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THE NEW IRRIGATION ERA

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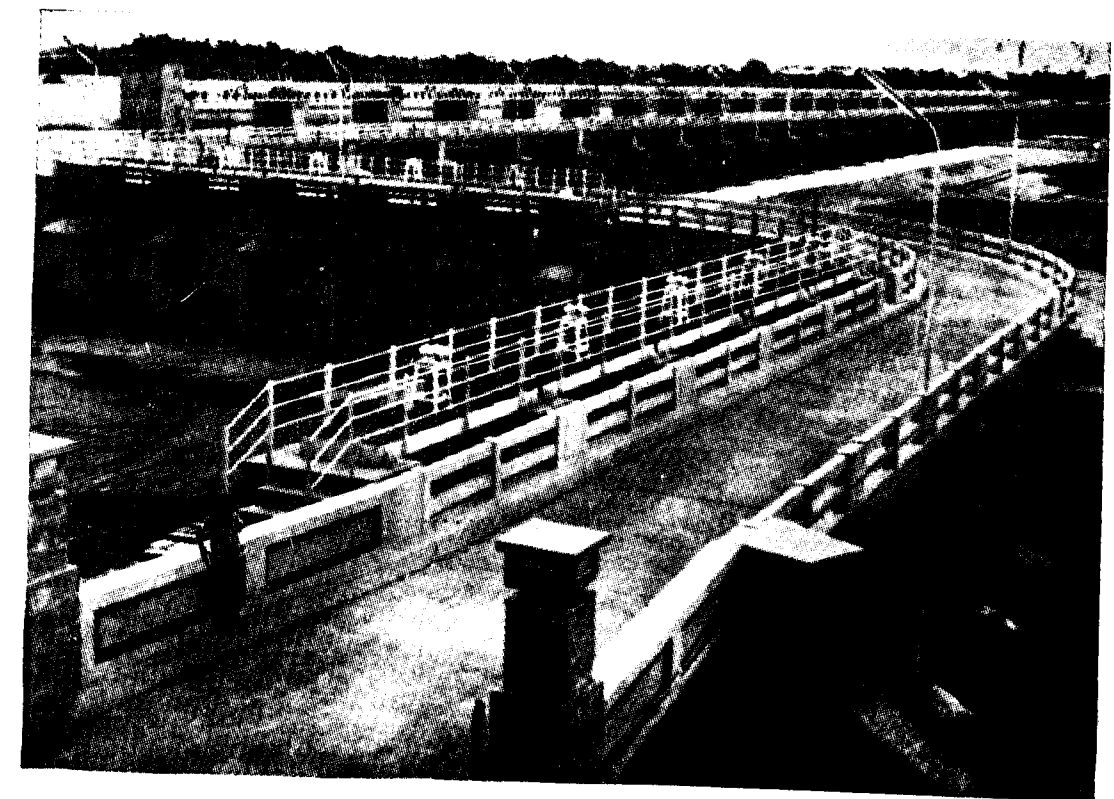
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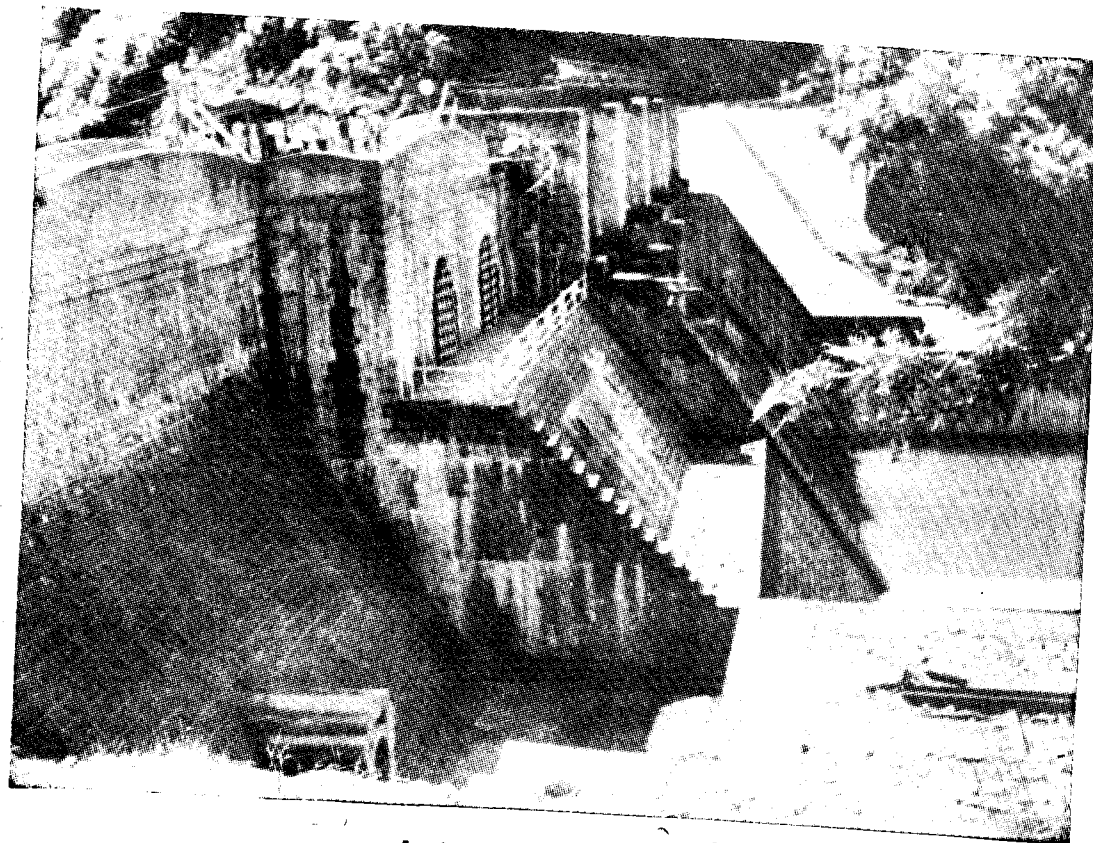
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Parthibanur Regulator across Vaigai



