THE NEW IRRIGATION ERA

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THE REASON WHY SOME PEOPLE CANNOT FIND OPPORTUNITY IS BECAUSE IT GOES ABOUT DISGUISED AS HARD WORK.

(For Departmental Circulation only)

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ENGINEER'S MOTTO.

When we build let us think that we build for ever.
Let it not be for present delight nor for present use alone.
Let it be such work as our descendants will thank us for.

John Ruskin.

PARAMBIKULAM CHIEF RETIRES.

Born in the year 1903 in a distinguished family, Sri. U. Ananda Rao had a still more distinguished academic career, followed by a long and devoted public service. Securing the first rank in the Guindy Engineering College in the year 1926, he was taken into the Indian Service of Engineers in the same year and began his service as Assistant Executive Engineer in Madras. As Executive Engineer, he was in charge of many important works including the construction of the Poondi Reservoir, investigation of Lower Bhavani Project, etc. During the brief period he was associated with the Tungabhadra Project, he was responsible for proposing an aqueduct instead of a barrage across the River Hagari, which change resulted in a savings of about Rs. 10 lakhs in those days. In recognition of this, Government were pleased to confer on him the title of Rao Bahadur. As Superintending Engineer (Food Production), he organised and gave fillip to the numerous Minor Irrigation Schemes spread over the entire composite State of Madras before the separation of Andhra. He had assumed charge as Chief Engineer for Irrigation in 1954 and directed the execution of many of the First and Second Plan Projects, such as Sathanur, Amaravathi, Krishnagiri and Araniar, etc. His notable achievement is the Parambikulam-Aliyar Project which was conceived and investigated by him from the beginning. In February 1959, he was appointed as Special Chief Engineer solely for the execution of the Parambikulam-Aliyar Project. He had begun works simultaneously in all the dams and tunnels which are now in fast progress. He completed the construction of the Aliyar Dam, one of the eight dams in the Parambikulam-Aliyar Project and it was opened for irrigation of 7,500 acres on 2nd October 1962, by the Chief Minister of Madras. Thus he had the unique opportunity of not only investigating a giant project from the beginning but also had the fortune of bringing it into fruition. With such a distinguished record of service for the last 37 years, he retired in February 1963, at the age of sixty. He was President of Central Board of Irrigation and Power during the years 1961-63.

We wish him long life and happiness in his retirement.

SAPINDUS EMARGINATUS

By

Sri J. WALTER, B.A.,B.E., M.I.E. (Colorado). *

Synopsis.

Sapindus Emarginatus is the botanical name for the commonly known soap-nut which is used by goldsmiths for cleaning ornaments. Its efficacy as an air entraining agent in concrete is discussed in this article. The effect of sapindus emarginatus on the workability and compressive strength of concrete as well as its suitability as an air entraining agent has been studied in the Concrete and Soil Research Laboratory.

Introduction.

Among the outstanding developments that concrete technology has undergone in recent years, purposeful air entrainment obtained by the addition of external agents to the concrete is worth mentioning. Purposeful entrainment of air is accomplished by adding an air entraining agent to the Concrete mix which results in dispersion throughout the mix of non-coalescing spheroids of air having diameters from 0.003 to 0.05 inch. Entrained air acts as an additional flexible aggregate which greatly increases the workability for the same slump with substantial reduction in sand content and water content. In many cases this permits the use of lower slump. Other immediate benefits of using air entrained concrete such as reduction of bleeding, segregation and time of vibration and finishing, etc., have been generally well demonstrated and accepted during the past.

Materials that are used for the purpose of air entraining in concrete fall into one or more of the following classes :—

1. Natural wood resin and other soaps.

2. Animal or vegetable fats or oils, their fatty acids and their soaps.

3. Alkali salts of sulphonated or sulphated organic compounds, such as synthetic detergents.

From this general classification it will be seen that there are innumerable materials which will entrain air. In India where vegetable growth is abundant the exploitation of suitable air entraining agents under the first two classifications mentioned is justified. With these points in view pilot experiments were conducted in the Concrete Laboratory at Madras on "Sapindus Emarginatus" (which goldsmiths call as "Nuraikai") for use in air entrainment in concrete. Sapindus Emarginatus is widely grown in India. The annual yield of this material in Madras State alone is about 240 tons.

Preparation of the agent.

This air entraining agent was used in a powder form prepared from peels and shells of Sapindus Emarginatus after roasting it in an oven at 60° C for about 15 minutes. The ovendried shells of Sapindus Emarginatus were pulverised well and passed through ASTM sieve No. 8. This powder was added to the mixing water in different ratios to the quantity of cement used to obtain the required air entrainment.

Test Procedure.

1. Compressive strength experiments were conducted on concrete with maximum size of coarse aggregate 1½ inches and sand of medium fineness. Coarse aggregates used in the tests were broken metal from Pallavaram quarries. River sand of medium fineness available near the city of Madras was used as fine aggregate. The optimum percentage of sand to total aggregate which gave the least unit water content for the concrete of 3 inches slump was selected for each

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of the three water cement ratios 0.45, 0.5, 0.55. With these three optimum percentages obtained, different percentages of air entrainment up to about 6 per cent by volume were tried for a constant slump of 3 inches and without altering the mix proportion. This resulted in a reduction in water content (please *see* tabular statement I, II and III).

Durability.

2. As there is no specific procedure for conducting durability tests of concrete, soundness tests of aggregates as per ASTM procedure No. 88-46-T was adopted for concrete. Six inches cubes were cast with mix 1:1.98:3.2 with water cement ratio = 0.5. Sapindus Emarginatus powder was added in proportions 0 and 15 grams|15.775 pounds of cement. A saturated solution of sodium sulphate was prepared before starting the test. Cubes after 28 days curing were dried in an oven at 100°C for 5 hours and weighed and then kept in the solution for 18 hours and then again dried in an oven for 5 hours. After removing from the oven, cubes were allowed to cool for 18 hours. Each weathering and drying constitutes a cycle. The experiment was repeated for 12 cycles. It was found that there was no loss in weight. The results can be seen in statement IV.

Further experiments.

Experiments are under way to introduce the air entraining agent in a liquid form (as in the case of Koynæa air entraining agent). The Koynæa a.e.a has been prepared by dissolving rosins in sodium hydroxide to obtain a 10 per cent solution. The Sapindus Emarginatus powder was dissolved in sodium hydroxide and an extract obtained. The extract which was readily soluble in water has been compared for the stability of the air bubbles with the Koynæa a.e.a. The photos enclosed show the comparative stability of bubbles after 2 hours. Even to-day large amounts of vinsol and other air entraining agents are imported into our country.

Conclusions.

1. Sapindus Emarginatus can be used successfully for entraining air in concrete up to 5 per cent by volume.

2. There is an increase in strength of concrete up to 5 per cent of entrained air for the same workability.

3. The concrete with purposeful air entrainment using Sapindus Emarginatus is found to be quite durable.

4. There lies a great potential for manufacturing on a large scale at national level the a.e.a. out of sapindus emarginatus.

TABLE I.

MAX. SIZE OF AGGREGATE = $1\frac{1}{2}''$

MIX. PROPORTION 1 : 1·65 : 2·94

SLUMP = 3"

PERCENTAGE OF FINE AGGREGATE TO COMBINED AGGREGATE=36.

Serial number. (1)	Materials used. Metal in lb. (2)	Sand in lb. (3)	Cement in lb. (4)	Water in lb. (5)	$\frac{Water}{Cement}$ (by weight). (6)	Weight of sapindus emarginatus (in gms.) (7)	Ratio of weight of sapindus emarginatus in gms. to the weight of cement in lb. (8)	Percentage of entrained air. (9)	Mean compressive strength (of six cylinders 6" dia. 12" in ht.) at 28 days in lbs./Sq. in (10)	in Kgm/Sq. c.m. (11)
1.	100	56	34	15·30	0·450	0	0	1·7	2,123	149·3
2.	100	,,	,,	15·00	0·440	10	0·294	2·6	2,849	200·3
3.	,,	,,	,,	14·80	0·435	20	0·588	3·8	3,398	238·9
4.	,,	,,	,,	14.38	0·423	30	0·882	4·6	3,557	250·1
5.	,,	,,	,,	14·20	0·415	40	1·176	5·0	2,831	199·0
6.	,,	,,	,,	14·00	0·412	50	1·470	5·0	2,583	181·6
7.	,,	,,	,,	14·00	0·410	60	1·764	5·8	2,335	164·2

TABLE II.

MAX. SIZE OF AGGREGATE = $1\frac{1}{2}''$

MIX. PROPORTION=1 : 1·98 : 3·23.

SLUMP=3"

PERCENTAGE OF FINE AGGREGATE TO COMBINED AGGREGATE=38.

Serial number. (1)	Materials used. Metal in lb. (2)	Sand in lb. (3)	Cement in lb. (4)	Water in lb. (5)	$\frac{Water}{Cement}$ (by weight) (6)	Weight of Sapindus emarginatus. (in gms.) (7)	Ratio of weight of Sapindus emarginatus in gms to the weight of cement in lb. (8)	Percentage of entrained air. (9)	Mean compressive strength (of six cylinders 6" dia. 12" in ht. at 21 days in lbs. Sq. in (10)	in Kgm Sq. c.m. (11)
1.	100	61·3	31	15·50	0·50	0	0	1·8	1,974	138·8
2.	,,	,,	,,	14·63	0·47	10	0·323	3·2	2,548	179·1
3.	,,	,,	,,	13·62	0·45	20	0·646	4·0	3,008	211·5
4.	,,	,,	,,	13·58	0·44	30	0·969	5·0	3,397	238·8
5.	,,	,,	,,	13·50	0·43	40	1·292	5·2	2,548	179·1
6.	,,	,,	,,	13·50	0·43	50	1·615	5·4	2,335	164·2
[illegible]	,,	,,	,,	13·25	0·42	60	1·938	6·0	2,266	156·5

TABLE III.

MAX. SIZE OF AGGREGATE = $1\frac{1}{2}''$

MIX. PROPORTION= 1: 2·2 : 3·45

SLUMP=3"

PERCENTAGE OF FINE AGGREGATE TO COMBINED AGGREGATE= 39.

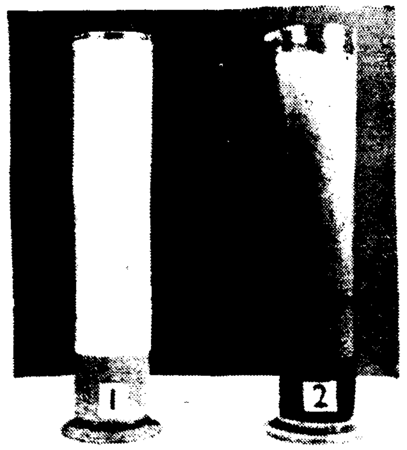
Serial number. (1)	Materials used. Metal in lbs. (2)	Sand in lbs. (3)	Cement in lbs. (4)	Water in lbs. (5)	$\frac{Water}{Cement}$ (by weight). (6)	Weight of sapindus Emarginatus (in gms.). (7)	Ratio of weight of sapindus emarginatus in gms. to the weight of cement in lbs. (8)	Percentage of entrained air. (9)	Mean compressive strength (of six cylinders 6 dia. 12" in height) at 28 days. in lbs./Sq. in (10)	in Kgm/Sq. c.m. (11)
1.	100	64	29	15·96	0·550	0	0	1·9	1,841	129·4
2.	,,	,,	,,	15·50	0·530	10	0·345	3·6	2,141	150·5
3.	,,	,,	,,	14·75	0·510	20	0·690	4·6	2,248	158·0
4.	,,	,,	,,	14·38	0·497	30	1·035	5·4	2,530	172·9
5.	,,	,,	,,	13·94	0·480	40	1·380	5·4	2,123	149·3
6.	,,	,,	,,	13·50	0·465	60	2·070	6·8	1,773	12 ·7

STATEMENT IV.

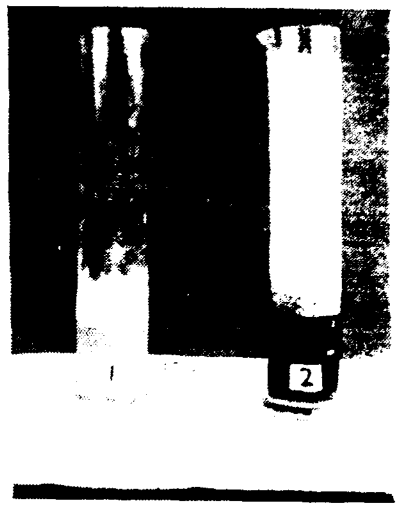
DURABILITY TESTS FOR SAPINDUS EMARGINATUS.

Percentage of solid sapindus emarginatus to weight of cement.	Sapindus Emarginatus added.		Final weight of cubes in lbs.	Original weight of cubes in lbs.	Percentage of loss.
0	0	1.	19·40	19·40	
		2.	19·45	19·45	No loss.
0·022	15	1.	19·80	19·80	
		2.	19·58	19·58	No loss.

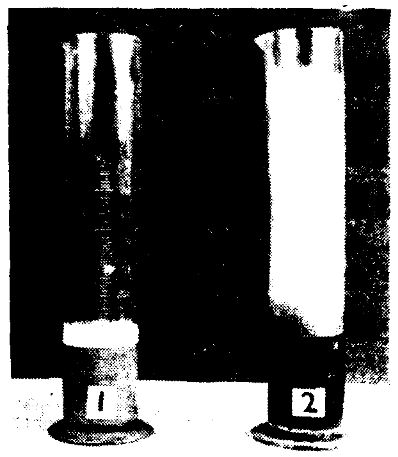
A PHOTOGRAPHIC ILLUSTRATION TO COMPARE THE STABILITY OF SAPINDUS EMARGINATUS WITH KOYNAEA



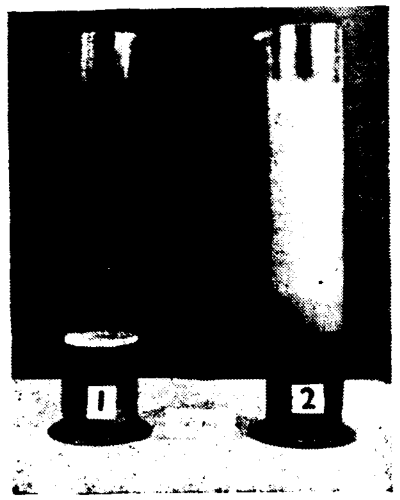
At 0 minutes



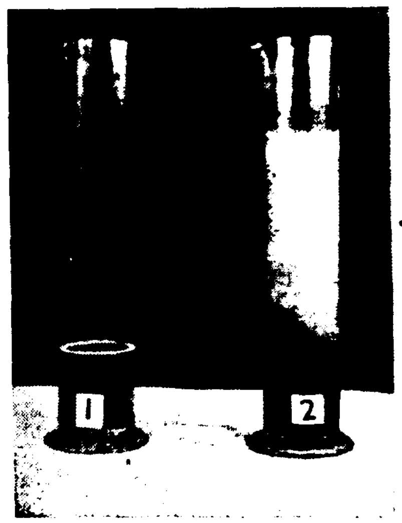
After 15 minutes



After 30 minutes



After 60 minutes



After 120 minutes

1. Koynaea. 2. Sapindus Emarginatus.

SATHANUR RESERVOIR PROJECT

SECOND STAGE

By

* SRI SYED BASHIRUDDIN, B.E.

The Sathanur Dam is constructed across river Ponniar which rises from the Chennakesava Hills in Mysore State and flows through Salem, North Arcot and South Arcot districts. The river enters the Bay of Bengal near Cuddalore Town. The drainage area of the river is nearly 5,000 square miles and is under the influence of south-west and north-east monsoons. The floods in the river are usually of short duration rising and dwindling rapidly.

2. Prior to the construction of Krishnagiri Reservoir Project and Sathanur Reservoir Project under Second Five-Year Plan there were no reservoirs across the river except the one near Hosikote in the head reach of the river. Irrigation was carried on by channels taking off with open heads or from anicut at Aliyalam, Nedungal, Thirukkoilur and Ellis Choultry and the storage was limited to small tanks fed by these channels.

3. The Krishnagiri Reservoir recently constructed at a distance of about 108 miles from the origin of the river has a storage capacity of 2,410 m.c.ft., and is designed to irrigate an extent of 9,000 acres.

4. The Sathanur Reservoir is constructed at a distance of about 178 miles from the origin of the river. The project consists of a dam 2,580 feet in length to hold a storage of 4,565 m.c.ft. in the initial stage. As the main reservoir is situated in a narrow gorge with rocky margin, the main canal could not be taken directly from the reservoir. Water is let down in the river through five river sluices of size 5 feet by 6 feet and this water is diverted into the main canal by means of a pick up anicut constructed 4½ miles below Sathanur Dam across the river. The canal irrigates a total extent of 21,000 acres in the Taluks of Chengam, Tiruvannamalai of North Arcot district and Thirukkoilur taluk of South Arcot district.

5. The maximum flood discharge of the river has been computed as 2,00,000 cusecs at the Dam site. The surplus works consists of 9 vents of spillway 40 feet by 20 feet which are at present uncontrolled. In addition, there is a saddle on the right end for surplusing. The present F.R.L. or the crest of the spillway is plus 709 and M.W.L. is plus 729. As there is considerable fluctuation in the flow of the river, the need for a reservoir with greater capacity was kept in view while designing the dam. It is possible by installing gates of size 40 feet by 20 feet over the spillway to increase the capacity of the reservoir from the existing capacity of 4,565 m.c.ft., to 8,100 m.c.ft. Examining the flow in the river for the period of 35 years, from 1919–20 to 1953-54, it is seen from working tables, that a reservoir with a capacity of 4,565 m.c.ft., will be successful for 19 years. However, omitting five continuous bad years, and examining the cycle of 30 years it is found that the reservoir will be successful for 20 out of 30 years. With a bigger reservoir of 8,100 m.c.ft., capacity, it is possible to increase the number of successful years to 25. However, 7 years will be partially successful and 3 years will be failure. It is thus possible to stabilize the supplies to 5,000 acres of II crop under the Thirukkoilur anicut system, lower down in 25 years out of 30 years.

