest of the combinations may occur at site in a few cases and are not so significant. All the above combinations except Nos. (5) & (7) were outside the limits of U.S.B.R. criterion. Combination Nos. (1), (2) & (6) represented the worst case. It would however be interesting to note that all the above combinations except at Serial No. 1 satisfy Terzaghi's criterion.

5.2.2 The results of this second phase of testing are shown in Figures 7, 8, 9 & 10 and Tables III, IV and V. The ratios R-15 and R-50 before and after test have also been shown in these exhibits.

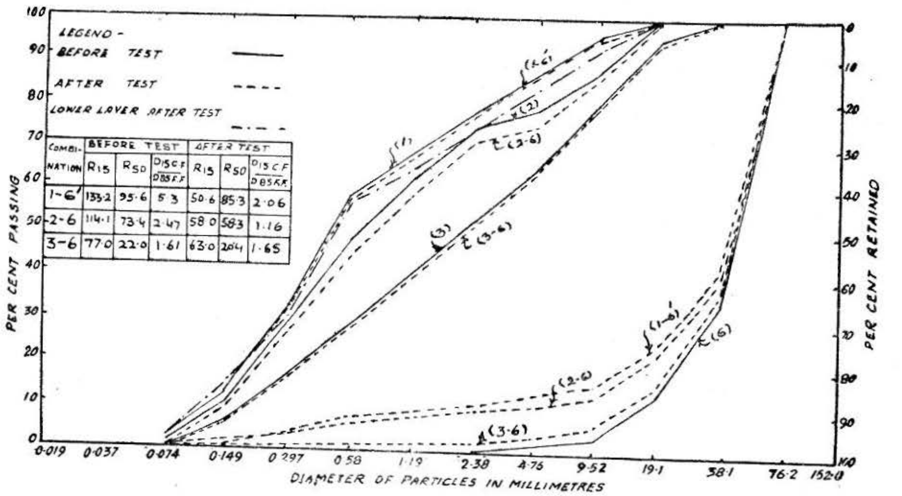


FIGURE 9 : Grades of combination Nos. (1), (4) & (6) of the Report
(For data see Table V).

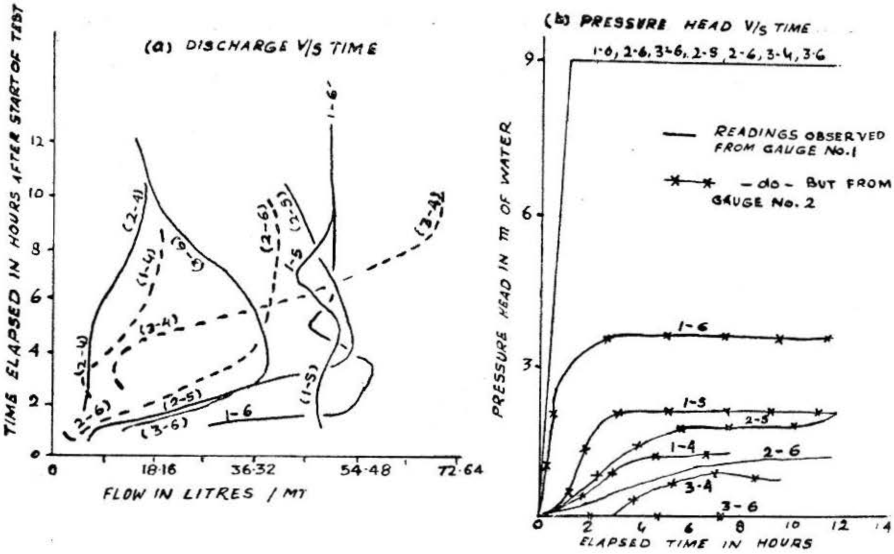


FIGURE 10.

The behaviour of the filters as noticed in this phase of testing is detailed below :-

(*i*) There was migration of fine filter particles into the coarse filter in each case. The percent migration was greatest in the worst combination when *R*-15 and *R*-50 exceeded far beyond the criteria range.