A view of Nirar Weir



THE NEW IRRIGATION ERA

Vol. XIV

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No. 4

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The Editorial Board of New Irrigation Era of Tamil Nadu Public Works Department accepts no responsibility for the views expressed by the author.

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EDITORIAL

In the first article of this issue Thiru A. Mohanakrishnan, Senior Deputy Chief Engineer (Irrigation) has brought out an article on Search for Water for Food for Hungry Millions. Water is one of the important basic element for sustenance of life on earth. The author has detailed out the percentage of water resources now utilised and also how the water was and is being utilised by man kind from periods earlier to 1890s to date. Water saving methods in Irrigation Practice has also been enunciated to some extent. With the River basin plans made out it is possible to indicate deficit and surplus basins. National Water Grid proposed by Dr. K. L. Rao, envisages such basin to basin transfers from a surplus basin to an adjacent deficit basin. In conclusion, water, the nature's gift to man kind becoming scarce on account of increased demand is to be economically used and hence it is the Engineers' and Scientists' responsibility to devise such means for economical use and the best use of available water.

Second article by Prof. S. Panchanathan, Chief Engineer (Ground Water) has explained the techniques like aerial photography, Satellite imageries and other methods of remote sensing technique used for evaluating earth resources. The author has explained about modern remote sensing devices and how it is useful to man kind particularly Engineers. The author has also explained photo interpretation, Landsat space craft method, Radar and its applications, etc. Application of the remote sensing techniques to agriculture is large and appealing. The availability of timely information on agricultural condition is most essential and the use of above technique will be helpful.

"Drip Irrigation" explained by Thiru Sivanappan, Professor and Head of Department of Soil Engineering, Agriculture University forms third article of this issue. Irrigation is a major instrument in the advancement of ancient civilization. Advancement in Irrigation methods is not much compared to advancement in all the fields of man's life. The author has explained improvements made in western countries in irrigation methods and how Drip Irrigation is useful for India. Concluding, the author states that drip irrigation is an important advance recently made, eventhough there are still some problems.