6. It is now proposed in the second stage to raise the present F.R.L. of the reservoir by 20 feet and make the F.R.L. same as the M.W.L.

* Superintending Engineer, P.W.D., Madras Circle, Madras-5.

thereby increasing the capacity from 4,565 to 8,100 M.Cft. To achieve this, 20 lift gates are to be provided for the 9 vents of spillway with necessary counterweight operating arrangements and platform.

7. The saddle on the right flank which is now at a low level will be converted into a vented escape. Eleven vents of 40 feet by 15 feet with sill at plus 714 and with gates, counter-weight operating arrangements, etc., similar to those over the spillway are proposed to be provided to the vented escape. The piers shall be 9 feet wide and will be founded on hard rock. There will be a roadway 12 feet wide over the piers The ventway shall be excavated to plus 710 and concrete 1:3:6 for a depth varying from 1 foot 6 inches to 3 feet 6 inches will be laid as a leveling course. Over this a 6 inches wearing coat of 1:2:4 concrete will be provided. The concrete apron in rear shall be formed to a slope of 1 in 25 and that in front shall be formed to a slope of 1 in 16. The cut off walls in front at the sill, the subsidiary cut off near the rear cut water and the cut off wall at the rear shall be 5 feet in width. There will be two flanking earthdams, the one on the left of the saddle, connecting it to the existing earth dam and the other on the right side, ending upto levels required to give adequate free board. In addition, it is proposed to have a flush escape 150 feet long with sill at plus 723.

8. The cost of the works described above, comes to Rs. 53.16 lakhs for works portion and Rs. 60 lakhs including direct and indirect charges. No additional expenditure will be involved on the canals as no extension of ayacut is proposed under the canal.

9. The Revenue return for the second stage works out to 0.45 percent without any better ment fee and to 0·31 percent with a betterment fee of Rs. 100 per acre on the 5,000 acres under the Thirukkoilur anicut system. The revenue return combined for the first stage and second stage works out to 0·65 per cent without any betterment levy and 1.18 percent with a betterment fee of Rs. 100 per acre on the 5,000 acres, against 0·68 percent and 1·24 percent for the first stage works alone.

10. As it is proposed to store in the reservoir, only the surplus waters during high floods which would otherwise go to waste, the interests of the lower down irrigation are not affected. On the other hand, the construction of the second stage which is now taken up under the Third Five-Year Plan will facilitate better regulation aiming at an uniformly distributed supply to the lower down ayacut.

11. The work on the second stage has been taken up in October 1961. The 9 numbers of gates for the spillway of size 40 feet by 20 feet and 11 numbers of gates for the saddle 40 feet by 15 feet are lift gates. The gates, groove angles, hoist bridge, etc., are being manufactured in the Public Works Workshops and Stores at Madras.

12. The Salient features of the Sathanur Reservoir Project second stage, indicating the quantity of works involved, are furnished below :

SALIENT FEATURES OF S.R.P. II STAGE.

1. Gates 40' x 20' over spillways	9	Nos.
2. Earthwork excavation in all soils.	3,244	Units.
3. Excavation in hard rock.	34,572	,,
4. C.C. 1 : 3 : 6.	1,320	,,
5. C.C. 1 : 2 : 4.	220	,,
6. R.C.C. 1 : 2 : 4.	200	,,
7. R.R. in cement mortar 1 : 4.	2,000	,,
8. Chissel dressed face work.	320	,,
9. Hammer dressed face work.	50	,,
10. Total quantity of cement required	2,500	Tonnes
11. Total quantity of steel required.	80	,,

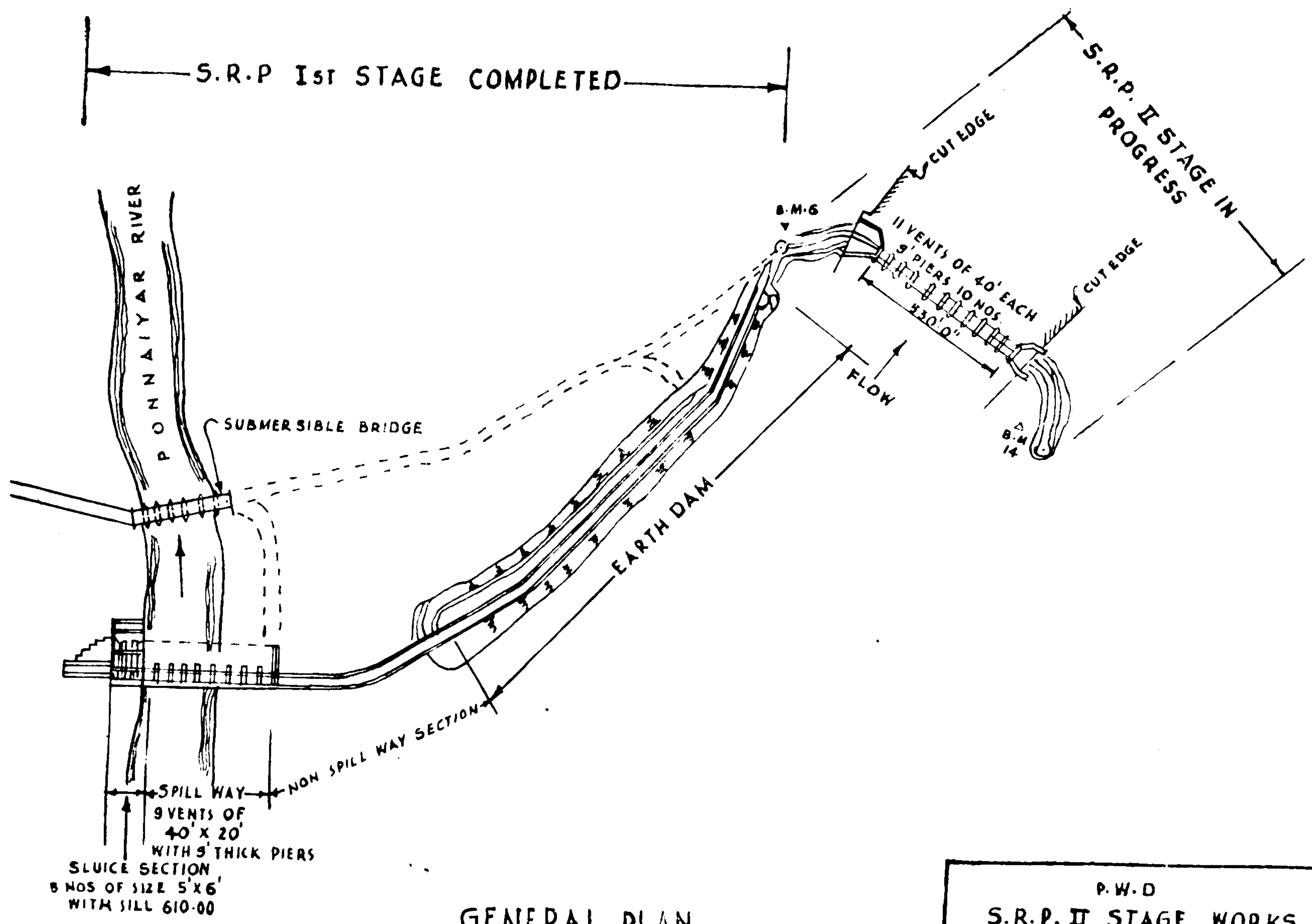
CLASSIFIED ABSTRACT.

I. Head works.		
A. Preliminaries	10,000	
C. Works	51,76, 00	
K. Buildings	25,000	
O. Miscellaneous ..	30,000	
	52,41,000	
II. Special Tools and Plants.	3,00,000	(Gross)
Deduct depreciation charges debited to the works and relate to T and P ..	(—) 2,25,000	
	75,000	(Net)

Direct charges.

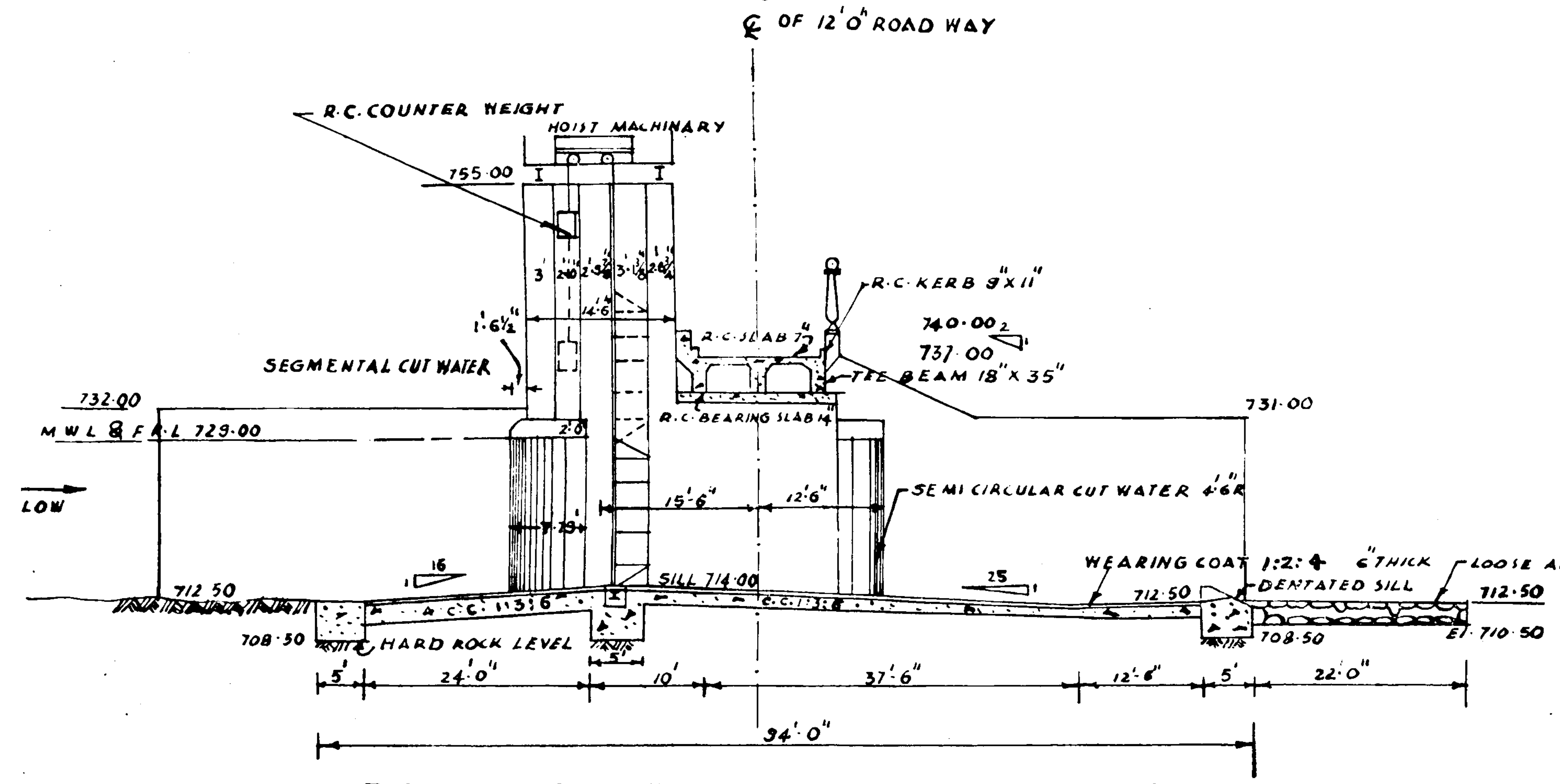
Establishment	4,95,000
Tools and Plant ordinary ..	99,000
Pensionary charges of Establishment	41,000
Audit and Account ..	49,000
	60,00,000

13. It is expected that the II stage work will be substantially completed before the commencement of the monsoon of 1963.



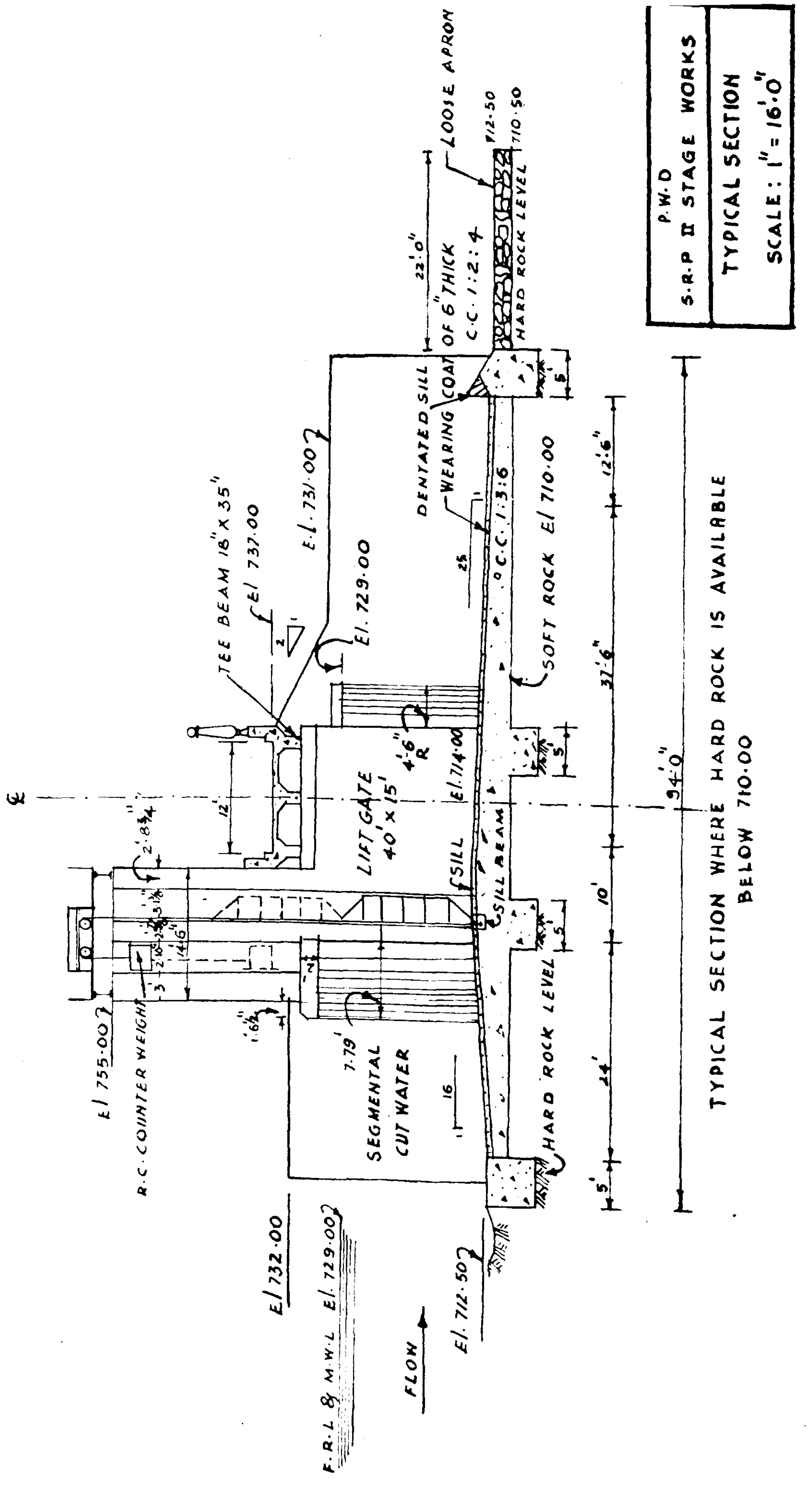
GENERAL PLAN

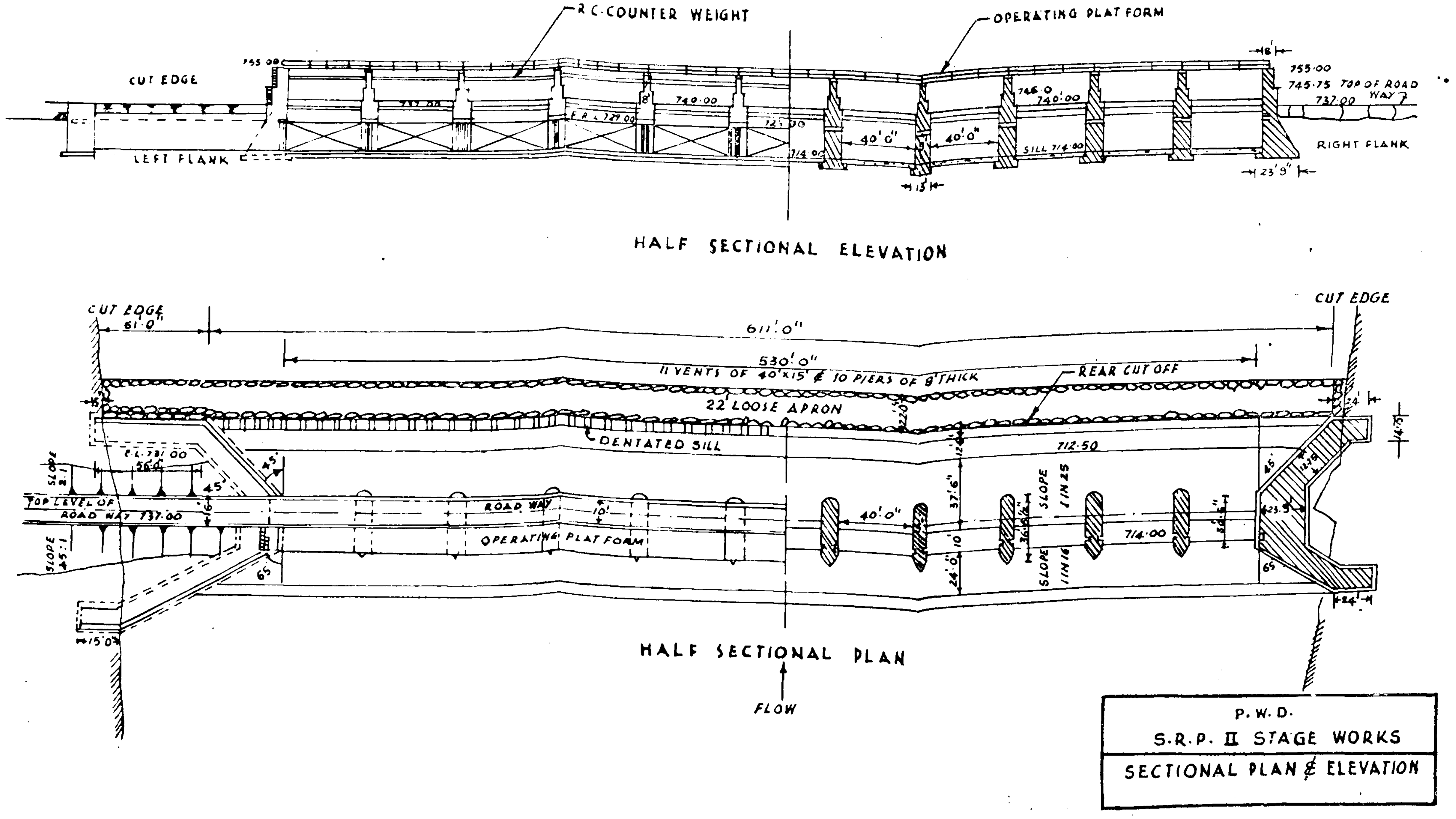
P.W.D
S.R.P. II STAGE WORKS
GENERAL PLAN
SCALE: 1" = 500'