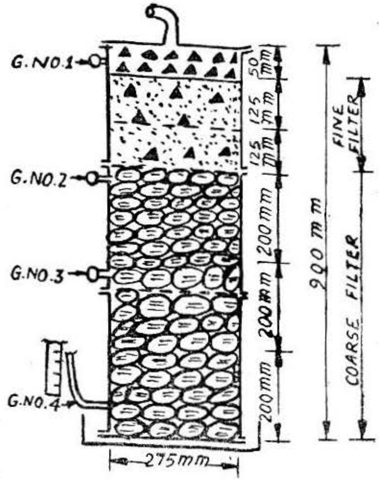
(*ii*) After 2 to 4 hours of testing clear water discharged out and the filters attained stability.

(*iii*) There was no wash out of any particular particle size of fine filter predominantly. The migration of particles took place only from bottom half layer of fine filter in contact with the coarse filter. Migration of particles from upper half layer of fine filter was *insignificant.* *(Tables III, IV and V).*

(*iv*) The fine filter and coarse filter at their content adjusted themselves during tests. The fine filter in the lower half became coarser due to migration of fine particles from it and the coarse filter became finer due to penetration of fines. Due to this adjustment of filters further migration stopped and clear water discharged out.

(*v*) Due to penetration of the fine filter particles into coarse filter, the pressure head in coarse filter steadily increased from zero and reached to a value of about 1.2 to 3.6 m in different combinations as shown in Figure 10. After about three hours of test this increase stopped and pressure head became constant.

SIZE OF PARTICLES IN mm / SERIES A.S.T.M. SIEVE	FINE FILTER PERCENTAGE / wt. IN Kg.			COARSE FILTER PERCENT / wt. IN Kg.			
	BEFORE TEST	AFTER TEST		BEFORE TEST	AFTER TEST		
	EACH LAYER	UPPER LAYER	LOWER LAYER	EACH LAYER	UPPER LAYER	MID. LAYER	LOWER LAYER
1	2	3	4	5	6	7	8
76.2 — 38.1				66.00 / 16.5	62.90 / 16.50	65.22 / 16.50	65.60 / 16.50
38.1 — 19.1				20.00 / 5.00	19.00 / 5.0	19.80 / 5.00	19.90 / 5.0
19.1 — 9.52	5.00 / 0.75	5.00 / 0.75	4.82 / 0.59	11.00 / 2.75	11.10 / 2.91	10.90 / 2.75	10.92 / 2.75
9.52 — 4 No	7.00 / 1.05	7.00 / 1.05	7.44 / 0.91	2.00 / 0.50	2.44 / 0.64	1.98 / 0.50	1.87 / 0.47
4 No — 8 No	9.00 / 1.35	9.20 / 1.38	9.22 / 1.13	1.0 / 0.25	1.45 / 0.38	1.14 / 0.29	0.95 / 0.24
8 No — 16 No	10.00 / 1.50	9.85 / 1.48	10.30 / 1.26		0.65 / 0.17	0.12 / 0.03	0.08 / 0.02
16 No — 30 No	10.00 / 1.50	10.05 / 1.51	10.20 / 1.25		0.42 / 0.11	0.16 / 0.04	0.12 / 0.03
30 No — 50 No.	26.00 / 3.9	25.90 / 3.89	26.70 / 3.27		0.84 / 0.22	0.24 / 0.06	0.16 / 0.04
50 No — 100 No	19.00 / 2.85	19.05 / 2.86	19.60 / 2.28		0.69 / 0.10	0.20 / 0.05	0.16 / 0.04
100 No — 200 No	11.00 / 1.65	11.15 / 1.67	10.11 / 1.24		0.41 / 0.11	0.16 / 0.04	0.15 / 0.04
200 No —	3.00 / 0.45	2.80 / 0.42	2.61 / 0.32		0.10 / 0.03	0.08 / 0.02	0.08 / 0.02
TOTAL	100.0 / 15.0	100.0 / 15.01	100.00 / 12.25	100.00 / 25.00	100.0 / 26.25	100.00 / 25.28	100.00 / 25.15



NOTE :-

1. HEAR TEST NO.-1 OF PARA 5.2 IS REPEATED WITH INCREASE OF C.F. THICKNESS.
2. INITIAL PRESSURE BEFORE MIGRATION OF PARTICLES IN GAUGE NO. 1, 2, 3 & 4 WERE 9 m, 5 m, 0.0 & 0.0 RESPECTIVELY, BUT AFTER STOPPAGE OF MIGRATION, THESE, WERE 9 m. 1 m, 0.0 & 0.0 RESPECTIVELY.

FIGURE 11.