Thiru J. K. Jain, Department of Agriculture and Member, Central Ground Water Board has explained in the fourth article "Integrated Development of Water Resources for Irrigation". It has now been recognised that a Major factor responsible for integrated development of water resources is the massive development of Ground Water for Irrigation in recent years. Various Irrigation Systems including salient Technical features and limitations are explained in this article. By Integrated Development we understand that by simultaneous utilisation of the surface water and ground water resources through judicious combination we can achieve better results.

The concepts and practice of concrete mix design has been explained by the Soil Mechanics and Research Division of Tamil Nadu P.W.D., in the next article of this issue. Concrete is one of the important items of construction that is encountered by an Engineer. In order to achieve economy in concrete mix without sacrificing quality, the use of (i) stiffest practical mix (2) Largest possible size of aggregate (3) Optimum ratio's of fine and coarse aggregate is required to be adopted. Similarly water cement ratio, compactability of concrete, mobility and workability, etc., has been explained in this article.

The Sixth article by Er. P. V. Sahadevan under the Caption "EGGLIPSE" gives the basic equation, method of describing the curve "EGGLIPSE" and the possible uses of EGGLIPSE. The theory of EGGLIPSE is reported to be useful in Sciences like Astronomy, Dynamics, etc., apart from its use in Tunnel sections, Sewer sections and also many hydraulic structures and is bound to expand in due course.

In conclusion, The Editor thanks all the authors of the articles of this issue for the co-operation extended in furnishing valuable articles. In this regard we request all the other Engineers to send as many articles as possible of technical importance and help the noble cause.

SEARCH FOR WATER / FOR FOOD FOR HUNGRY MILLIONS.

BY

*THIRU A. MOHANAKRISHNAN, B.E., (HONS.),
Msc., MIE



1. Water for food

Water is one of the basic elements that sustains life on the earth. Next to air, water is indispensable and every living being that breaths and grows requires water. Water is the first requirement for the growth of food for the living beings on the earth.

Nature has of course endowed this world with large volumes of water in various forms in the rivers and lakes, in the snowy peaks and ice bergs and also in the vast oceans. But 95 per cent of these large volumes is saltish. Out of the 5 per cent fresh 4 lies frozen in the Polar regions leaving only 1 per cent to be really useful for mankind. This water is again travelling in different forms in the hydrologic cycle. The large mass of it is however is not actively moving in this cycle in this mass transfer. Only a small part of it is travelling up by evaporation, condensing to fall on ground as precipitation and runs off or infiltrates into the ground to add to fresh water storages. Precipitation is the main source of water for our use on earth.

Confining ourselves to the water for human needs, we see that the world wide escalation in the population has increased the need for water. The global population which is now estimated at 4 billion is expected to go upto 6 billion by 2000 A.D. In India the population as per 1971 census stood at 574 million and this is expected to reach 900 million by the turn of the century. Similarly Tamil Nadu population is expected to grow to 65 million from 41.2 million. The demographers who project the population figures come to this conclusion in spite of the Governmental efforts to contain the population by family planning measures. The problem now is to find water for human needs in the days to come for this increasing population.

The total water mass in the globe in various forms is a constant, accounting for all forms, liquid, gaseous and solid, below the surface of the earth, in the oceans and on earth and also in the Ionosphere around the earth. In our attempt to search for more water for human needs, using the technological developments, we may have to inevitably adopt processes which will force more of the dormant waters to get activated and move in the hydrologic cycle, from one form to another and from one place to another. Our attempts at desalination of ocean water, melting of Polar ice bergs forcing in thermal energy are some of these processes meant to increase the fresh water content

of the water mass. These attempts which are now uneconomical will become inevitable necessities in course of time.

Human needs of water spreads over irrigation requirements for growing food, hydropower uses for producing energy, industrial uses, drinking water and other domestic consumption. Among all these water used for irrigation is the largest in quantity. Since the natural precipitation is not uniformly distributed in space or time we have to resort to artificial supply of water for plants to ensure cropping and yield. With the growth in population man has to develop more and more of area for cultivable purposes. The extent under food crops is continuously increasing. Yet it is not possible to ensure irrigation for the entire cultivable area for various reasons, geographical, hydrological, paucity of supplies, etc.