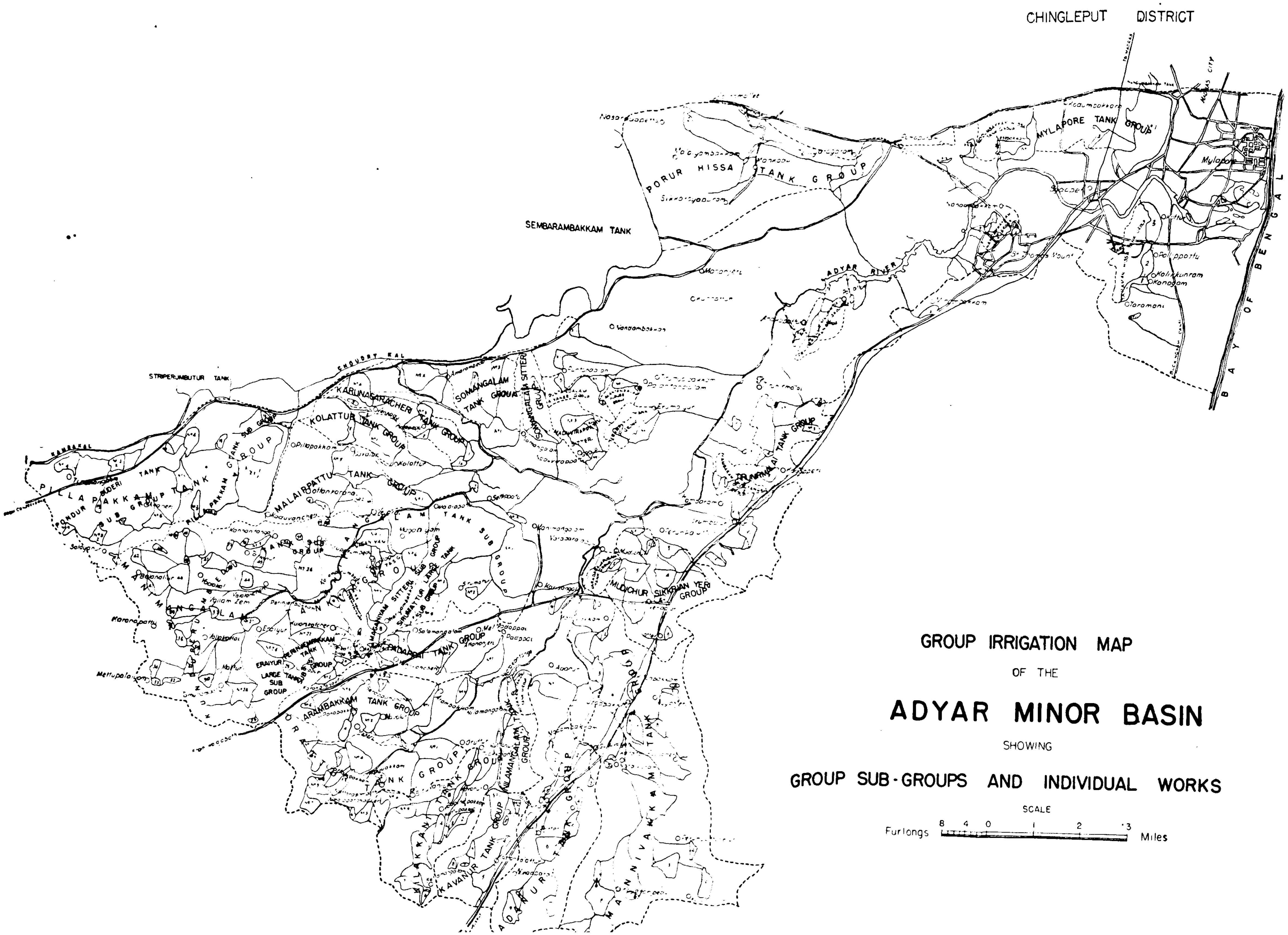


TYPICAL SECTION WHERE HARD ROCK IS AVAILABLE AT 714.00
SCALE: 1" = 16'0"

P.W.D
S.R.P II STAGE WORKS
CROSS SECTION OF REGULATOR
TYPICAL SECTION
SCALE: 1" = 16'0"


P.W.D
S.R.P II STAGE WORKS
TYPICAL SECTION
SCALE: 1"=16'0"
TYPICAL SECTION WHERE HARD ROCK IS AVAILABLE BELOW 710.00
LOOSE APRON
HARD ROCK LEVEL
DENTATED SILL
WEARING COAT OF 6" THICK C.C. 1:2:4
C.C. 1:3:6
SOFT ROCK El 710.00
TEE BEAM 18"X35"
El 737.00
El. 731.00
El. 729.00
LIFT GATE 40'X15'
SILL
SILL BEAM
El 714.00
HARD ROCK LEVEL
SEGMENTAL CUT WATER
R.C. COUNTER WEIGHT
El 755.00
El 732.00
F.R.L & M.W.L El 729.00
El. 712.50
FLOW
94'0"


R.C. COUNTER WEIGHT
OPERATING PLAT FORM
CUT EDGE
LEFT FLANK
RIGHT FLANK
745.75 TOP OF ROAD WAY
SILL 714.00
HALF SECTIONAL ELEVATION
CUT EDGE
611'0"
530'0"
11 VENTS OF 40'X15' & 10 PIERS OF 8' THICK
REAR CUT OFF
22' LOOSE APRON
DENTATED SILL
712.50
TOP LEVEL OF ROAD WAY 737.00
ROAD WAY
OPERATING PLAT FORM
SLOPE 1 IN 25
SLOPE 1 IN 16
HALF SECTIONAL PLAN
FLOW
P.W.D.
S.R.P. II STAGE WORKS
SECTIONAL PLAN & ELEVATION



GROUP IRRIGATION MAP

OF THE

ADYAR MINOR BASIN

SHOWING

GROUP SUB-GROUPS AND INDIVIDUAL WORKS

SCALE

Furlongs 8 4 0 1 2 3 Miles

TANK SYSTEM OF SOUTH INDIA AS FLOOD MODERATORS

By

* Sri J. WALTER, B.A., B.E., M.I.E. (Colorado).

Abstract :

Floods are among the earliest of human experiences. Floods of considerable magnitude periodically visit various parts of our country. Flood control measures are being taken by the Central and State organisations. Short term and long term plans have been formulated to effectively control the floods step by step. Normally flood control measures are associated with the construction of big flood control or flood moderating reservoirs raising and strengthening flood banks, etc. Some flood control measures are also thought of, in clearing supply channels and desilting tanks. This article deals with one of the generally considered as less important measure of improving tanks to control floods. Partly, it may come under land management practices as well in view of the fact that some neglected tank beds are unscientifically developed for agricultural purposes or for housing schemes. One may feel that the scope of such flood control measure is very limited. The author has given an example to illustrate the importance of paying attention to the flood controlling capacity of a tank system and has suggested some measures for serious considerations.

2. In South India, especially in Madras State the tank system of irrigation forms the backbone of our economy even after having completed all the major projects. These tanks are found in every district of the State and in large numbers in Chingleput, South Arcot, North Arcot and Ramanathapuram districts. Most of these tanks are ancient works, brought into being by our benevolent rulers of the past, for the benefit of their people. Though these tanks were mainly meant for irrigation, the part they have played in the prevention of floods of minimising the damage that would have caused by them over these years cannot be over emphasised. It can be said that these tanks have more than repaid their capital cost by the savings caused to the State by the prevention of floods alone.

3. Madras State is mostly dry as the rainfall is scanty and not dependable. Therefore it was necessary for the people of the past to construct these tanks and store water for their needs all the year round. For this the gradually sloping terrain is most suited. Basins were selected as per site conditions and were bunded up at the lower end to collect the water that had come from higher reaches. These tanks submerge many acres of lands as they are mostly shallow but in a country where land had no value without water, it was a practical and useful compromise. In certain parts of Madras State even up to 60 per cent of land area is made up of tank beds.

4. Tanks are small storage works generally so called in South India, but a few exceptionally of large sizes are referred to as reservoirs. There is no technical difference between them. The great majority of these tanks are of small depths less than 15 feet while some are as deep as holding 25 to 30 feet of water and in a few quite exceptional cases the maximum depth of water exceeded 35 feet.

5. These tanks are provided with sluices for irrigation. These sluices also act as surplus vents. There are various types of surplus works adopted in these tanks, chief of them being open weirs, weirs with shutters, flush escapes, regulators, sluices, etc. The surplus works are designed for the maximum flood discharge computed for

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the free and combined catchments of the tank concerned.

6. Most of the tanks in South India form part of groups of tanks and either receive the surplus of upper tanks or surplus into lower tanks or do both. A tank which neither receives water from an upper one nor discharges surplus into a lower tank is termed as Isolated Tank. In the group system considerable economy is effected as the surplus water of each tank and also the drainage of its wet cultivation are caught up by the next lower tank. Each tank of the group takes a share in the yield of the whole catchment above it which are classified as follows :—

(i) The "Free catchment" which is the area which only drains into the tank under consideration : and

(ii) The "Combined catchment" which is the area of the whole catchment above the tank.

7. The difference between the combined and the free catchment thus gives the area of catchment intercepted by upper tanks, the whole catchment of the highest tank on each drainage is free, each tank receives all the run off from its free catchment but from the remainder of its catchment only the balance which remains after the upper tanks have been filled.

8. The great objection to grouping tanks in this way is that a breach in an upper tank exposes all the tanks in the series below it to the risk of similar failures. It is thus important in taking up repairs and restoration to consider groups of tanks collectively as a whole and to carry out repairs from the upper end of each group. The danger to which lower tanks are subjected by breaching of upper ones is in proportion to their relative capacities. There is little danger to a tank of large capacity from a very small one breaching into it, although the breach may completely empty the small tank.

9. *Run-off and yield from catchment.*—The total approximate catchment of a basin taken up for study is about 200 square miles but the total combined catchment of all the groups is only 123.47 square miles. The average annual rainfall is 51 inches. Treating the catchment as average and the rainfall practically as of monsoon, depth of run off due to rainfall in inches per square mile is taken as 19.086 (*vide* Irrigation Manual by ELLIS) which gives a total yield of 200 × 44.342 = 8,868.4 m.c.ft. for the whole basin. The ayacut under each tank requires more than the total capacity of tank. As per the irrigation practice in vogue, the tanks go on replenishing the supplies as and when drawn, subject to certain local regulations. Approximately each tank receives about two fillings. The total capacity of all tanks making provision for tanks whose capacity is not known may be taken as 2,000 m.c.ft.

From column (3), statement II, it is found that the total requirement of water for crops is 3.868 m.c.ft. in an average year of well distributed rainfall, this quantity is usually received in the tanks. Therefore the balance quantity that goes to waste for the basin is only 5,000 m.c.ft. As about 43.6 per cent of yield is absorbed by the tanks the balance that goes to waste which when distributed over a period of 6 months from June to December as the tanks receive the supplies in two seasons, the south-west and north-east monsoon periods, the chances for any heavy floods are reduced considerably.

10. *Flood absorbing capacity.*—Almost all the tanks have their M.W.L. 1½ to 2 feet above F.T.L. (*vide* statement No. I). This provides the tank with a large flood absorbing capacity. As most of the tanks are shallow, the top 1½ to 2 feet capacity may even constitute 30 to 40 per cent of the total tank capacity. This large margin acts as a great flood moderator and has saved the region from great loss. Besides, these tanks which occupy a large percentage of the area of the basin, help to detain the flood waters in the event of a sudden flood even when the

tanks are full. As there are statistics, of village-war daily rainfalls, daily storage levels and discharge particulars, etc., it is not possible to study the exact behaviour of these tank systems and the extent to which they help in flood control. A systematic and a detailed study would be worthwhile. But for an approximate study and understanding of the problem we have chosen the Adyar Minor Basin which is one of the smallest in the Madras State.

11. *An example—Adyar Minor Basin.*—So called after the river of that name, lies in the Conjeevaram, Chingleput and Saidapet taluks of the Chingleput district. It covers an area of about 200 square miles and comprises all tanks draining into the river down to its out fall into the Bay of Bengal.

The irrigation works in this minor basin depend solely on the local rainfall, except a few of them situated lower down the valley which in addition get a supply from the river. The average annual rainfall in the basin is about 51 inches.

The discharge from catchment areas in minor basin is calculated from the formula $Q = CM^{\frac{2}{3}} - cm^{\frac{2}{3}}$ where C (as a working coefficient) being taken as 500 and that of c as 100, for the area of basins of upper tanks, which operate as moderators of flood discharges.

In the minor basin there are 238 irrigation works of which 202 belong to Government and the remaining 36 are private works. These works have been arranged for professional treatment into 30 groups and 19 isolated works. A statement giving the names of tanks, name of groups, hydraulic particulars, etc., with a map showing the various tanks is enclosed for information. In statement II, the abstract of totals of catchment areas, capacities, etc., is given.

12. Though many of the tanks in the basin have been "investigated", all the particulars required for assessing the flood control effect of the system are not available, viz., water spread area of tank, capacities at different contours, catchment areas, etc. Therefore only an approximate idea can be obtained from the data available.

Taking Orattur group, item VIII in the statement II, the total catchment is 5·17 square miles. A maximum rainfall of 12 inches in 24 hours is assumed for a wet catchment when all the tanks are full at F.T.L. assuming 30 per cent capacity between F.T.L. and M.W.L. the total flood absorbing capacity of the group will be 24;717 m.c.ft. Assuring 70 per cent run off, the total yield will be $\frac{5·17 \times 5280 \times 5280 \times 0·7 \times 12}{1,000,000 \qquad 12} = 100·9$ m.c.ft. The available flood absorbing capacity is 24;717 m.c.ft. which is 24 per cent of the total It is too much to expect all tanks to be full and expect the heaviest rainfall but in case it happens, the capacity of a large area of water spread to act as a delaying agent of the rushing water also cannot be littled. In actual practice, as the rain is of a intermittent character the tanks get filled up one by one and as there is regular supply of water for irrigation, the water in all the tanks will not be at F.T.L. throughout.

In actual practice, the system of regulation in these tank irrigation systems is complicated and varies from place to place. There are no elaborate flood regulating regulations for these tanks. Water is allowed to surplus from one tank into the other and only when the lowest tank in the group gets filled up and the major part of the monsoon is over, attempts are made to store water up to M.W.L. But this is seldom achieved in practice. The details furnished for the tanks in Adyar Minor Basin were for conditions about 40 years back. Since then, many of the tanks have considerably silted and a few tanks nearer the City have gone out of existence to make room for the growing Madras City.

But the Adyar Basin was taken up for study as it is one of the smallest and compact one to demonstrate how the tank system of irrigation in South India has incidentally saved quite often the region from recurring floods though this fact is seldom realised or understood.

Conclusion :

The importance of paying attention to tanks has been illustrated very vividly with calculations. As the maintenance and improvement of tanks fall in the hands of lower level organisations and branches of irrigation and other departments, scientific analysis of the flood control potential of tank system has not been taken up in a unified manner practically. Organised desilting of several tanks and their supply channels has not been taken up for many decades. Raising and strengthening bunds and improving and controlling the surplus arrangements of all tanks are of paramount importance. Shallow tank beds near towns and cities are encroached or reclaimed for raising building, etc., blissfully forgetting the loss of flood control potential thereby. Statistics may be taken of tanks and tank beds which have been invaded by agriculturists, industrialists and building schemes during the past century to assess the loss of flood storage. We may not be sorry for what has been lost but we can make up by improving and protecting the existing tanks by strengthening bunds, desilting, etc. Tanks are even to-day comparatively less looked after than any other works. This paper indicates that diverting a part of our attention more seriously on the innumerable tanks can bring about as much benefit as the glamorous schemes to build a few modern dams which are necessary even otherwise. This can be appreciated by the fact that in one of the districts in Madras State 60 per cent of the area of part of the district is occupied by tanks. Such tank infested tracks of land will be found in other parts of India as well.