TABLE-III

SIZE OF SCREEN	FINE FILTER									COARSE FILTER						PARTICLES MIGRATED FROM FINE FILTER		
	PERCENTAGE / WT. IN KG. OF EACH LAYER BEFORE TEST.			WT. OF PARTICLE AFTER TEST						BEFORE TEST			WT. OF PARTICLE AFTER TEST					
				UPPER LAYER	LOWER LAYER	UPPER LAYER	LOWER LAYER	TOTAL LAYER OF F.F.		%	WT. IN KG.	WT. IN KG.						
SET NO	1-4	2-4	3-4'	1-4	1-4	2-4	2-4	3-4'		4	4	4'	1-4	2-4	3-4'	1-4	2-4	3-4'
1	2	3	4	5	6	7	8	9		10	11	12	13	14	15	16	17	18
76.2 – 38.1 mm	-	-	-	-	-	-	-	-		36.0	10.8	12.24	10.80	10.80	12.24	-	-	-
38.1 – 19.1 mm	-	1.0 / 0.18	5.0 / 0.90	-	-	0.180	0.180	1.80		37.0	11.10	12.58	11.10	11.10	12.58	-	-	-
19.1 – 9.52 mm	5.0 / 0.875	12.0 / 2.16	15.0 / 2.70	0.90	0.85	2.170	2.150	5.40		9.0	2.70	3.06	2.70	2.70	3.06	-	-	-
9.52 mm – 4 No	7.0 / 1.225	8.0 / 1.44	15.0 / 2.70	1.22	1.17	1.440	1.370	5.39		7.0	2.10	2.38	2.14	2.15	2.37	0.06	0.07	0.010
4 – 8 No.	9.0 / 1.575	4.0 / 0.72	12.0 / 2.16	1.52	1.39	0.730	0.600	4.305		4.0	1.20	1.36	1.28	1.28	1.35	0.24	0.11	0.015
8 – 16 No.	10.0 / 1.750	12.0 / 2.16	12.0 / 2.16	1.71	1.66	2.155	2.080	4.285		3.0	0.90	1.02	0.95	0.92	1.03	0.14	0.085	0.035
16 – 30 No.	10.0 / 1.750	14.0 / 2.52	12.0 / 2.16	1.70	1.52	2.475	2.430	4.160		1.0	0.30	0.34	0.45	0.35	0.47	0.28	0.135	0.160
30 – 50 No.	26.0 / 4.550	19.0 / 3.42	12.0 / 2.16	4.54	3.53	3.450	3.210	4.290		0.5	0.15	0.17	0.77	0.27	0.19	1.03	0.18	0.03
50 – 100 No.	19.0 / 3.325	20.0 / 3.60	12.0 / 2.16	3.32	2.56	3.550	3.400	4.250		0.5	0.15	0.17	0.52	0.295	0.20	0.77	0.25	0.07
100 – 200 No.	11.0 / 1.925	9.0 / 1.62	5.0 / 0.90	1.93	1.50	1.600	1.500	1.790		1.0	0.30	0.34	0.52	0.345	0.31	0.42	0.14	0.01
-200 No	3.0 / 0.525	1.0 / 0.18	-	0.52	0.45	0.160	0.140	-		1.0	0.30	0.34	0.21	0.27	0.24	0.08	0.06	-
TOTAL	100.0 / 17.50	100.0 / 18.0	100.0 / 18.0	17.36	14.62	17.910	17.060	35.67		100.0	30.0	34.0	31.40	30.48	34.06	3.02	1.03	0.33