Emphasising the need for development of irrigation President of the "The International Commission on Irrigation and Drainage (ICID)" Mr. E. Alexseevsky said in its Silver Jubilee Session in Moscow on July 28th, 1975 "Irrigation is undoubtedly the main factor to meet the food problem". Lack of irrigation renders farming practically impossible in the arid zone of the world. It provides the possibility to cultivate new high yielding and water-loving crop varieties. And at last irrigation lands more efficiency to fertilisers. The fact that, irrigated lands covering only 16 per cent of the aggregate cultivated area in the world accounts for over 50 per cent of the total agricultural output, bears out convincingly the effect of irrigation.

India is one Country where Irrigation has been practiced in a vast scale from ancient times. Even now India has the largest area of irrigated lands for any single country. Out of a gross geographical area of 329 million hectares, leaving the hilly areas and other uncultivable wastes 169 million hectares are under crop. But the irrigated extent is only 44.9 million hectares thus covering 27 per cent of the cropped area. In Tamil Nadu the percentage is slightly above 40 per cent. We have to now strain hard to increase his percentage adopting various methods like harnessing further resources, reuse of drainage water, saving water losses, etc.

2. Water resources—

Precipitation is the only source of all usable waters on earth. The most easily tapped portion of this precipitation is the surface flow. From very early times man has been planning utilisation of these surface flows first in a crude way and then with a technical skill developed through the centuries. Irrigation practiced as an art in ancient

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times came to be recognised as a technical science in course of time. Temporary bunds were thrown across flowing rivers when they were in low flows, heading up the water level to flow through open head channels carrying irrigation supplies in the country side. With floods those temporary bunds were disturbed and washed off only to be replaced by human effort again.

By the second half of the last century, permanent structures could be built across rivers in place of temporary korumbus with the development of Engineering Science. Major diversion works like the Ganga and Yamuna Canals, the structures across Sutlej and Sind, the Krishna and Godavari anicuts, the Upper and Lower anicuts across Cauvery sprang up all over the country in an attempt to boost irrigation and food production and to avert the miseries of droughts.

With the turn of this century we thought in terms of creating storage reservoirs in river basins. Our Mettur Dam is one of the earliest built dam structures in the country. The Periyar Dam built a little earlier in 1890s is a unique structure built for an unique purpose.

After Independence, through our Five Year Plans substantial investments have been made for irrigation sector as may be seen from the Annexure. We have built as many as 150 masonry and concrete dams and 370 earth and rockfill dams 25 of which are over 60 metres in height. While the total storage built through our small irrigation tanks was hardly 12,300 m. cubic metres we have added a storage of 1,40,000 m. cubic metres after Independence. About 17,000 km. of big canals have been dug out. All these have been done with the indigenous know-how.

We have yet about 67 million hectare metres of surface water potential to be utilised most of them in the large rivers like Godavari, Krishna, Narmada, etc. Estimated surface water potential is given basinwise in the Annexure. Enunciation of a National Water Policy, recognising the political boundaries as the boundaries for river waters, harnessing and utilisation, inter-state mutual agreements on potential utilisation and investments can expedite irrigation development through surface waters.

Simultaneously progress is to be maintained in the development of ground water potential and also in planning the conjunction use of surface and ground water. Dugwells have served irrigation from ancient days and lift irrigation has been largely practiced. This registered a boost with the ushering in of electrical pumps in the rural areas. The physical achievements in this sector is given in the Annexure.

Prospecting for the ground water is now done utilising the latest techniques. The centre has set up the Ground Water Board and each State has ground water departments who work for assessing the potential, the recharging possibilities and plan for extraction without dangerous depletion. The estimated ground water potential, the present utilisation and the scope for development are given in the Annexure.

Surface water potential is fast getting exhausted. Over extraction of ground water can only be detrimental. With advancing technology and with the demand for water more pressing, methods that now seem uneconomical and impracticable would become necessities and may have to be adopted to augment our water resources.

Desalinisation of sea water is one such. At present this process is attempted in a few countries to meet the drinking water needs. Large scale development of this process to meet deficiencies in irrigation requirement will remain uneconomical for a long time to come.

Recycling used water is another attempt. Purifying sewage water to varying degrees and making them fit for agricultural and other needs is already in general practice.