In a system of tanks surplus from one tank falls into another. So also, a breach of one tank brings about a breach in another. Attention is therefore drawn to prevent the chain reactions which result in a deluge because eventually they flow into the river channels which make themselves to be known as floods of consequence as generally understood. While the author do not claim that attention to tanks and land practices in areas occupied by the existing and obsolete tanks is the last word to flood control it is claimed that if properly investigated, scrupulously tackled and diligently pursued, statistically it can be proved that by proper land practices and management a great flood control potential can be found in our innumerable tanks.

STATEMENT I

"DESCRIPTIVE MEMOIRS OF IRRIGATION WORKS IN THE ADYAR MINOR BASIN"
"STATEMENT OF THE HYDRAULIC DETAILS OF TANKS IN THE ADYAR MINOR BASIN."

Number in group.	Name of tank.	Coefficient. C =	Catchment Basin (in square miles.) Free.	Combined.	Approximate capacity of tank at F.T.L. in m. c.ft.	Total annual storage required in m. c.ft.	Levels with reference to B. Ms. F.T.L.	M.W.L.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
I.	*Manimangalam Tank Group*—							
1	Manimangalam Tank	500 and 100	7·44	27·63	225·39	338·08	42·00	44·00
1-A.	Melakalani Tangal	500	0·035	0·035	3,50	7,00	38·45	39·45
2	Sirumathur Sitteri	500	0·30	0·30	4·39	8·78	44·75	46·00
3	Sirumathur large tank ..	500 and 100	0·92	1·23	15·18	30·37	43·50	45·00
	Salamangalam reddi Tangal ..	500	0·15	0·15	0·61	1·22	46·00	47·00
5	Do. Komman Tangal	500	0·16	0·16	1·66	5·00	47·50	48·50
6	Maganiyam Sitteri	500 and 100	0·97	2·06	25·57	51·15	44·25	46·00
7	Alagur large tank	500 and 100	0·67	1·09	7·47	22·42	45·50	47·00
8	Neriyambakkam tank ..	500 and 100	0·31	0·42	4·29	8·58	47·00	48·50
9	Kavalkalani Kalanjeri tangal ..	500 and 100	0·07	0·11	0·33	1·34	48·00	49·00
10	Sudai Kuttai	500	0·04	0·04	0·428	1·71	49·25	50·00

Number in group.	Name of tank.	Coefficient. C =	Catchment Basin (in square miles.) Free.	Combined.	Approximate capacity of tank at F.T.L. in m. c.ft.	Total annual storage required in m.c.ft.	Levels with reference to B.Ms. F.T.L.	M.W.L.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
I.	*Manimangalam Tank Group*—cont.							
11	Magamiyarm large tank ..	500 and 100	0·72	0·81	18·54	27·82	45·00	46·50
12	Alagar tangal	500	0·09	0·09	0·228	1·82	46·00	47·00
13	Paracheri tangal	Not taken up.						
14	Kunduperumbedu Komman tangal.	500 and 100	0·09	0·20	0·61	1·83	46·50	47·50
15	Nallaperumbudu tank	500	0·11	0·11	0·539	1·61	47·50	48·50
16	Perinjempakkam madateri ..	Not taken up.						
17	Kulankatcheri large tank ..	500 and 100	0·35	0·67	8·78	17·56	48.50	50·00
18	Kulankatcheri tangal	500	0·05	0·05	0·34	1·37	48·75	50·00
19	Kavalkalani pudu tangal ..	500	0·05	0·05	0·37	1·85	49·35	50·60
20	Kavalkalani tank	500 and 100	0·10	0·22	1·59	6·36	49·34	50·34
21	Karanai tangal tank	500	0·12	0·12	3.26	8·15	50·50	51·50
22	Perinjambakkam tank ..	500 and 100	0·62	0·83	17·66	35·32	46·84	48·34
23	Vaippur Sitteri ..	These being private works were not investigated.						
24	Eraiyur large tank ..							
25	Vaippur large tank ..							
26	Kunduperumbedu tank ..	500 and 100	2.86	13·13	51·84	77·76	46·00	47·25
27	Eraiyur thevaleri	This being private work was not investigated.						
28	Mattur tank	500 and 100	1·05	1·20	21·80	43·60	48·00	49·50
29	Mattur Sitteri	500	0·15	0·15	0·566	2·26	48·70	49·70
30	Jamunampattu large tank ..	Private work. Not investigated.						
31	Vallakottai Maveri	Private work. Not investigated.						
32	Buderi	500 and 100	0·24	0·39	2·75	4·50	47·91	49·41
33	Rokkanna tangalj	500	0·15	0·15	1·60	2·00	48·47	49·97
34	Mettupalayam Sitteri	500	0·25	0·25	3·82	7·64	48·75	50·25
35	Vallakottai alleri ..	Private works. Not investigated.						
36	Vallakottai Sundaleri ..							
37	Vallam Sitteri							
38	Karanapattu tank ..							
39	Periyan tangal tank ..							
40	Vallam tank							
41	Balanallur tumpa tangal							
42	Balanallur large tank ..							
43	Papukana tangal ..							
44	Valatancheri tank	500	0·57	0·57	8·066	12·09	46·50	48·00
45	Tattanur tank	Private works. Not investigated.						
46	Oddai tangal							
47	Sirukalattur tank	500 and 100	0·44	0.81	4·50	9·00	47·95	49·45
48	Vadakal Vannar tangal	Private works. Not investigated.						
49	Pettunayakam tangal ..							
50	Oddan tangal							
51	Kannan tangal large tank							
52	Nallatanni tangal ..							
53	Maun tangal							
54	Kannan tangal							
55	Kunduperumbedu Raja tangal.	500	0·03	0·03	0·118	0·775	47·00	48·00
56	Kunduperumbedu Reddi tangal.	500 and 100	0·04	0·14	0·317	1·26	44·25	45·25
57	Kunduperumbedu Vannar tangal.	500	0·10	0·10	0·137	0·418	48·50	49·50
II.	*Malippattu Tank Group* —							
1	Malippattu tank	500 and 100	1·39	4·60	14·00	28·00	43·73	44.73
2	Velleri tank	500 and 100	0·77	3·21	13·00	26·00	43·00	44·50
3	Ottankaranai tank ..	Private works. Not investigated.						
4	Ottankaranai Tangal ..							
5	Navalur large tank	500	2·05	2·05	12·44	24·86	44·50	46·25
III.	*Pillapakkam Tank Group*—							
1	Pillapakkam tank	500 and 100	3·82	11·19	122·04	183·06	46·59	48·59
2	Pondur odda tangal	500 and 100	0·09	0·39	0·39	1·17	47·00	48·50
3	Pondur Sitteri	500	0·30	0·30	3·26	8·00	47·50	49·00
4	Pondur Boderi tank	(Palar anicut system)						
5	Pondur large tank	500 and 100	0·90	3·00	15·00	30·00	47·25	49·25

Number in group. (1)	Name of tank. (2)	Coefficient. C= (3)	Catchment Basin (in square miles.) Free. (4)	Combined. (5)	Approximate capacity of tank at F.T.L. in m. c.ft. (6)	Total annual Storage required in m. c.ft. (7)	Levels with reference to B.Ms. F.T.L. (8)	M.W.L. (9)
III. Pillappakam Tank Group.—cont.								
6	Araneri large tank	500 and 100	1·11	2·06	12·70	19·00	47·75	49·50
7	Salayanur Sitteri	Private works. Not investigated.						
8	Salayanur tank							
9	Sirumankadu tangal	500	0·15	0·15	1·77	3·54	50·00	51·00
10	Araneri Naga tangal	500	0·16	0·16	0·75	2·25	48·39	49·89
11	Irunkulam	500	0·16	0·16	1·43	4·50	47·25	48·75
12	Mambakkam tank	Private works. Not investigated.						
13	Mambakkam Sitteri							
14	Tirumangalam tank	500	0·58	0·58	14·80	22·20	48·73	49·73
15	Pondur Vettukuttai tangal	500	0·09	0·09	0·74	1·48	46·75	47·75
16	Kanchupattu tangal	500	0·17	0·17	1·57	4·71	46·00	47·00
IV. Kolattur Tank Group—								
1	Kolattur tank	500 and 100	1·24	1·75	37·60	79·00	40·00	41·50
2	Navalur tangal	500	0·48	0·48	3·55	14·20	41·00	42·50
3	Nallatanni tangal	500	0·03	0·03	0·45	1·35	41·75	42·75
V. Karunagaracheri Tank Group :—								
1	Karunagaracheri tank	500 and 100	0·57	1·62	2·57	10·28	36·00	37·25
1A	Karunagaracheri Achukattu tangal	Not taken up.						
2	Then tangal	Private works. Not investigated.						
3	Irumbedu tank							
4	Venkadu tank	500 and 100	0·51	0·55	22·50	45·00	44·25	45·25
5	Venkadu Ichan tangal	500	0·04	0·04	0·09	0·27	45·00	46·00
VI. Padappai Tank Group—.								
1	Padappai tank	500 and 100	1·64	3·37	35·12	69·86	42·62	44·12
2	Attananjeri tank	500 and 100	1·03	1·73	13·50	27·60	45·00	46·25
3	Salamangalam large tank	500 and 100	0·47	0·70	9·31	18·63	47·14	48·64
4	Nochili tangal	500 and 100	0·02	0·23	0·35	1·40	48·50	49·50
5	Vanjivancheri large tank	500	0·21	0·21	4·40	8·80	48·70	49·70
VII. Arambakkam Tank Group—								
1	Arambakkam tank	500 and 100	1·21	1·41	20·71	41·42	47·00	48·00
2	Navalur tank	500 and 100	0·57	2·22	12·59	25·18	47·90	49·40
3	Nemmeli tangal	Not taken up.						
4	Moseri tank	500	0·37	0·37	4·13	12·41	48·50	49·50
5	Serappananacheri large tank	500	0·70	1·10	17·80	26·70	48·79	50·29
6	Panapakkam tank	500	0·45	0·45	4·79	14·38	49·80	50·80
7	Velleri tangal tank	500 and 100	0·14	0·20	1·20	6·65	48·09	49·09
8	Porateri tangal	500	0·04	0·04	0·27	1·08	48·60	49·60
9	Pudu tangal	500	0·02	0·02	0·14	0·56	48·55	49·05
VIII. Orattur Tank Group—								
1	Orattur tank	500 and 100	1·78	5·17	31·4	62·80	48·00	49·50
1A.	Tiamarakarai tangal	500	0·04	0·04	0·19	1·14	48·70	49·70
2	Nattarasampathu sitteri	500 add 100	0·20	0·36	3·01	9·33	49·25	50·50
3	Rettapallam tank	500	0·16	0·16	2·24	4·48	50·00	50·00
4	Kanjivakkam tank	500 and 100	0·93	2·99	15·01	30·02	49·00	50·50
5	Punthottathu yeri	500 and 100	0·32	0·83	6·07	9·12	52·00	53·25
6	Nattapallam yeri	500	0·08	0·08	0·74	1·488	53·00	54·00
7	Umayaparanacheri large tank	500	0·43	0·43	8·83	22·08	56·00	57·50
8	Putteri	500 and 100	0·11	0·65	2·09	6·27	51·00	52·00
9	Vettambakkam large tank	500	0·54	0·54	6·98	10·48	52·00	53·50
10	Pulicheri	500	0·23	0·23	0·82	3·28	49·59	50·59
11	Katteri	500	0·35	0·35	5·01	10·02	52·65	53·65
IX. Kilakkalani Tank Group—								
1	Kilakkalani tank	500 and 100	0·59	4·03	9·02	27·06	52·00	53·50
2	Kattupakkam tank	500	0·36	0·36	5·19	10·39	53·00	54·50
3	Sitteri	500	0·02	0·02	1·33	3·99	49·36	50·36
4	Vedamelpakkam tank	500 and 100	0·29	1·62	6·36	12·72	56·50	58·00

Number in group. (1)	Name of tank. (2)	Co-efficient. C= (3)	Catchment basin (in square miles). Free. (4)	Combined. (5)	Approximate capacity of tank at F.T.L. in m.c.ft. (6)	Total annual Storage required in m.c.ft. (7)	Levels with reference to B.Ms. F.T.L. (8)	M.W.L. (9)
IX. Kilakkalani Tank Group—cont.								
5	Siruvanjur katteri	500 and 100	0·93	1·33	27·90	34·80	62·50	63·75
6	Settamangalam tangal	500	0·10	0·10	1·88	3·76	68·00	69·00
7	Settamangalam tank	500	0·30	0·30	4·58	6·87	70·25	71·75
8	Erivakkam tank	500 and 100	0·53	1·44	5·19	10·38	53·25	54·75
9	Buderi	500	0·33	0·33	10·33	20·66	62·50	64·00
10	Siruvanjur large tank	500	0·58	0·58	12·68	19·02	59·53	61·03
X. Kavanur Tank Group—								
1	Kavanur tank	500 and 100	1·05	3·04	29·70	59·40	53·39	54·89
2	Konadi tank	500	0·13	0·13	2·56	3·84	53·50	54·50
3	Konadi tangal	500	0·16	0·16	0·273	1·365	53·48	54·48
4	Buderi	500 and 100	0.29	1·19	1·72	6·88	54·00	55·50
5	Kattankolattur large tank	500	0·9	0·9	23·88	35·82	55·25	56·50
6	Maruderi	500 and 100	0·17	0·51	1·90	3·80	54·40	55·90
7	Korakan tangal	Not taken up—insignificant.						
8	Korakan tangal tank	500	0·23	0·23	0·99	2·97	56·66	57·66
XI. Adanur Tank Group—								
1	Adanur tank	500 and 100	1·27	1·83	36·09	72·18	45·96	47·46
2	Guduvanjeri tank	500 and 100	1·30	5·00	8·02	24·06	52·44	53·94
3	Guduvanjeri tangal	500	0·10	0·10	0·595	1·79	57·37	58·37
4	Vallanjeri tank	Not taken up.						
5	Vallanjeri tangal	500	0·53	3·25	13·42	26·84	60 50	62·00
6	Potteri tank	500 and 100	1·49	2·72	26·02	52·04	60·99	62·49
7	Karai yeri	500	0·28	0·28	6·42	9·63	67·90	69·40
8	Ninnakarai sitteri	500 and 100	0·11	0·53	0·182	0·91	70·00	71·40
9	Ninaparai poria eari	500	0·84	0·84	14·00	21·00	72·50	74·00
10	Poetteri tangal	500	0·24	0·24	5·10	6·10	61·75	62·75
11	Madambakkan tangal	500 and 100	0·17	0·25	1·40	4·20	53·00	54·00
12	Madambakkam tank	500 and 100	0·51	0·56	15·94	25·41	48·00	49·50
13	Tailapuram tangal	500 and 100	0·06	0·13	0·175	0·88	52·00	53·00
14	Tailapuram tank	500	0·07	0·07	0·76	1·90	52·87	53·87
XII. Nilamangalam Tank Group—								
1	Nilamangalam tank	Private work—Not investigated.						
2	Kuttanur tank.	500	0·45	0·45	4·2	12·6	47·40	48·90
XIII. Korakantangal Tank Group.—								
1	Korakantangal tank	500 and 100	0·12	0·21	0·72	3·60	40·00	41·00
2	Korakantangal tank Kulam tangal	500	0·09	0·09	0·25	1·50	45·00	46·00
XIV. Manivakkam Tank Group—								
1	Manivakkam tank	500 and 100	2·18	14·98	23·69	47·40	40·50	42·00
2	Vottakaram tangal	500	0·26	0·26	0·70	3·50	41·50	42·75
3	Manivakkam Sitteri	—	—	—	—	—	—	—
4	Kilampakkam tank	500	0·56	0·56	14·52	9·68	41·05	42·55
5	Urappakkam tangal	500	0·11	0·11	1·24	3·10	45·50	46·50
6	Urappakkam Sitteri	500 and 100	0·02	0·02	0·76	3·80	47·50	48·50
7	Urappakkam tank	500	0·58	1·84	9·32	27·96	50·50	52·00
8	Karanai Pudacheri tank	500	0·93	1·26	4·27	10·68	52·50	54·25
9	Ayyanjeri tangal	500	0·33	0·33	1·55	7·55	53·56	54·56
10	Ayyanjeri tank	Not taken up.						
11	Karanai Puducheri tangal	500	0·24	0·24	1·35	5·40	55·25	56·50
12	Nandivaram hissa tank	500	4·62	8·99	59·70	179·10	57·20	59·20
13	Perimathunellur tank	500	1·02	1·67	15·43	30 86	58·50	60·00
14	Perimathunellur tangal	500 and 100	0·21	0·54	2·06	6·18	59·50	60·50
15	Kannivakkam tank	500	0·98	0·98	14·96	27·80	60·00	61·50
16	Kayarambedu tangal	500	0·21	0·21	1·74	2·61	60·17	61·42
17	Kayarambedu sitteri	Not taken up.						
18	Kayarambedu tank	500	1·72	1·95	35·24	46·99	60·36	61·86
18A	Gudalur Kambi tangal	500	0·23	0·23	1·33	2·66	154·70	154·70
19	Nandivaram tangal	500 and 100	0·05	0·16	0·55	2·20	57·60	58·60
20	Kandigai tangal	Not taken up.						