TABLE-IV

SIZE OF SCREEN	FINE FILTER						COARSE FILTER					PARTICLES MIGRATED FROM FINE FILTER	
	% WT. IN Kg OF PARTICLES IN EACH LAYER BEFORE TEST		WT. OF PARTICLE AFTER TEST				BEFORE TEST			WT. OF PARTICLE AFTER TEST			
			UPPER LAYER	LOWER LAYER	UPPER LAYER	LOWER LAYER	WT. OF EACH PARTICLE	WT. IN Kg. OF EACH PARTICLE					
COMBINATION	(1-5')	(2-5)	(1-5')	(1-5')	(2-5)	(2-5)		5'	5	(1-5')	(2-5)	(1-5')	(2-5)
1	2	3	4	5	6	7		8		9	10	11	12
76.2-38.1 mm	–	–	–	–	–	–	46.0	13.80	15.64	13.800	15.64	–	–
38.1-19.1 mm	–	1.0 / 0.180	–	–	0.18	0.18	31.0	9.30	10.54	9.300	10.54	–	–
19.1-9.52 mm	5.0 / 0.875	12.0 / 2.160	0.920	0.820	2.16	2.16	13.0	3.90	4.42	3.900	4.42	0.01	–
9.52-4 No mm	7.0 / 1.225	8.0 / 1.440	1.225	0.900	1.41	1.45	6.0	1.80	2.04	2.045	2.050	0.325	0.02
4-8 No	9.0 / 1.575	4.0 / 0.720	1.620	1.210	0.700	0.62	2.0	0.60	0.68	0.725	0.780	0.32	0.12
8-16 No	10.0 / 1.750	12.0 / 2.160	1.830	1.480	2.15	1.90	0.5	0.15	0.17	0.220	0.420	0.19	0.27
16-30 No	10.0 / 1.750	14.0 / 2.520	1.7 0	1.480	2.5	2.16	0.5	0.15	0.17	0.260	0.430	0.24	0.38
30-50 No	26.0 / 4.550	19.0 / 3.42	4.670	3.070	3.28	3.20	1.0	0.30	0.34	0.900	0.480	1.36	0.36
50-100 No	19.0 / 3.325	20.0 / 3.60	3.310	2.540	3.40	3.10	–	–	–	0.300	0.430	0.80	0.70
100-200 No	11.0 / 1.925	9.0 / 1.62	1.820	1.460	1.50	1.33	–	–	–	0.100	0.260	0.57	0.41
-200 No	3.0 / 0.525	1.0 / 0.18	0.500	0.420	0.13	0.12	–	–	–	0.040	0.05	0.13	0.11
TOTAL	100.0 / 17.50	100.0 / 18.0	17.675	13.38	17.41	16.22	100.0	30.0	34.0	31.59	35.500	3.945	2.37

TABLE V

SIZE OF SCREEN	FINE FILTER — PERCENTAGE / WT. IN KG EACH LAYER BEFORE TEST			FINE FILTER — WT. OF PARTICLE AFTER TEST				COARSE FILTER — BEFORE TEST			COARSE FILTER — WT. OF PARTICLE AFTER TEST			PARTICLES MIGRATED FROM FINE FILTER		
				UPPER LAYER	LOWER LAYER	TOTAL LAYER OF F.F.	TOTAL LAYER OF F.F.	%	WT. IN KG	WT. IN KG						
SET No.	1-6'	2-6	3-6	1-6'		2-6	3-6		6'	6	1-6'	2-6	3-6	1-6'	2-6	3-6
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
76.2-38.1 mm	-	-	-	-	-	-	-	66.0	19.8	24.44	19.80	22.44	22.44	-	-	-
38.1-19.1 mm	-	1.0 / 0.180	5.0 / 0.900	-	-	0.360	1.800	20.0	6.0	6.80	6.00	6.80	6.80	-	-	-
19.1-9.52 mm	5.0 / 0.875	12.0 / 2.160	15.0 / 2.700	0.880	0.870	4.320	5.400	11.0	3.30	3.74	3.30	3.74	3.74	-	-	-
9.52 mm - 4 No	7.0 / 1.225	8.0 / 1.440	15 / 2.700	1.260	0.900	2.615	5.240	2.0	0.60	0.68	0.90	0.91	0.83	0.29	0.265	0.16
4-8 No.	9.0 / 1.575	4.0 / 0.720	12.0 / 2.160	1.510	0.980	1.305	4.210	1.0	0.30	0.34	0.78	0.44	0.44	0.66	0.135	0.11
8-16 No	10.0 / 1.750	12.0 / 2.160	12.0 / 2.160	1.750	1.020	3.620	4.160	-	-	-	0.58	0.50	0.15	0.73	0.700	0.16
16-30 No	10.0 / 1.750	14.0 / 2.520	12.0 / 2.160	1.760	0.810	3.860	4.060	-	-	-	0.73	0.63	0.22	0.93	1.180	0.26
30-50 No.	26.0 / 4.550	19.0 / 3.420	12.0 / 2.160	4.700	2.730	6.060	4.160	-	-	-	1.15	0.36	0.12	1.67	0.780	0.16
50-100 No.	19.0 / 3.325	20.0 / 3.600	12.0 / 2.160	3.420	1.840	5.850	4.130	-	-	-	0.86	0.59	0.15	1.39	1.350	0.19
100-200 No.	11.0 / 1.925	9.0 / 1.620	5.0 / 0.900	1.740	1.300	2.670	1.630	-	-	-	0.39	0.27	0.14	0.81	0.57	0.17
-200 No	3.0 / 0.525	1.0 / 0.180	-	0.590	0.260	0.240	-	-	-	-	0.02	0.06	-	0.20	0.12	-
TOTAL	100.0 / 17.50	100.0 / 18.0	100.0 / 18.0	17.610	10.710	30.900	34.79	100.0	30.0	34.0	34.51	36.74	35.03	6.58	5.10	1.21