Weather modification to upset the hydrological balance in order to obtain more of usable water is tried experimentally in several countries. Cloud seeding and attempting to melt icebergs are some efforts already in the thinking.

3. Water saving methods in irrigation practice

With the pressure on demand of water for agricultural purposes continuously rising study of all aspects of use of water to achieve the maximum efficiency becomes imperative. While searching for more water for use economic use of available water becomes the first responsibility.

To understand the best management of water, an understanding of the soil moisture relationship with reference to crop growth is essential.

The depth of the rock zone depends on the nature of the crop. The water requirements for the crop depends on several factors like the kind of crop, texture of soil, weather condition, seasonal variations, stage of growth and so on. The infiltration of the irrigation water depends on very many factors like the texture of soil, grain size, structure, initial soil moisture condition, temperature and so on.

The ideal conditions for the irrigation of the crop can be provided in the hypothetical condition.—

(i) Maintaining the ground water level just below the rock zone such that the capillary rise feeds the roots of the plants continuously. This is a very difficult condition to maintain although the crop season. Water logging is a possible danger.

(ii) Providing irrigation such that enough moisture is given to the soil in the rock zone direct avoiding watery loss by either deep percolation or evaporation. Water saving processes now adopted attempt this possibility.

In the traditional methods of irrigation like the inundation irrigation, the borderstrip irrigation, furrow irrigation, water is allowed to flow over land by gravity and spread and rise to the required standing depth on the field. Water loss occurs in deep percolation as well as by evaporation from the vast surface spread.

Sprinkler irrigation is done through a net work of pipe lines laid on the crop land in which water is maintained under pressure and sprinkled on the surface. The design and regulation is so done that soil is kept moist to the requirements. Deep percolation loss is avoided. Loss by evaporation is still there.

Underground or drip irrigation is done through a net work of pipe lines designed and buried underground. Issues are controlled such that water is fed in slow drips around the roots of plants through specially designed outlets and the zone is kept moist to the requirements. Both deep percolation and evaporation are very much under control in this process.

Both the sprinkler and drip irrigation are particularly useful in the case of orchards and similar crops and are not now adoptable for food crops like paddy.

Providing polythene sheet base in the crop fields to avoid deep percolation is now gaining ground. Soil to a depth of about 30 cm. is dug out, black polythene sheets are spread to cover the land area and the soil is spread back and cultivation processes continued. Other base materials like concrete or stabilised soil spread were earlier tried and now almost given up being costly.

4. Water in a basin—

Since our water resources are fast getting utilised, it is going to be increasingly difficult to match supplies with demands. Taking into account the existence of imbalance of special and temporal availability as well as quality, our measures for storage, processing and optimum utilisation cannot any longer be looked upon from the technological angle alone but have to be deeply interlinked with socio-economic considerations. The whole problem should hence be solved by systematic approach.

A river basin is a natural unit. It has a defined watershed boundary and within it there is inter relation of resource elements. Stressing on this concept the Irrigation Commission 1972 has recommended formulation of river basin plans which give a comprehensive outline of the development possibilities of land and water resource to meet the anticipated regional and local needs. These plans should indicate the broad framework of various engineering works, priorities in respect of water use for various purposes and priority of projects.

Master plans for the optimum utilisation of water resources in a basin based on the decided water use are hence to be drawn dovetailing into this the existing schemes already in operation. This needs as pre requisites.

(a) a fairly accurate survey of the resources both surface and subsurface and also underground in the basin;

(b) an assessment of the water requirements for various uses within the basin with fair projections for the future;

(c) a clear statistics of the existing use;

(d) an exercise on the possible saving in the existing use;

(e) a water balance sheet;

(f) a decision on the priorities for future use; and

(g) a detailed plan for the optimum utilisation of the available water balance.

On every aspect of the above mentioned stages the latest technologies are to be brought to play if we are to gain from the knowledge. On this basis a National Water Plan and National Water Policy have to be evolved.

5. Water transfer basin to basin.

With the River Basin Plans made out, it is possible to identify the surplus and deficit basins. Based on the decision on priorities the National Water Plan has to provide for transfer of water from a surplus basin to an adjacent deficit basin. The National Water Grid proposed by Dr. K. L. Rao envisages such basin to basin transfers covering a number of States in the Country.