Number in group. (1)	Name of tank. (2)	Co-efficient. C= (3)	Catchment basin (in square miles). Free. (4)	Combined. (5)	Approximate capacity of tank at F.T.L. in m.c.ft. (6)	Total annual Storage required in m.c.ft. (7)	Levels with reference to B.Ms. F.T.L. (8)	M.W.L. (9)
XV. Mudichur Sikkrian Yeri Group—								
1	Mudichur Sikkrian yeri	500 and 100	0·49	4·03	1·64	8·20	40·50	41·50
2	Rangupuram tank	500 and 100	0·10	1·40	0·95	2·85	45·50	47·00
3	Perunkulathur sitteri	500 and 100	0·64	1·32	18·76	37·50	51·50	53·00
4	Perunkulathur tank	500	0·68	0·68	15·30	23·00	47·00	48·50
5	Mudichur tank	500 and 100	0·80	2·15	20·55	41·10	45·90	47·40
6	Vendalur tangal	500	0·19	0·19	0·83	3·30	49·00	50,00
7	Vendalur Tank	500 and 100	0·81	1·16	4·36	13·83	52·75	54·75
8	Vendalur Otteri	100	0·35	0·35	2·22	6·66	54·00	55·00
XVI. Varadarajapuram Tank Group—								
1	Varadarajapuram tank ..	500 and 100	0·44	0·48	3·20	19·20	38·50	40·00
2	Sanan tangal	100	0·04	0·04	0,58	1·16	39·00	46·00
XVII. Tambaram Pudu Tangal Group -								
1	Tambaram pudu Tangal ..	500 and 100	0·17	0·38	2·77	8·31	32·25	33·75
2	Tambaram Yetti tangal ..	500 and 100	0·05	0·21	0·21	1·05	35·40	36·40
3	Tambaram Vannan yeri ..	500	0·16	0·16	2·06	5·15	36·50	38·00
XVIII. Tirunirmalai Tank Group—								
1	Tirunirmalai tank and Sitteri ..	500 and 100	1·20	2·30	24·29	68·62	29·10	31·10
2	Pammal tangal	Private work—Not investigated.						
3	Viraraghavan yeri	500	0·26	0·26	5·31	10·62	32·20	33·20
4	Kadapperi	500 and 100	0·47	0·77	1·33	5·44	42·90	44·40
5	Hissa Putteri	500	0·60	0·60	11·22	16·80	48·00	49·50
XIX. Somangalam Tank Group—								
1	Somangalam tank	500 and 100	1·47	2·34	43·39	86·78	34·00	35·50
2	Sakkili tangal	500	0·33	0·33	0·98	4·90	43·50	44·25
3	Nallur tank	500	0·54	0·54	7·45	14·90	40·80	42·30
XX. Somangalam Sitteri Tank Group—								
1	Somangalam Sitteri	500 and 100	0·79	1·25	11·74	23·48	34·00	35·50
2	Melattur tank	500	0·46	0·46	4·36	13·08	35·50	36·75
XXI. Naduvirappattu Sitteri Group—								
1	Naduvirappattu sitteri	500 and 100	0·65	1·49	3·42	13·68	30·50	32·00
2	Nadu tangal	500	0·84	0·84	19·17	28·80	39·25	40·75
3	Naduvirappattu tank ..							
XXII. Erumaiyur Tank Group—								
1.	Erumaiyur tank	500 and 100	0·41	0·50	10·48	20·96	34·50	36·00
2.	Erumaiyur Tumman tangal ..	500	0·09	0·09	1·72	3·44	36·50	37·50
XXIII. Palantandalam Pudu Yeri Group—								
1.	Palantandalam Pudu yeri ..	500 and 100	0·25	0·39	3·23	6·46	37·00	38·50
2.	Vannan Kuttai	500	0·14	0·14	0·76	3·80	37·25	38·25
XXIV. Puntandalam Aiyaneri Group—								
1.	Puntandalam Aiyaneri	500 and 100	0·38	0·83	6·34	20·50	36·88	38·63
2.	Naduvirappattu tangal ..	500	0·11	0·11	0·45	1·80	42·00	43·00
3.	Puntandalam sitteri	500	0·34	0·34	3·82	7·64	47·85	49·35
XXV. Polichanallur Melandai Tangal Group—								
1	Polichanallur Melandai tangal ..	500 and 100	0·49	0·69	1·48	2·96	33·30	34·80
2	Perari tangal	500	0·02	0·02	0·46	0·92	33·30	34·80
3	Velarkani Serar tangal	Not taken up—Insignificant.						
4	Otteri	500	0·18	0·18	2·88	7·20	40·00	41·00

Number in group. (1)	Name of tank. (2)	Co-efficient. C= (3)	Catchment basin (in square miles.) Free. (4)	Combined. (5)	Approximate capacity of tank at F.T.L. in m.c.ft. (6)	Total annual Storage required in m.C.ft. (7)	Levels with reference to B.Ms. F.T.L. (8)	M.W.L. (9)
XXVI. Mylapore Tank Group—								
1	Mylapore tank	500 and 100	2·81	3·61	122·03	183·05	21·80	23·30
2	Mambalam tank	Private work—Not investigated.						
XXVII. Taramani Hissa Tank Group—								
1	Taramani Hissa tank	500	0·47	0·47	6·82	20·46	15·58	17·58
2	Pallipattu tank	500	0·26	0·26	8·98	17·96	18·50	19·50
3	Kottur tank	500	0·71	0·71	13·89	27·78	19·00	20·00
XXVIII. Kodambakkam Hissa Tank Group—								
1	Kodambakkam Hissa tank ..	500 and 100	1·42	1·62	14·07	58·16	33·25	34·25
2	Nesapakkam tank	500	0·20	0·20	0·26	1·30	36·75	38·00
XXIX. Porur Hissa tank—								
1	Porur Hissa tank	500 and 100	8·46	8·74	33·60	100·80	40·70	42·70
2	Mappattu vattur tangal ..	500	0·28	0·28	2·14	5·35	54·80	55·80
XXX. Nandambakkam Tank Group—								
1	Nandambakkam tank	500 and 100	0·31	0·48	1·33	5·32	34·96	36·21
2	Nandambakkam tangal ..	500	0·17	0·17	0·64	2·56	37·60	38·60
XXXI. Isolated Works—								
1	Settupattu tangal	500	0·27	0·27	2·42	9·20	30·50	32·00
2	Ammanambakkam large tank ..	Private work —Not investigated.						
3	Tandakalani tangal	500	0·20	0·20	1·60	4·80	35·00	36·00
4	Vumara tangal	500	0·10	0·10	0·28	1·68	38·50	39·50
5	Tambaram tank	500	0·36	0·36	4·70	14·10	38·33	39·83
6	Irumbuliyur tank	500	0·81	0·81	12·53	25·06	40·50	42·00
7	Pirkankaranai tank	500	0·30	0·30	4·49	8·98	36·00	37·00
8	Ninayeri	500	0·17	0·17	2·62	5·24	27·50	28·50
9	Pullikoradu Jadamaneri ..	500	0·19	0·19	0·65	3·25	34·60	35·60
10	Amarambedu tank	500	0·53	0·53	36·70	73·40	43·00	44·50
11	Puntandalam large tank ..	500	0·54	0·54	7·14	14·28	47·85	49·35
12	Nandambakkam tank	500	0·28	0·28	2·99	7·47	46·00	48·00
13	Minambakkam tank	500	0·32	0·32	2·87	10·96	38·50	39·50
14	Songal tangal	500	0·04	0·04	0·19	0·95	35·00	36·00
15	Nallarkulam tangal	500	0·04	0·04	0·41	1·23	29·50	30·50
16	Anakaputtur Kalmadugu tangal.	500	0·16	0·16	1·93	5·79	42·50	43·50
17	Taramani tangal..	500	0·07	0·07	0·11	0·56	10·00	11·00
18	Ramapuram Pallan tangal ..	500	0·19	0·19	1·04	4·16	40·50	41·50
19	Ramapuram Pudu tangal ..	500	0·09	0·69	0·25	1·25	39·00	40·00

STATEMENT II.

" DESCRIPTIVE MEMOIRS OF IRRIGATION WORKS IN THE ADYAR MINOR BASIN "

" STATEMENT OF THE HYDRAULIC DETAILS OF TANKS IN THE ADYAR MINOR BASIN "

Serial number.	*Name of tank group.*	*Total combined catchment of groups in square miles.*	*Approximate capacity of tank at F.T.L. in m. c. ft.*	*Total annual Storage required in m. c. ft.*	*Remarks.*
(1)	(2)	(3)	(4)	(5)	(6)
1.	Manimangalam	27·63	436·24	740·64	
2.	Malippattu	4·60	39·44	78·86	
3.	Pillapakkam	11·19	174·45	279·99	
4.	Kolattur	1·75	41·60	94·55	
5.	Karunagarachari	1·62	25·16	55·55	
6.	Padappai	3·37	62·68	125·69	
7.	Arambakkam	1·41	62·33	128·38	
8.	Orattur	5·17	82·39	170·20	
9.	Kilakkalani	4·03	84·46	149·65	
10.	Kavanur	3·04	61·02	114·07	
11.	Adanur	6·97	128·12	246·94	
12.	Nilamangalam	0·45	4·20	12·60	
13.	Korakantangal	0·21	0·97	5·10	
14.	Manivakkam	14·98	188·41	417·47	
15.	Mudichur Sikkrian	4·03	64·61	136·44	
16.	Varadarajapuram	2·30	3·78	20·36	
17.	Tambaram Pudu Tangal	0·38	5·04	14·51	
18.	Tirunirmalai	2·30	42·20	101·48	
19.	Somangalam	2·34	51·82	106·58	
20.	Somangalam Sitteri	1.25	16·10	36·56	
21.	Naduvirappattu Sitteri	1·49	22·59	42·48	
22.	Erumaiyur	0·50	12·20	24·40	
23.	Palantandalam Puduyeri	0·39	3·99	10·26	
24.	Puntandalam Aiyaneri	0·83	11·11	29·94	
25.	Polichallur melandai	0·69	4·82	11·08	
26.	Mylapore	3·61	122·93	183·05	
27.	Taramani Hissa	1·44	29·69	66·29	
28.	Kodambakkam Hissa	1·62	14·33	59·46	
29.	Porur Hissa	8·71	35·74	106·15	
30.	Nandambakkam	0·48	1·97	7·88	
31.	Isolated works	4·66	82·92	192·36	
	Total ..	123·47	1,916·40	3,768,80	

TAMBRAPARANI IRRIGATION SYSTEM IN TIRUNELVELI DISTRICT.

BY

SRI D. I. PAUL, B. E., (Hons),

In Tamilnad, the Tambraparani is an important river and its importance is great as it is the chief source of irrigation in Tirunelveli district. It drains with its tributaries an area of about 1,750 square miles. From its source Peria Pothigai in Western Ghats up to its infall into the Gulf of Mannar, it runs for about 75 miles. Owing to its extensive catchment area in the Ghats it enjoys the full benefits of both the monsoons and its bed is never dry.

The chief tributaries to the river in the Ghats are the Peyar, Ullar, Kariar, Servalar and Pambar in the Government Forests. In the plains, the first tributary to join the river on the right side is Manimuthar. Next joins Varahanadhi, bringing down the combined supply of Ramanadhi and Jambunadhi. Both these tributaries are having their sources in the hills above Meladayam. The Gatananadhi into which flow the waters of KALLAR AND KARUMANIAR from Sivasailan hills. joins the Varahanadhi near Pappankulam and flows into Tambraparani on its left bank at Thiruppudiamarudur. The Pachaiyar carries the supply of Karumandiamman channel, and irrigates portions of Nanguneri and Tirunelveli taluks, before joining the river Tambraparani. The last tributary is Chittar which rises in the hills above Courtallam and joins Tambaraparani river near Sivalaperi village.

As most of the aforesaid tributaries have their origin in the hilly tracts, there will be heavy flood invariably in the river during north-east monsoon period. The early Rajahs of the south took pains to construct 7 anicuts across the river to provide irrigation facilities to vast areas of nearly 56,000 acres similar to Upper Anicut and Grand Anicut across the river Cauvery constructed for irrigating lands in the Tiruchi and Thanjavur districts respectively. The eighth anicut at Srivaikuntam was constructed much later in the year 1869 during the British days to serve an additional area of about 26,000 acres.

THE DETAILS OF THE ANICUTS ARE AS BELOW :—

	ACRES
1. Kodamelalagian Anicut—	
Length 1,084 ft.	
Crest level+262.86	
North Kodamelalagian channel at Left— Length-#M· 7 F ayacut	2,284.32
South Kodamelalagian channel at Right— Length 5 M 2F—ayacut	882·21
Total ayacut ..	3,166·53
Direct ayacut	2,226·53
Indirect ayacut	940·00
2. Nadhiyunni Anicut—	
Length 1,690 ft.	
Crest level+221·27	
Nadhiyunni channel at Left— Length 7 M2 F—ayacut	2,592·96
(NOTE.—There is no indirect ayacut under this channel)	
3. Kannadian Anicut—	
Length 1,700 ft.	
Crest Level+212.90	
Kannadian Channel at Right— Length 23 M of—ayacut	11,779·70
Direct ayacut	8,731·78
Indirect ayacut	3,047·92

* Superintending Engineer, P.W.D. Tirunelveli Circle, Tirunelveli.

	ACRES.
4. Ariyanayagipuram Anicut—	
Length 2,337 ft.	
Crest level+164·50	
Kodagan channel at Left— Length 15 M 4 F—ayacut	5,600·88
Direct ayacut	2,765·66
Indirect ayacut	2,835·22
5. Palavoor Anicut—	
Length 2,410 ft.	
Crest level +145·45	
Palayam channel at Right— Length 27 M of—ayacut	8,789·42
Direct ayacut	3,542.81
Indirect ayacut	5,246·61
6. Suthamalli Anicut—	
Length 2,731 ft.	
Crest level +138.50	
Tirunelveli Channel at left— Length 17 M 5 F—ayacut	6,325·60
Direct ayacut	2,058·59
Indirect ayacut	4,267·01

7. Marudur Anicut—

Length	4,097 ft.
Crest level	+77·30

	ACRES.
Marudur Melakal at Right— Length 13 M 1 F—ayacut.	10,009·61
Marudur Keelakkal at Left— Length 10 M-1 F—ayacut.	7,721·49
Total ..	17,731·10

Direct Ayacut ..	4,223·32
Indirect ayacut ..	13,507·78

8. Srivaikuntam Anicut—

	ACRES.
Length	1,380 ft.
Crest level	+39·40

	ACRES.
South Main channel at Right— Length 20 M 2 F 528 ft.—ayacut.	12,760 00
North Main channel at Left— Length 11 M 7 F 230 ft.—ayacut.	13,229·34
Total ..	25,989·34

The first 7 anicuts constructed by the early Rajahs show the admirable insight on the part of the poineering designers in the past. All the 7 anicuts are founded on rock, and consequently are zig zag in alignment. But a close observation of the alignment brings to light a very special features. Wherever only one channel takes off from an anicut, the alignment of the anicut across the stream is in the form of an inverted " L " one arm of the " L " across the river and the other arm parallel to the direction of flow so as to provide a leading approach waterway to the channel taking off from the anicut and also a straight entry of flow into the head sluice which is constructed at the lower end of this portion of the anicut. The scouring vents are located at right angles to this approach channel a few feet above the head sluice. The method of giving the direct approach to the supply channels and right angular entry into the scouring vent has been able to create proper curvature effect of flow in front of the head sluice into the scouring vent thus scouring away the heavier bed load of silt, keeping the channel mouth fairly silt free. Similarly, where two channels take off. the alignment of the anicut is in the form of an inverted " U ". Typical example of this type of anicut is Marudur.

On 93 per cent of the Tambaraparani ayacuts two crops are raised in all goods years. The richest lands, for instance, those lying on the upper reaches of Kannadian, Kodagan and Palayam channels, produce annually over two tons of rice per acre. Many of them bear the double crop assessment of Rs. 25·50.

The pattern of direct and indirect (under tank) ayacut under the various anicuts indicate natural utilisation of the river. The first two anicuts have very little indirect ayacut, i.e., ayacut irrigated through tanks. This enables utilising the steady continuous flows in the river under these two anicuts for direct irrigation of one or two crops as the case may be. But as we go lower down, the percentage of direct ayacut gets reduced and indirect ayacut gets increased

This is because only surplus of high floods will flow down the river and tanks are necessary to catch them and use for irrigation. On this basis, it is seen that tanks of very big capacity are constructed under the last anicut where practically the whole of the ayacut is indirect through tanks fed by the flood waters of the river.

All the channels that take off from these anicuts are typical contour channels with irrigation only on one side of the channel, i.e., the river side. An important feature of the alignment of these channels is that the drainage from the upper channels and high level areas falls into channels and tanks taking off from the anicuts below. By this arrangement, all the drainage water from the upper areas is caught and utilised again without wasting any quantity of water at any stage.

The chief crop raised is paddy which is regularly irrigated by the north-east and south-west monsoons. The period of the former is from September to February and the crop (usually long-term) raised during this season is named as " Pishanam " crop and the crop cultivated during the south-west monsoon June 1st to August 31st is called " Kar crop " (Usually short-term). Out of the total ayacut of 81,975·33 acres under Tambaraparani system, 70,469.64 acres are double crop and the balance single crop or water rate lands.

Under the last two anicuts a peculiar crop called " Advance Kar crop " is raised from April to August (in place of the regular Kar crop) with the help of summer flows in the river and also the power issues from the Papanasam Power House for irrigation, which are not utilised by the upper channels during April and May when they are closed for attending to annual maintenance works.