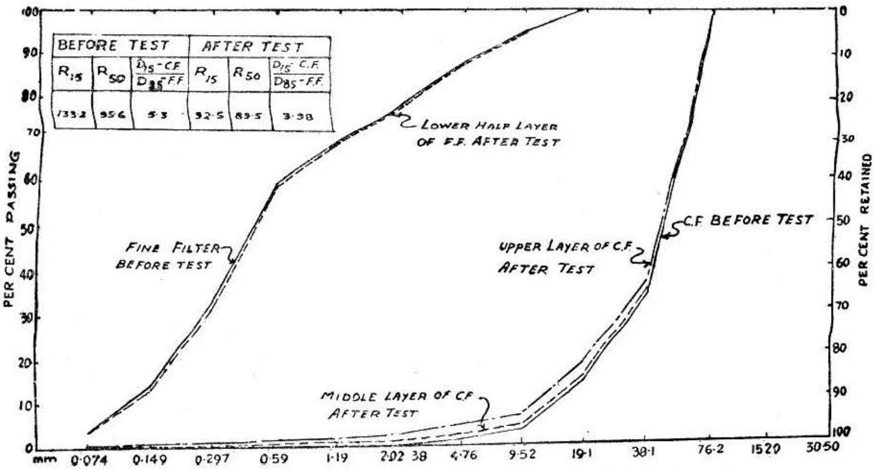


FIGURE 12 : Gradation curves of filters used in check test.

5.2.3 *Check Test*

A check test was performed by selecting grades of filters similar to those adopted in test No. 1 of para 5.2.1. Three containers of 300 mm height were used in check test, to provide a large thickness of coarse filter. The fine filter was first placed and compacted in the container in two layers of 125 mm each. The coarse filter was placed and compacted over it in three layers of 200 mm each. The filters were compacted to 70 percent relative density. The bottom plate was then bolted over the container. The container was thereafter turned upside down and placed in position as shown in Figure 11. The gradation of each layer after testing was determined separately as shown in Figure 12.

Comparison of test No. 1 of para 5.2.1 with the check test shows the following salient points :-

(*i*) Percentage migration of particles from fine filter, when the thickness of coarse filter layer was 60.96 cm, was much less than when the thickness of coarse filter layers was 25.4 cm.

(*ii*) The particles of fine filter which migrated were mostly retained in a small depth of coarse filter adjacent to fine filter. Hydraulic pressure of very low magnitude developed only in the so affected width of coarse filter.

6. Conclusions

The behaviour of fine filter and coarse filter laid at main dam, the gradation of which fall outside the required limits of U.S.B.R. criterion, can therefore be assessed on the basis of above tests as below :-

(*i*) The tests conducted on all possible combinations of various gradations of fine filter, as laid at main dam in the working season of 1969-70 showed that the fine filter has fairly good distribution of different particle sizes and that it has a capacity to form a stable filter after initial migration of some fine filter particles.

This initial migration shall take place from a very small depth of fine filter adjacent to coarse filter and the upper layers of fin e filter would not be affected at all.

(*ii*) The particles of fine filter will penetrate into coarse filter and pass through its voids, until the coarse particles of fine filter clog the voids of the coarse filter creating in turn smaller openings in coarse filter smaller than the particles of fine filter. In this process there would be change of gradation of coarse filter in a small depth adjacent to the fine filter. This re-adjustment of small widths of fine filter and coarse filter, itself brings these filter layers within such limits that further movement of particles does not take place and stable condition develops.

(*iii*) The drainage capacity of coarse filter is not likely to be affected as the movement of fine filter particles into coarse filter will be limited in only a small width. Hydraulic pressure which would develop in small affected width of coarse filter would be of small magnitude.

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