Inter-basin transfer of water was first effected in the Country in the Periyar Project executed in the 1890s through which the surplus waters of the basin of River Periyar flowing west were diverted to the east flowing River Vaigai.

In the second Five Year Plan, another major effort to inter basin transfer was made through the Parambikulam, Aliyar Project, a multi-valley multi-purpose venture. The flows through Nirar, Shclayar and Parambikulam. the west flowing streams of Chalakudi basin are inter-linked through a chain of storages and tunnels and are carried to the east of the Western ghats to combine with the flows of Aliyar and Palar to serve a large ayacut in the Coimbatore district.

There are possibilities of some more inter basin transfers which can be effected by mutual co-operation among the States concerned.

The proposal recently announced by the Prime Ministers of India for bringing Krishna Waters for drinking to Madras City is again another instance of inter-basin transfer of waters made possible by the benevolent gesture of Maharashtra, Karnataka and Andhra.

6. Conclusion.

Water, the Nature's gift to mankind is becoming scarce, because of the fast rising demands on its use. While it is the Engineer's and Scientist's responsibility to devise ways of its economical use, it is the common man's responsibility to avoid waste of usable waters.

ANNEXURE

I. WATER RESOURCES POTENTIAL IN INDIA :

Unit : Million hectare metre.

Estimated Basin-wise Surface Water Resources Potential—

I west flowing Rivers—

1 River basins of Kerala	3.69
2 River basins of Madras and Bombay below Tapi	18.03
3 Tapi basin	1.97
4 Narmada basin	4.00
5 Basin above Narmada	2.77
	30.46

II East Flowing Rivers—

6 Tambaraparani and Vaigai River Basins	0.87
7 Cauvery basin	1.85
8 Mahanadi and other basins between Ganga and Godavari	13.10
9 Godavari basin	11.50
10 Krishna basin	5.76
11 Pennar	0.68
12 Basins between Cauvery and Pennar	1.68
	35.44

III Indus Basin 7.92

IV Ganga Basin—

13 Chambal river basin	2.42
14 Jamuna river basin	6.54
15 Ram Ganga basin	1.85
16 Tons river basin	6.62
17 Gomti basin	0.84
18 Sone and other basins between Tons and Sone	5.00
19 Gogra	11.40
20 Right Bank tributaries below Sone	4.50
21 Left Bank tributaries below Gogra	17.42
22 Main Ganga	4.24
	54.83

V 23 Brahmaputra and Barak basin 58.90

Grand Total .. 187.55

B. Estimated utilisation already made	34.44
C. Available for further utilisation	153.11
D. Possible further utilisation (about)	67.00
E. Ultimate feasible surface water utilisation	101.54
F. Estimated Ground Water recharge	26.91
G. Annual draft present	11.81
H. Available for further ground water development	14.88
I. Ultimate Irrigation Potential from both surface and ground water	128.50
J. Scope for development	72.25
K. Present utilisation both surface and ground water	46.25

II. STATISTICS ON IRRIGATION DEVELOPMENT IN INDIA

A. Progress in Development of Irrigation potential—

Item.	Utilisable water resources (million hectares).	Ultimate irrigation potential (million hectares).	Achievement to end of (cumulative)		
			1950-51 irrigation potential (million hectares).	1973-74 irrigation potential (million hectares).	1978-79 irrigation potential (Target)
(1)	(2)	(3)	(4)	(5)	(6)
1. Surface Water	67.0	72.0	16.1	28.9	36.4
(a) Major (above Rs. 50 million) and medium (Rs. 2.5 to Rs. 50 million)	67.0	57.0	9.7	21.4	27.4
(b) Minor (costing less than Rs. 2.5 million each).	..	15.0	6.4	7.4	9.0
2 Ground Water	26.5	35.0	6.5	16.0	20.5
Total	93.5	107.0	22.6	44.9	56.9