Before construction of Papanasam Reservoir across Tambraparani river, advance Kar crop was used to be raised in limited areas not exceeding 8,600 acres of double crop wet lands under the channels of the last anicut, viz.. Srivaikuntam Anicut, due to the limited availability of summer flows in the river. After construction of the Papanasam Power House in 1944, there has been steady and dependable release of increased quantity of water (about 100 to 200 cusecs) which is available for irrigation under the tail end of Tambraparani river, besides the already available variable and limited quantity of summer flows in the river. This has enabled more area to be cultivated with advance Kar crops. About 27,000 acres are being cultivated in good years and about 24,000 acres in normal years.

In order to utilise the increased availability of flow in the river during summer, preference was given in G.O. No. 1418, P.W.D., dated 20th April 1949 (as a Grow More Food campaign) to authorise the single crop and water rate lands (which are normally to be irrigated during Pishanam Season alone) to be cultivated with advance Kar crops. But the availability of water is not sufficient to irrigate the entire extent under the four channels of the last two anicuts. Hence a turn system was introduced in the above said Government Order, dated 20th April 1949 to authorise the area under the left and right side channels of these two anicuts in alternate years respectively. But this turn system as well as the question of giving preference to single and double crop lands could not work permanently due to the claim of double crop land owners under both side channels of Srivaikuntam anicut who were enjoying cultivation of Advance Kar crops by utilising spring flows of the river in summar. Hence localisation of areas for advance Kar cultivation on a permanent principle is being examined by Government.

No regular ' Kar crop ' will be raised in the lands where ' Advance Kar crop ' has been raised. Thus this system of cultivating ' Advance Kar ' helps to spread over the period of cultivation of the short-term crop according to the available supply. This eases the situation to a great extent especially at the fag end of the crop period, when the supply position is critical as the advance Kar crops would be 'off' the ground by this time and hence there will be no need to supply water to these.

The Papanasam Reservoir.

The Papanasam Reservoir across the Tambraparani has been constructed and brought into operation in the year 1944, with the primary object of developing Hydro-Electric Power. But the basis of impounding the surplus waters in a reservoir like this across the Tambraparani takes definitely into consideration the irrigation needs. The Papanasam Dam has a full capacity of 5,500 M.cft. Water is drawn from it through two pipes of 8 feet 6 inches diameter each. A diversion weir has been constructed lower down the river near the head of Papanasam Falls just before the confluence with the Servalar river. Water is let down to the power house through penstock pipes. The gross head available for development of power is 350 feet and three generators of 9,000 Horse power each capable of developing power of 28,000 kilo watts have been installed in the Power House.

Since this reservoir has been built more for development of power, the water that is available at the end of the irrigation season in March is utilised for development of power during the summer months. This quantity flowing down the river is utilised since the year 1945 to cultivate what is called "Advanced Kar" similar to "Palantholi". Every year definite areas are thrown open for advanced Kar depending upon the flow in the river and the additional flow expected to be released from the Papanasam for development of Power.

Manimuthar river.

Manimuthar is the principal tributary of the Tambraparani river. Since there has been surplus in the river over the Srivaikuntam anicut even after the construction of the Papanasam Dam and also there was acute shortage of water at the fag end of the irrigation season especially under the anicuts lower down, the necessity for the construction of another Dam was felt to impound the surplus waters. Therefore, the construction of the Manimuthar dam and reservoir with a capacity of 5,500 M.cft. was taken up and completed in January 1958. Water is drawn from this reservoir for supplying to the Tambraparani ayacut through four river sluices each of size 5 feet by 6 feet. In addition to catering to the needs of the existing ayacut, the Manimuthar Reservoir is intended to provide irrigation facilities for an additional area of 20,500 acres all indirect, under tanks in Ambasamudram, Tirunelveli, Srivaikuntam, Tiruchendur and Nanguneri taluks under the newly constructed Manimuthar High Level canal.

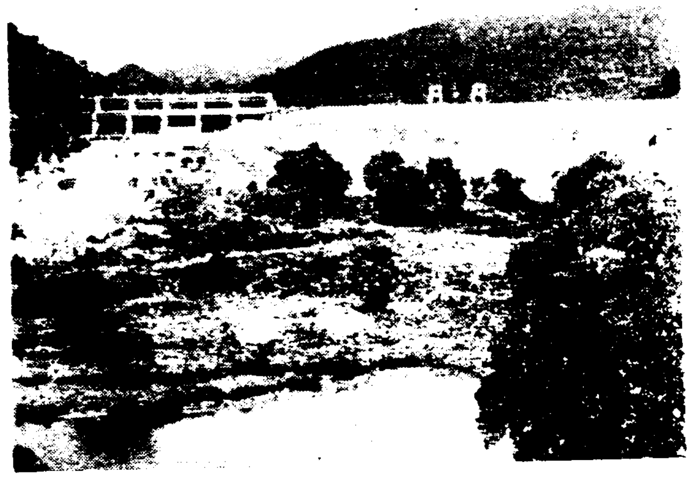
With the completion of the Papanasam Dam and the Manimuthar Reservoir, it has become now necessary to remodel the channel taking off from these various anicuts, so as to redesign them and make them function for the revised altered conditions obtaining at present. This is now engaging the attention of Irrigation Engineers of the Public Works Department.

Bhanatheertham—Origin of Tambraparani River.

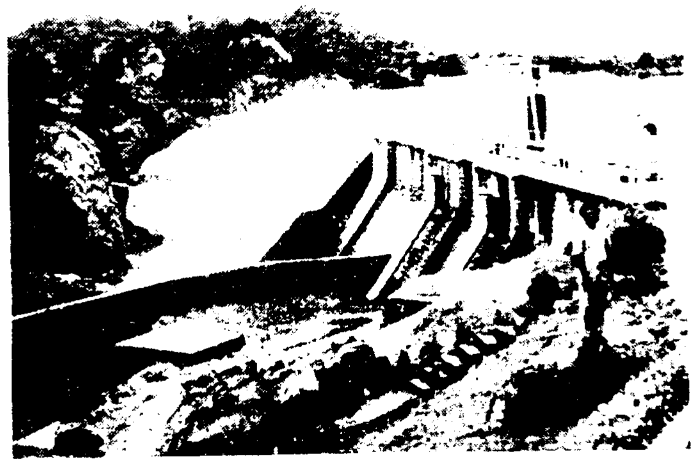
Kodamelalagian Anicut.

Nadhiyunni Anicut.

Kannadian Anicut.



Papanasam Upper Dam.

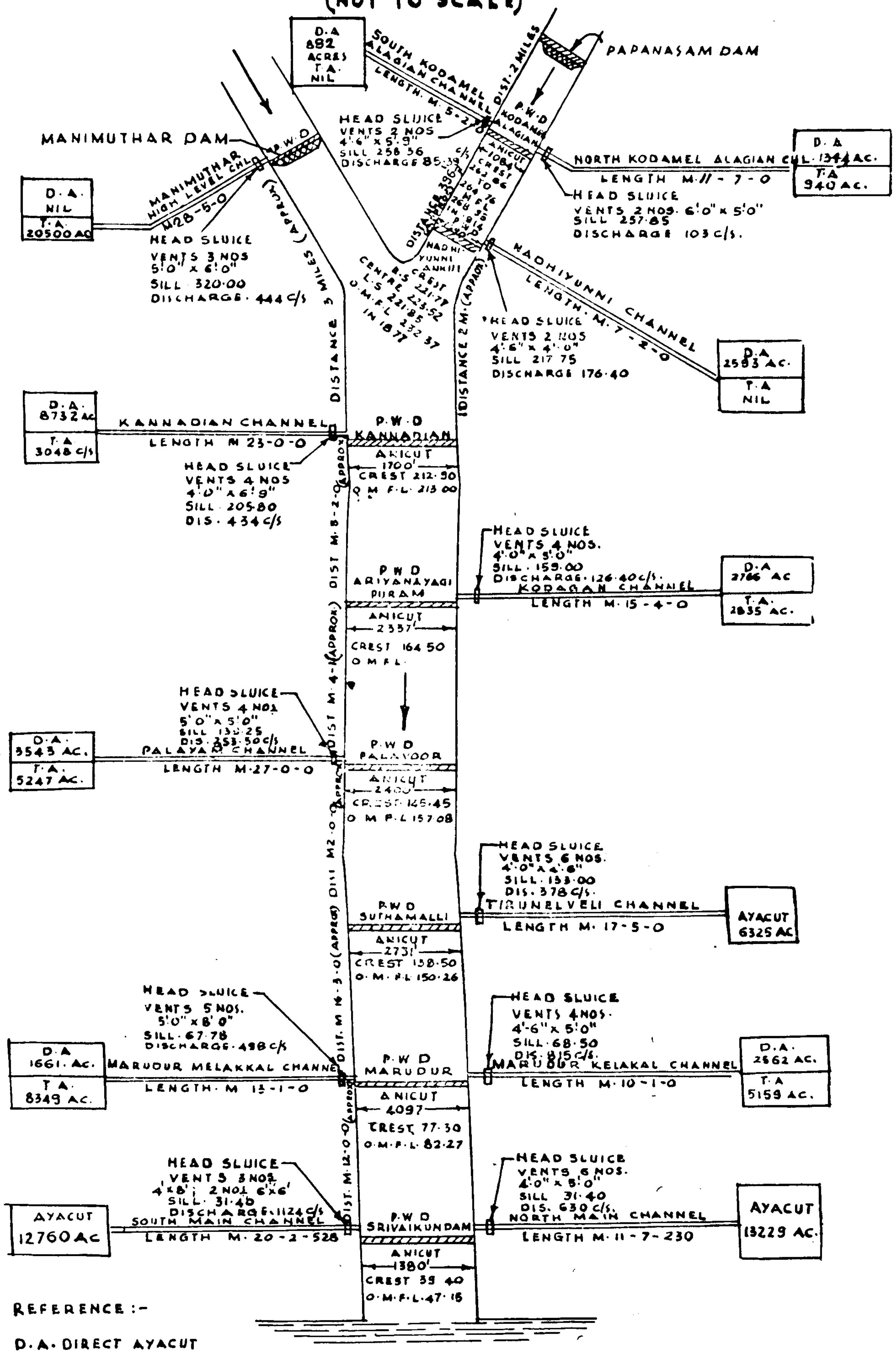


Papanasam Lower Dam.

Marudur Anicut.

Srivaikuntam Anicut.

KEY PLAN OF THE TAMBARAPARANI ANICUT SYSTEM
(NOT TO SCALE)

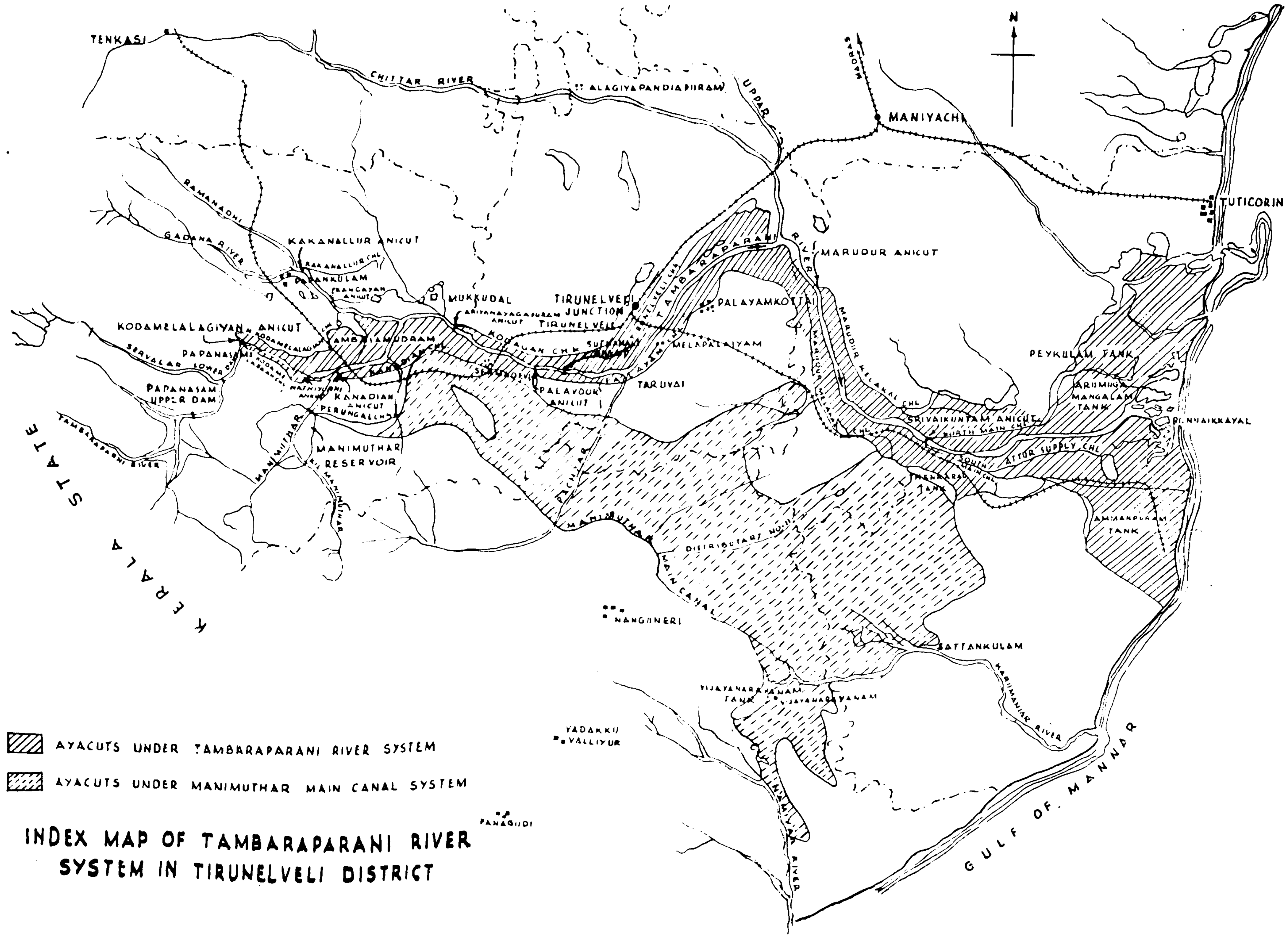


REFERENCE :-

D.A. DIRECT AYACUT

T.A. TANK AYACUT

O.M.F.L. OBSERVED MAXIMUM FLOOD LEVEL



INDEX MAP OF TAMBARAPARANI RIVER SYSTEM IN TIRUNELVELI DISTRICT

STUDY OF THE CHEMICAL COMPOSITION OF CEMENTS

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Synopsis.

In this article the chemical composition of various types of cements are given together with a brief outline on their methods of manufacture and properties. The significance of the limitations imposed by standard specifications as well as the effect of altering the chemical composition to obtain different types of cements to suit different requirements are also brought out.

1.1. *Introduction.*—Cement is one of the most important and commonly used building material next to lime. In recent years the production of cement has increased by leaps and bounds, thanks to the rapid developments made in the field of engineering under the Five-year Plans. Various types of cements to suit different requirements have been manufactured and specifications to control their quality were laid down as the demand for portland cement especially as an ingredient of concrete increased and the requirements of engineers called for a perfect material. The nature and properties of cements from the point of view of their chemical composition, are discussed.

1.2. *Classification of Cements.*—The cements discussed in this article will be confined mostly to portland cements of various types and other special types of cements with and without additives. These cements solidify when mixed with water and can be divided into the following five categories:—

1. Portland cements.
2. Natural cements.
3. High alumina cements.
4. Supersulphate cements.
5. Special types of cements.

The portland cements (1) are further subdivided as follows:—

(*a*) *Oridinary portland.*

(*b*) Rapid hardening or high early strength.

(*c*) Extra rapid hardening.

(*d*) Low-heat.

(*e*) Sulphate resisting.

(*f*) Portland blast furnace.

(*g*) White and coloured portland cements.

Under the category of special cements (5) the following may be mentioned:—

(i) Masonry cement.

(ii) Trief cement.

(iii) Expansive cement.

(iv) Oil well cement.

(v) Kuhl cement.

(vi) Erz and Ferraritypes of cements.

(vii) Sorel or Magnesium oxychloride cement.

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1. 3. Apart from all the above there are portland cements with additives. The most important ones are the *Portland Pozzolona Cements, Air entraining cements, and Water-proofed cements*. The above three also will be described briefly later.

2.1. It is proposed to take up for discussion the normal portland cements first. Before going into their nature and properties, the method of manufacture is described below briefly.

2.2. In 1824, Joseph Aspdin calcined a mixture of limestone and clay and called the resulting product as "Portland Cement", since the cement product obtained resembled the famous oolitic limestone used in ancient days by English Engineers for building purposes at Portland, England. The present accepted definition for portland cement runs as follows: "It is a product obtained by intimately mixing together calcareous and argillaceous or other silica, alumina and iron oxide bearing materials, burning them at a clinkering temperature and grinding the resulting clinker." To the cooled clinker obtained as above, gypsum is added and ground in ball mills to the requisite fineness. Two processes, namely, wet and dry, according to which the raw materials are ground either in a wet or dry condition are in vogue. Fig. 1 gives the flow diagram for process of manufacture bringing out the essential details. The manufacturing process for other types of portland cements are also similar with a variation of the quantities or qualities of raw materials used in order to suit the different requirements. Brands such as Dalmia, A.C.C., Shanker are being manufactured by various companies in India.