B. Outlays for Irrigation Programme :—

Plan.	Financial Outlays Rs (millions)		
	Major and Medium Irrigation Programme. Public sector.	Minor Irrigation Programme.	
		Public sector.	Institutional sector.
(1)	(2)	(3)	(4)
1. First Plan (1951-56)	3,800	656	N. A.
2 Second Plan (1956-61)	38,00	1,433	280
3 Third Plan (1961-66)	5,760	3,279	1,000
4 Annual Plans (1966-69)	4,197	3,144	2,051
5 Fourth Plan (1969-74)	11,700	5,309	4,500
6 Fifth Plan (1974-79) proposed	24,010	8,106	5,000

C. Physical Achievements under Minor Irrigation Programme.—

Item.	Position at the commencement of plans. (1950-51)	Position at the end of 1973-74.	
		1968-69	(provisional).
(1)	(2)	(3)	(4)
1 Dug wells	50,00,000	56,95,000	67,00,000
2 Pump sets	90,800	10,89,000	25,00,000
3 Private tube wells	N.A.	2,66,000	8,00,000
4 Government tube wells	2,400	15,000	20,000

III. WORLD STATISTICS OF IRRIGATED AREA:

1. Available assessments of the World's irrigated area:—

Author (Country).	World's irrigated total. (million hectares).	Year of Publication.	Reference.
(1)	(2)	(3)	(4)
D. Thorne and H. Peterson (USA)	106.3	1949	Not mentioned.
N. D. Gulhati (India)	121.0	1955	Not mentioned, tentatively, FAO Production Yearbook.
L. M. Cantor (USA)	148.0	1964	UN & FAO materials.
E. M. Highsmith (USA)	172.6	1965	FAO Yearbooks and ICID bulletins.
V. M. Borovsky (USSR)	203.2	1969	FAO Production Yearbook.
S.A. Girshkan (USSR)	225.3	1969	FAO Production Yearbook and ICID Bulletins.

2. Irrigated Areas in a few Countries of the World.—

Name of Country.	Total area.	Cultivated area.	Irrigated area.	Percentage of cultivated area to total area.	Percentage of irrigated area to total area.	Percentage of irrigated area to cultivated area.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1000 hac.						
<i>Europe.</i>						
Austria	8,385	1,681	30	20.0	0.3	1.8
Belgium	3,051	813	100	27.6	3.2	11.8
Denmark	4,307	2,662	60	61.7	1.3	2.2
France	54,703	19,101	825 (2)	34.9	1.5	4.3
Federal Republic of Germany	24,728	8,083	300	32.7	1.2	3.7
German Democratic Republic	10,793	4,813	355	44.6	3.3	7.3
Greece	13,194	3,631	753	27.5	5.7	20.7
Italy	30,123	14,409	3,500	41.1	11.6	29.0
United Kingdom	24,401	7,227	120	29.6	0.5	1.6
<i>Asia.</i>						
Afghanistan	64,750	7,980	2,900	12.3	4.4	30.5
Bangladesh	14,277	9,069	686	63.5	4.8	7.5
Burma	67,803	18,920	839	27.6	1.2	4.4
India	3,26,809	1,64,610	38,969	50.3	11.9	23.6

2. Irrigated areas in a few Countries of the World—cont.

Name of Country.	Total area.	Cultivated area.	Irrigated area.	Percentage of cultivated area to total area.	Percentage of irrigated area to total area.	Percentage of irrigated area to cultivated area.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1,000 hac.						
<i>Asia—cont.</i>						
Indonesia	1,90,435	18,000	6,800	9.4	3.5	37.7
Iran	1,64,800	16,727	5,251 (4)	10.1	3.1	31.3
Iraq	43,492	10,163	4,000	23.3	9.1	39.3
Israel	1,400 (3)	417	173	29.7	12.3	41.4
Japan	37,208	446	2,626 (7)	14.6	7.0	48.2
Malaysia	33,300	3,523	255	10.7	7.6	7.2
Nepal	14,080	1,980	181	14.0	1.2	9.1
Pakistan	80,700	21,700	12,400	26.8	15.3	57.1
Philippines	30,000	11,146	1,090	37.1	3.6	9.7
South Arabia	2,14,969	809	131 (1)	0.3	0.06	16.1
Sri Lanka	6,561	1,979	465 (7)	30.1	7.0	23.5
<i>Africa.</i>						
Algeria	2,38,174	6,792	300	2.0	0.1	4.4
Ghana	23,800	2,835	12 (8)	11.9	0.05	0.4
Libya	1,75,954	2,521	120	1.4	0.07	4.7
Malagasy Republic	58,704	2,856	900	4.8	1.5	31.5
Mauritius	186	105	15	5.6	8.0	14.2
Morocco	44,505	7,900	680	17.7	1.5	8.6
Sudan	2,50,581	7,000	2,520	2.8	1.0	25.4
Switzerland	1,736	251	20	14.5	1.4	10.3
UAR (now ARE)	1,00,145	2,852	2,852	2.8	2.8	100
<i>North and Central America.</i>						
Canada	9,97,614	43,767	627	4.3	0.06	1.4
Jamaica	1,096	241	35	21.8	3.2	14.4
Mexico	1,97,255	23,817	4,200	12.0	2.1	17.5
Puerto Rico	889	236	39	26.3	4.3	12.3
USA	9,36,335	1,92,318	21,489 (15)	20.5	2.2	11.1