3.1. *Analysis of cements*.—It is generally found that most of the properties of the cements are generally related to the nature, quality and quantity of the chemical constituents which are present and to their calculated contents of the compounds present. Although the amounts of the various oxides present in cement vary only between restricted limits, the calculated compounds would vary much and hence the properties of cement would differ considerably. Therefore it is essential to find out the analytical composition of cements for assessing their properties. A chemical analysis is done according to the methods prescribed in the standards to be adopted. The various standards that are normally used for this purpose are A.S.T.M. (American Society of Testing materials), B.S.S. (British Standard Specification), I.S.I. (Indian Standards Institution). In the concrete and Soil Research Laboratory the Indian Standards Institution standards are being followed wherever they are available. A chemical analysis comprises of the estimation of the following constituents for routine purposes in the case of cements:—

1. Silica (SiO_2)
2. Alumina (Al_2O_3)
3. Iron oxide (Fe_2O_3)
4. Calcium oxide (CaO)
5. Magnesium oxide (MgO)
6. Sulphur trioxide (SO_3)
7. Acid insoluble residue.

An estimation for the loss on ignition is also done. For special research purposes the following additional estimations are done:—

(a) estimation of Free lime (Free CaO).

(b) estimation of alkalies ($Na_2O + K_2O$). (Potash and Soda).

The methods of chemical analysis are given in the I.S. Standards (I.S. No. 269—1958) as well as standard text books on chemical analysis which can be referred to. From the chemical analysis results the compounds present can be calculated.

41.1 *Compound Composition of portland Cements*.—As stated earlier, the properties of cements depend more on their compound contents. The constituents forming the raw materials used in the manufacture of Portland cements combine to form compounds in the finished product. The most important compounds are as follows:—

(i) 3 CaO. SiO_2 (Tricalcium silicate) C_3S.

(ii) 2 CaO SiO_2 (Dicalcium silicate) C_2S.

(iii) 3 CaO Al_2O_3 (Tricalcium Aluminate) C_3A.

(iv) 4 CaO Al_2O_3 Fe_2O_3 (Tetracalcium alumino ferrite). C_4AF.

The difference in properties of the various kinds of Portland cements arises from the relative proportion in which these principal compounds are present in the cement and the fineness of the cement. The C_3S and C_2S constituents form 70-80 per cent of all Portland cements and are the most stable and contribute most to the eventual strength and resistance of the concrete to corrosive salts, alkalies and acids. The C_3S hydrates more rapidly than the C_2S and it therefore contributes more to the early strength and heat generated and therefore the rise in temperature. The C_3A component is liable to decompose to hydroxides of calcium and aluminium on exposure to air and water and gets easily attacked by salts and alkalies. The C_4AF component is comparatively inactive and contributes little to the strength or heat of hydration of cement.

4.2. *Limitations of Cement Composition in specifications*.—The first association formed to control the quality of cement was in 1877 in Germany. The B.S.S. (British Standard Specification) was drawn up as early as 1904 and revised from time to time. In America the quality of cements are generally judged by the A.S.T.M. specifications. In India, the quality of the cement can be judged by the Indian Standard Specifications. the I.S.I. No. 269—1958 relates to the normal Portland, rapid hardening and low heat cements. All these specifications in general define not only the quality of cements but also the nature and properties of raw materials to be used. The specifications are liable to revision from time to time, the alteration made being mostly to increase the stringency of the requirements.

4.3. *Limits of chemical composition* in general for the Portland cements are approximately as follows (after Lea):—

			Percentage.
1	Calcium oxide	(CaO) percentage	60—67
2	Silicon dioxide	(SiO_2)	17—25
3	Alumina	(Al_2O_3)	3—8
4	Iron oxide	(Fe_2O_3)	0·5—6·0
5	Magnesium oxide	(MgO)	0·1—5·5
6	Alkalies	($Na_2O + K_2O$) ..	0·5—1·3
7	Sulphur Trioxide	(SO_3) ..	0·1— 3

The A.S.T.M. requirements for Chemical composition are given in Table I. As seen from the table there are mainly five types and in each type there is a slight variation in the requirements so that it can be adopted to the particular type of work, it is to be put to. Types I and III correspond to ordinary and rapid hardening types of cements while type II is slightly slower in rate of strength development than type I but has additional limitations on chemical composition. Type IV corresponds to lower-heat Portland cements while type V may come under the sulphate resisting type of cements. Table II gives the typical composition of these five types.

4.4. Ordinary and rapid hardening Portland cements are covered by I.S. No. 269|1958. The same specification holds good for low-heat cement also with some modifications. The chemical requirements for the above cements as per I.S.I. Specification No. 269|1958 are reproduced below.

The cement when tested in accordance with the methods given in Appendix A shall comply with the following chemical requirements:—

(I) For ordinary and rapid hardening types.—

(*a*) Ratio of percentage of lime to percentages of silica, alumina and iron oxide when calculated by the formula.

$$\frac{CaO - 0{\cdot}7\ SO_3}{2{\cdot}8\ SiO_2 + 1{\cdot}2\ Al_2O_3 + 0{\cdot}65\ Fe_2O_3}$$

Not greater than 1·02 and not less than 0·66.

(b) Ratio of percentage of alumina to that of iron oxide.	Not less than 0·66.
(c) Weight of insoluble residue ..	Not more than 1·5 per cent.
(d) Weight of magnesia ..	Not more than 5 per cent.
(e) Total sulphur content calculated as sulphuric anhydride (SO_3).	Not more than 2·75 per cent
(f) Total loss on ignition ..	Not more than 4 per-cent

II. *Low-heat Portland cement.*—When tested in accordance with appendix A shall comply with the following requirements as to its chemical composition. The precentage of lime after deduction of the amount necessary to combine with sulphuric anhydride present, shall be not more than 2·4 times the percentage silica plus 1·2 times and percentage of alumina and plus 0·65 times the percentage of iron oxide nor be less than 1·9 times the percentage of silica plus 1·2 times the percentage of alumina plus 0·65 times the percentage of iron oxide. All other requirements are as for the ordinary cements.

5.1. *Necessity for the limitations.*—The loss on ignition is estimated in cements to find out the degree of deterioration. When the clinker issues out of the kiln at bright white heat it has no loss on ignition. If the finished cement stands in a humid atmosphere it will pick up moisture and also carbon-di-oxide from the air and may ultimately set hard while it is still in the sack. If any attempt should be made to regrind and put on the market the cement that had deteriorated thus, the excessive loss on ignition would detect it.

5.2. Fresh Portland cement is almost completely soluble in dilute acid. The insoluble residue tests only to find out whether any adulteration in the shape of finely ground sand or other inert material.

5.3. The silica in Portland cement combines with lime to form the cementing compounds C_3S and C_2S. Any change in the silica content which increases the proporation of C_3S will affect the early strengths favourably but at long ages the strength depends only on the sum of the two. If the silica content is increased the setting time is prolonged though the strength increases. A higher content of alumina usually reduces the setting time though there is an increase in strength. Iron oxide imparts colour, combines with lime and silica and helps in the fusion of the materials during manufacture. The main role of Al_2O_3 (Alumina) and iron oxide in Porland cement seems to be one of reducing the clinkering temperature to make the process more economical. Also a high content of alumina and iron oxide makes possible the production of a cement with the minimum amount of lime so that all the silica gets used up forming tricalcium silicate without any high content of free lime remaining in the clinker. An excess of lime if hard burnt, hydrates slowly and may make the resulting concrete unsound. Limitation on the lime content is based on the fact that if there is an excess of lime over that which can combine with the acidic oxide unsoundness is produced. The limitation for lime content is based on Lea and Parker formula. It is also seen that the lime content is not controlled in most of the British specifications now.

5.4. *Magnesia in cements.*—A high magnesia content in cement in general is undesirable as it produces unsoundness. The presence of crystals of MgO, *Periclase* in a clinker has been found to lead to long-term unsoundness in the resultant cement, because of the expansion that accompanies its slow hydration.

5.5. *Sulphur trioxide* content is also strictly limited in cements as like magnesia it produces slow expansion in the set cement. A high content of sulphur trioxide also prolongs the setting time considerably. It is only due to this fact that even the addition of gypsum as a retarder is done very carefully and in limited quantities just sufficient to retard the time of setting.

5.6. *Free lime in cement.*—Free or uncombined calcium oxide is present usually to a small extent in Portland cement clinker and in the ground cement. In a fresh clinker it is entirely present as calcium oxide but in a ground cement a considerable portion of the total free calcium oxide is usually found as calcium hydroxide. This is due to hydration of free calcium oxide during the grinding of the clinker by moisture contained in the added gypsum owing to the relatively high temperature developed in the grinding mill. Table III gives the total free limes as per cent calcium oxide in normal Portland cements and rapid hardening cements. The calcium hydroxide liberated during the setting of cement makes little or no contribution to the strength of the set cement but is readily subject to chemical attack. Hence to counter act the effect of free lime; the use of Pozzolonas like surki and flyash are being advocated nowadays. The pozzolonas have the property of combining with lime liberated and a lime pozzolona compound of cementitious value is formed.

5.7. *Alkalies (soda and potash) in cements.*—Though the total content of sodium and potassium in Portland cement is small and their water soluble alkali content is still less, they cause a number of troubles. like alkali—aggregate reaction efflorescence, and staining when used in concrete, brick work or masonry and the limestones in set cement mortar. In the case of the limestones the staining is traced to the solubility of the organic matter present in the limestone. in the alkali hydroxides liberated by the alkali compounds in cement mortar. The efflorescence on brick work or masonry is usually that of alkali or calcium salts derived both from the bricks and cement mortar.

5.8. The most Important damage caused by the alkalies is due to the alkali aggregate reaction. The reaction is due to the interaction of the alkali hydroxides (Sodium and Potassium hydroxides) released from the cement and a reactive form of silica, such as opal, chalcedomy, tridymite, cristobabite, etc., present with aggregates used. Out of the above opaline silica found in cherts, shales and in some impure limestones are the most reactive. The reaction leads to the formation of an alkali silicate gel and sets up expansive forces, leading to the cracking and destruction of concretes. It is also seen that this type of action takes place only when a high content of alkali is found in the cement and when the same is used with reactive type of aggregates. As a rule an alkali content below 0.6 per cent is found to cause little expansion even with reactive types of aggregates with some exceptions. Such cements are known as "Low alkali cements" and the use of these cements are recommended when reactive types of aggregates have to be employed in concrete. The pozzolonas and pozzolonic cements are found to be effective in counteracting the alkali aggregate reaction due to their ability to take up the sodium and potassium salts from solution. Hence the addition of pozzolonas to inhibit the destructive alkali aggregate reaction is recommended of late when reactive types of aggregates or cements with high alkali contents are to be made use of.

6.1. *Manufacture and properties of other types of Portland cement.*—The necessity for the manufacture of different types of Portland cements arose out of the fact that any one particular type was not found to be suitable for all types of construction, where cements with different properties are required. Thus for instance the formation of cracks in large masses of concrete has focussed attention on the necessity for cements which liberate heat slowly during the hydration process. Cements with high resistance to various external chemical agencies were required for use in different types of strata. Cements for use in frosty weather should evolve heat more quickly and hence the necessity for rapid hardening and quick setting cements arose. As mentioned earlier, the difference in the properties of various cements are due to the variation in their chemical compounds and to the fineness to which the cement clinker is ground. Even a small variation in the chemical constituents in the raw materials used can cause a large variation in the compound content of the cement and hence its properties (vide Table IV).

Therefore it is possible to obtain various types of cement by using raw materials slightly different and by grinding the cement finer. Thus *rapid hardening Portland cement* is similar to ordinary Portland but is ground finer with slight alteration in chemical composition. The extra *rapid hardening type* is obtained by grinding calcium chloride with rapid hardening Portland cements. The rapid hardening property is due to the presence of more C_3S and less C_2S ordinary as compared to ordinary Portland cements, and this gives high early strength also. The calcium chloride added in the extra rapid hardening cements imparts the quick setting properties in addition to accelerating the process of hardening. *Low-heat* cements are manufactured from raw materials with a low calcium content and a high silica content. In these cements the proportion of C_2S (Di calcium silicate) is increased and the proportion of C_3S (tricalcium silicate) is reduced as far as possible in addition to restricting the amount of C_3A (tricalcium aluminate). Since a reduction in temperature retards chemical action of hardening the rate of evolution of heat will be less, thereby extending the evolution of heat over a longer period. Though due to this fact the rate of gain of strength will be slow, it is beneficial in resisting the formation of cracks in concrete.

6.2. *The sulphate* resisting cements one similar to Portland cements but the amount of C_3A (tricalcium aluminate) present is strictly limited. Due to this reason the formation of calcium sulpho aluminate and the corresponding sulphoferrite which produce expansion in concretes is inhibited. In the place of these, the compound C_4AF (Tetra calcium almino ferrite) is formed which is resistant to chemical agencies. These cements are useful in counteracting the effect of sulphates present in waters and sulphatic clays when the cement is used in such places.

6.3. *Portland blast furnace slag* cements are manufactured by grinding together a Portland cement clinker and granulated blast furnace slag of high lime content obtained as a byproduct in the manufacture of Pig iron in proportions such that the content of granulated slag does not exceed 65 per cent of the whole. These cements which show a lower rate of hardening and a low heat of hydration can be used for concreting large masses in hot weather though they require more careful handling at extremes of temperature as they harden in cold weather rather slowly. These cements are more resistant, to sea water, peaty or slightly acidic water and sulphates. Their resistance to sulphates is generally attributed to the lesser content of free calcium hydrooxide present when they set, as well as the less basic nature of the hydrated calcium silicates present. The specifications for strength requirements are the same as for Portland cements and these cements find an extensive use in marine work. Indian Standards Specification No. 455-62 lays down the requirements for portland blast furnace slag cement.

6.4. *White Portland* cements are manufactured from chalks and limestones containing low iron contents. The kilns are also fired by oil fuel instead of coal so that the contamination by coal ash is avoided. Coloured Portland cements consist of Portland cements with 5-10 per cent of pigment, obtained by grinding the cement and pigment together. The more commonly used pigments are iron oxide (red, yellow, brown and black) manganesedioxide (black and brown), chromium oxide (green), cobalt blue (blue), ultramarine (blue) and carbon pigments (black). The white and coloured cements may be used more for decorative purposes. Table V gives the chemical composition of important cements other than those mentioned in table IV while table V gives the physical properties of eight types of cements including some of the special types mentioned below.

7.1. *Special types of cements.*—Natural cements: These are manufactured from naturally occuring cement rocks with composition similar to the artificial mix for the manufacture of Portland cements. Their properties closely resemble that of the natural cement rock from which they are manufactured.

7.2. *High Alumina cements.*—These cements are characterised by their dark colour, high early strength, high heat of hydration and resistance to chemical attack. They are manufactured by fusing or sintering a mixture of aluminous and calcareous substances and grinding to powder the resultant material. British standard specification No. 915 specifies that the total alumina content shall be not less than 32 per cent and the ratio of percentage alumina to percentage lime by weight shall be between 0·85 and 1·3. The rapid hardening properties of these cements are due to presence of chiefly mono calcium aluminate in the place of the tricalcium silicate. Due to the formation of a ceramic bond in concretes on setting, these cements are useful as refractory materials also. Mixtures of Portland and high alumina cements are used when quick setting properties are required. As compared to special types of quick setting cements these mixtures of Portland and high alumina cements are more useful as these mixtures can be stored for longer periods if they are kept dry. It is also seen that great care has to be exercised when these mixtures are used since their behaviour depends on various factors. The high alumina cement exhibits a very high resistance to sulphates. Usually it is seen that in Portland cements calcium sulpho aluminate (ettringite) is formed by the interaction of aluminate compounds with sulphate solutions and sulphate resistance decreases with increasing alumina content. But, in the case of high alumina cements, though the alumina content is very high, they show a higher resistance to sulphates. This has been explained as due to the fact that expansion can occur only if a cement compound in the solid state reacts with a substance in solution. But if the compound itself goes into solution first reacts and then precipitates as solid, no expansion can occur. In the case of normal Portland cements, the free lime produced during setting renders the hydrated calcium aluminates insoluble but in the case of high alumina cements this hydrated calcium aluminates pass into solution due to the absence of additional lime as very little free lime is liberated during their setting and hardening. The mono calcium aluminate which is its principal constituent forms dicalcium aluminate and a small amount of mono calcium silicate and free alumina in excess of that which can combine with any free lime, during the hydration process. The point to be noted is that while there is an excess of free lime over and above that which can combine with aluminates in Portland cements due to hydration of the tricalcium silicate, there is an excess of free alumina only in the case of high alumina cement. Hence this free alumina which is relatively inert imparts a high sulphate resistance, preventing the formation of calcium sulpho aluminate which produces expansion, the chief cause for destruction of concretes when used in conjunction with sulphates. There is no satisfactory and quick test for the resistance to chemical attack but the resistance to sulphate attack can be found out by strength tests on concretes immersed for long periods in sulphate solutions (soundness tests). There is another test known as "Anstett test" for sulphate resistance in which expansion of the cement is measured using gypsum. The quality of the cements also can be assessed from its chemical composition and from this an idea of its resistance to chemical attack can be had.

7. 3. *Super sulphate cements.*—These are made by inter grinding granulated blast furnace slag (80-85 per cent), calcium sulphate (10-15 per cent) and about 5 per cent of Portland cement. It has a low heat of hydration and resists chemical attack due to the relatively low content of free lime released during hydration.

7.4. *Masonry cements* were manufactured to avoid the laborious process of mixing lime, cement and sand as and when required in order to prepare mortar for brick work, as well as to avoid the presence of unslacked lime in the mixture of lime sand and cement so prepared. Lime has been used in mortar since it makes the mortar easier to work. Apart from this, much is not known about these cements as regards their specification, tests and performance though they enjoy a wide use in mortar.

Trief cements are similar in properties to blast furnace type except in the preparation of these cements the slag is ground wet and separately from the cement.

7.5. *Expansive cements.*—To counteract the effect of shrinkage of concrete during the hardening process expansive cements were manufactured to be used with Portland cement. These expansive cements contain the expanding calcium sulpho aluminate ($3\ CaO\ Al_2O_3\ 3CaSO_4$ aq.). One of the compositions for an expanding agent is a combination of kaoline (26-35 per cent), slaked lime (43-55 per cent) and Portland cement (about 31 per cent). A stabliser is also used, the commonly used one being the blast furnace slag which brings the expansion to the desired limit. The expansive action caused may be said to be made up of two parts namely the reaction of the calcium sulphate ($CaSO_4$) and C_3A (Tricalcium aluminate) of the Portland cement and the reaction of the $CaSO_4$ and the less basic aluminate in the " Sulpho aluminate " clinker. The expansion continues only as long as the concrete is kept moist and careful control of curing is necessary.

7.6. *Kuhl cements* have a low silica content and high alumina and iron content. They are similar to rapid hardening cements with respect to their strength.

7.7. *Erz and Ferrari cements* contain high iron oxides. the ratio of alumina to that of iron being 0.64-1.0. They have a high resistance to chemical attack.

7.8. *Oil well cements* are used in the petroleum industry for cementing the steel casing of oil wells. The type required varies according to the conditions but the setting time and rate of thickening must be retarded sufficiently. This is achieved by the adjustment of the compound composition of the cement and by adding retarders to portland cements. The proportion of Fe_2O_3 (iron oxide) is kept higher than that required to combine with all the Al_2O_3 (Alumina) to form $4\ CaO\ Al_2O_3\ Fe_2O_3$ (Tetra calcium Alumino ferrite). Hence the proportion of $3\ CaO\ Al_2O_3$ (Tricalcium aluminate) formed is small, thereby increasing the setting time considerably. If retarders are used with cements, then cements of the type A.S.T.M. II contained a low content of C_3A (Tricalcium aluminate) are used; since they are resistant to sulphates also if they are present in the strata where oil wells are dug:

7.9. *Sorel cements.*—These are otherwise known as magnesium oxychloride cement obtained by reacting magnesia and magnesium chloride solution. The product is hard and strong but is attacked by water easily and hence wax protection is given for these cements, on the surface when they are used as a flooring material.

8. 1 *Cements with Additives.*

Pozzolonic cements: Under the classification of cements with additives, the most important one is the Portland pozzolonic cements prepared by grinding together Portland cement clinker and a pozzolona or by mixing hydrated lime and a pozzolona. A pozzolona is a siliceous material which whilst itself possessing no cementitious properties will when in finely divided form react in the presence of water with lime at normal temperature to form compounds having cementitious properties. The materials generally consist of calcined clays and shales, diatomaceous earth, opaline cherts volcanic materials such as tuffs pumicites and trass and artificial materials such as blast furnace slag or fly ash. Pozzolonic activity is the property exhibited by the pozzolonas namely to combine with lime liberated during the hydration of cements to form cementitious compounds. There are various tests for determining this activity. The pozzolonas are useful in counteracting the bad effects of free lime liberated during hydration of the cement, which causes the disruption of the concrete. The pozzolonas also interact with alkalies present in cements thereby counteracting the effect of alkali aggregate reaction explained earlier. Hence the pozzolonas are used as admixtures to cements wherever the aggregate used is known to be reactive. Other reasons for using pozzolonic cements are improved durability, combined with

economy obtained in concrete constructed in marine, hydraulic and underground structures as also the reduction of heat evolved. The chemical composition of some of the American Pozzolonic cements are given along with the composition of natural and Portland cements (in Table VII). It will be seen that all pozzolonic cements are rich in silica and alumina and low in alkalies. For the pozzolona to be effective, the silica it contains should be in the amorphous form and not crystalline. It should also be in the finely divided form for easy chemical interaction. This explains the difference in the behaviour of different types of pozzolonas.

8.2. *The analytical* composition of a pozzolona affords no criterion of its activity. Also the finality in the routine testing of pozzolonic cements have not yet been reached, and are still being experimented upon. I.S. No. 1489-1962 lays down the specifications for portland pozzolona cements.

8.3. *Air entraining cements.*—There are Portland or Portland blast furnace cements to which a small amount of air entraining agents such as natural resins, sodium salts of sulphonates, glues salts of fatty acids, etc., are added during grinding. These materials reduce the surface tension of water and stabilise very small air bubbles in the mix in a manner analagous to the formation of a foam on soapy water. The entrainment of air increases frost resistance and to some extent imparts resistance to sulphate waters. It improves the workability and reduces the seggregation and bleeding of the concrete mix. The amount of air entrained varies to some extent with the richness of the concrete mix, the type and grading of the concrete mix, and aggregate and other factors. It is also seen that there is no advantage with respect to durability if the air content is increased to more than 6 per cent. as it may cause a decrease in compressive strength than what is normally allowed. The A.S.T.M. specification controls the amount of air entraining agent added by a test on the air content of a standard 1:3 cement -sand mortar in which the weight per 400 ml. is determined and the air content calculated from the theoretical weight of the air-free material. A number of indegenous and cheaper air entraining agents are being developed nowadays.

8.4. *Water proofed cements.*—These are ordinary Portland cements to which certain water proofing substances such as calcium stearates. aluminium stearates. and gypsum treated with tarnic acid and some non-saponifiable oils, are added during grinding. Special water proofing properties are attributed to these cements and much precise information has not yet been made available about the properties of the cement.

8.5. *Conclusion.*—The chemical composition as well as the necessity for the limitations of the amount of chemical constituents for the most important types of cements have been discussed briefly in this article. As a complete discussion on the various aspects of the physics and chemistry of cements involves the study of a large number of factors and as the same cannot be covered in an article of this type it is pointed out that references may please be made to a number of standard books on cements published. Out of a number of books the names of two important books are mentioned below which are useful as reference books.

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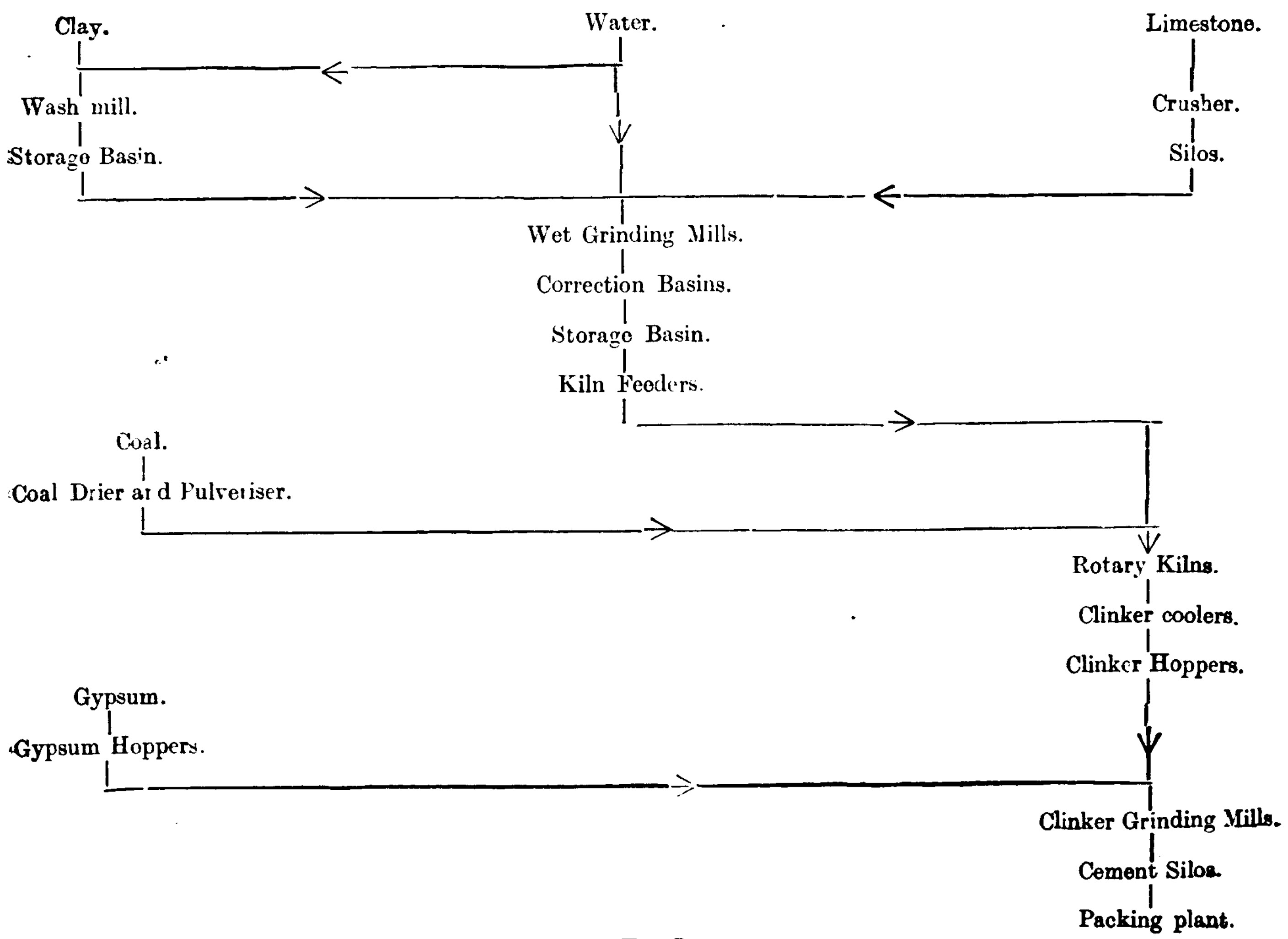

(Fig. I).
(Flow sheet for the manufacture of cement).
(After Lea).

TABLE I.

Chemical requirements (A.S.T.M. Standards).

(1)	*Type I,* (2)	*Type II.* (3)	*Type III.* (4)	*Type IV.* (5) *	*Type V.* (6
1. Silicon dioxide (SiO_2) max. per cent	..	21·0	..	..	..
2. Aluminium oxide (Al_2O_3) max. per cent...	..	6·0	..	..	*
3. Ferric Oxide (Fe_2O_3) max. per cent	..	6·0	6·5	..	*
4. Magnesium Oxide (MgO) max. per cent	5·0	5·0	5·0	5·0	4·0
5. Sulphur trioxide (SO_3) when 3 CaO, Al_2O_3 is 8 per cent or less max. percent	2·5	2·5	3·0	2·3	2·3
6. When 3 CaO. Al_2O_3 is more than 8 per cent max. per cent	3·0	..	3·0	...	..
6-A. Loss on Ignition, max. per cent	3·0	3·0	3·0	2·3	3·0
7. Insoluble Residue max. per cent	0·75	0·75	0·75	0·75	0·75
8. Tri calcium silicate (3CaO. SiO_2) max. per cent	..	50	..	35	50·0
9. Dicalcium silicate (2CaO. SiO_2) max. per cent	..	..	..	40	..
10. Tricalcium aluminate (3CaO Al_2O_3) max. per cent ..	..	8	15	7	5

* The tricalcium aluminate shall not exceed 5 per cent and the tetracalcium alumine ferrite (4 CaO. Al_2O_3 Fe_2O_3) plus twice the amount of tricalcium aluminate shall note exceed 20 per cent.

Remarks.—

Type I : For use in general concrete construction when the special properties specified for types II, III, IV and V are not required.

Type II : For general concrete construction exposed to moderate sulphate action or where moderate heat of hydration; is required.

Type III : For high early strength.

Type IV : Low heat of hydration.

Type V : High sulphate resistance required.

(Types I A, IIA and IIIA same as I, II and III but they have an air entraining agent added).

TABLE II.

Typical composition of various A.S.T.M. types of cements (after Lea).

Portland type. (1)	SiO_2. (2) PER CENT.	Al_2O_3. (3) PER CENT.	Fe_2O_3. (4) PER CENT.	CaO. (5) PER CENT.	MgO. (6) PER CENT.	SO_3. (7) PER CENT.	L.I. (8) PER CENT.	Insoluble Residue. (9) PER CENT.
Type I	21·3	6·0	2·7	63·2	2·9	1·8	1·3	0·2
Type II	22·3	4·7	4·3	63·1	2·5	1·7	0·8	0·1
Type III	20·4	5·9	3·1	64·3	2·0	2·3	1·2	0·2
Type IV	24·3	4·3	4·1	62·2	1·8	1·9	0·9	0.2
Type V	25·0	3·4	2·8	64·1	1·9	1·6	0·9	0·2

TABLE III.

FREE LIME CONTENTS IN NORMAL PORTLAND AND RAPID HARDENING CEMENT (AFTER LEA)

Cement. (1)		*Total free lime content expressed per cent CaO* (2)	*Cement.* (1)		*Total free lime content expressed per cent CaO* (2)
Rapid Hardening Portland cement	1	1·2	Normal Portland cement	7	0·4
	2	3·5		8	0·7
	3	3·7		9	1·4
	4	3·9		10	1·8
	5	4·2		11	2·3
	6	4·6		12	3·6

TABLE IV.

COMPOUND COMPOSITION AND COMPOUND CONTENT OF CEMENTS (AFTER LEA).

Percentage Composition-Main Oxides. (1)	*Ordinary Portland.* (2)	*Rapid hardening portland.* (3)	*Low heat portland.* (4)	*Sulphate Resisting portland.* (5)
CaO	63·1	64·5	60·0	64·0
SiO_2	20·6	20·7	22·5	24·4
Al_2O_3	6·3	5·2	5·2	3·7
Fe_2O_3	3·6	2·9	4·6	3·0
Percentage Compound composition :—				
C_3S	40	50	25	40
C_2S	30	21	45	40
C_3A	11	9	6	5
C_4AF	11	9	14	9

Remarks ; Note : The comparatively large variation in the compound composition which can result from a very small variation in the chemical analysis of raw materials.

TABLE V

(CHEMICAL COMPOSITION OF CEMENTS.)

Serial number. (1)	*Cement.* (2)	*CaO* (3) PER CENT	*Al_2O_3* (4) PERCENT	*Fe_2O_3* (5) PER CENT	*SiO_2* (6) PER CENT	*MgO* (7) PER CENT	*SO_3* (8) PER CENT	*FeO* (9) PER CENT
1.	Portland blast furnace slag	59·0	8·1	1·0	22·8	3·5	1·7	0·5
2.	Super sulphate cement	45.0	13·1	1·0	25·2	3·5	7·0	0·9
3.	High Alumina cement	37·7	38·5	12·7	5·3	0·1	0·1	3·9

TABLE VI.

PHYSICAL PROPERTIES OF DIFFERENT CEMENTS (AFTER LEA).

Cement. (1)	*Rate of strength development.* (2)	*Rate of heat evolution.* (3)	*Drying shrinkage.* (4)	*Resistance to cracking.* (5)	*Inherent resistance to chemical attack.* (6)
1. Rapid hardening	High.	High.	Medium.	Low.	Low.
2. Ordinary Portland	Medium.	Medium.	Medium.	Medium.	Low
3. Low heat Portland	Low.	Low.	Higher (Somewhat)	High.	Medium.
4. Sulphate Resisting cement	Low. to Medium	Low. to Medium.	Medium.	Medium.	High.
5. Portland Blast furnace slag	Medium.	Medium.	Medium.	Medium.	Medium.
6. Supersulphate cement	Medium.	Very low.	Medium.	No information.	High.
7. High Alumina cement	Very high.	Very high.	Medium.	Low.	Very high.
8. Pozzolonic cement	Low.	Low to medium.	Somewhat higher.	High.	High.

TABLE VII.

CHEMICAL COMPOSITION OF AMERICAN POZZOLONIC CEMENTS COMPARED TO NATURAL AND PORTLAND CEMENTS (AFTER KALOUSK AND JUMPER).

Constituent.	*Pozzolonic cements.*					*Natural cements.*		*Port land cements.*
SiO_2	28·2	28·1	33·3	31·2	26·4	26·2	21·1	21·8
Fe_2O_3	3·7	0·9(*a*)	5·3	5·3	3·3	2·2	2·7	5·3
Al_2O_3	8·2	10·7	13·3	7·1	7.3	7·9	6·0	4·5
CaO	48·6	55·6	39·7	49·8	57·5	58·9	63·0	65·1
MgO	3·5	2·2	2·1	2·0	1·6	2·8	3·3	1·0
SO_3	1·8	0·8	1·9	1·5	1·8	1·8	1·9	1·6
Ignition loss	5·8	(*b*)	2·7	0·8	(*b*)	5·6	2·1	0·8
Na_2O	*	*	0·04	1·61	0·22	*	*	
K_2O	*	*	1·24	0·93	0·98	*	*	
Insoluble	16·5	0·3	35·5	19·7	0·5	1·8	0·1	0·2
Free CaO	0·7	0·4	0·1	0·4	0·1	5·2	1·6	1·5

(*a*) Also 0·9 per cent FeO

(*b*) Gained wt.

(*) No data.

"My passage through school has not made me a Polytechnician in the ordinary sense of the term that is to say, a man with a belief hard as iron in the virtue and the power of deductive reasoning particularly in its mathematical forms. Of this faith I have been unable to acquire the smallest particle.

For me only two sources of information exist: the direct perception of facts and intuition, in which I see the expression and summary of all the experiences accumulated from the first life cell in the sub-conscious of all beings. Intuition must, of course, be checked by experience. But when it is found to be in contradiction with the results of calculation, I have the calculation done again, and my colleagues assure me that when all is said and done it is often the calculation which is wrong."

E. FREYASINET.

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