2. Irrigated areas in a few Countries of the World—cont.

Name of Country.	Total area.	Cultivated area.	Irrigated area.	Percentage of cultivated area to total area.	Percentage of irrigated area to total area.	Percentage of irrigated area to cultivated area.
(1)	(2)	1,000 hac. (3)	(4)	(5)	(6)	(7)
<i>South America.</i>						
Argentina	2,77,689	26,028	1,555 (16)	9.4	0.5	5.8
Bolivia	1,09,858	600	64	0.3	0.05	10.5
Chile	75,690	4,632	1,500	6.1	1.9	32.4
Colombia	1,13,891	5,054	226	4.4	0.2	4.4
Ecuador	28,356	3,815	463 (19)	1.3	1.6	12.1
Guyana	21,497	833	140	3.9	1.5	18.1
Peru	1,28,522	2,979	1,116	2.3	0.9	37.3
Surinam	16,327	38	27	0.2	0.1	71.4
Venezuela	91,205	5,214	1,000	5.7	1.1	19.1
<i>Australia and Oceania.</i>						
Australia	7,68,681	44,610	1,581	5.1	0.2	3.5
New Zealand	28,867	834	120	3.1	0.4	15.6
<i>USSR.</i>						
USSR	2,240,220	232,609	11,500 (20)	10.4	0.5	4.9

3. IRRIGATED AREAS IN THE WORLD.

(1)	Agricultural (1) Land (1,000) hectares.		Included irrigated Land.		
	Cultivated Land.	Meadows and Pastures.	Area (1,000 ha.)	Percentage area Cultivated Land.	Percentage area Agricultural Land.
(2)	(3)	(4)	(5)	(6)	(7)
USSR (2)	232,609	374,700 (3)	11,500 (4)	4.5	1.9
Europe excl. USSR	145,000	91,000	12,774	8.8	5.4
Asia Excl. USSR	463,000	5,511,000	164,640	35.5	16.9
Africa	214,000	822,000	8,929	4.0	0.8
North and Central America	271,000	362,000	27,431	10.0	4.0
South America	84,000	363,000	6,662	7.9	1.0
Australia and Oceania	47,000	463,000	1,701	3.6	0.3
Total	1,457,000	2,987,000	233,637	16.0	5.2

EARTH RESOURCES SURVEY BY
REMOTE SENSING TECHNIQUES.

By

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In the recent past, evaluation of earth resources techniques have been revolutionised by the use of aerial photographs, Satellite imageries and other methods of remote sensing techniques. Remote Sensing is the name given to the techniques of obtaining information about a subject of interest without being in direct contact with it. The technique relies on detecting electromagnetic radiation which is either reflected or omitted by the objects ranging in wave lengths from ultra-violet to the microwave region of the spectrum (Figure 1).

Modern remote sensing devices include passive and active systems and employ different bands in the visible spectrum, in the near infrared and the far infrared as well as in the centimetre radio waves. The reflectivity and emissivity of the terrestrial objects in the lithosphere, hydrosphere or biosphere in the various bands of the electromagnetic spectrum are quantitatively registered by the sensing devices.

The basic difference between the "passive system" and "active system" is that "passive systems" utilise energy which nature provides (solar energy) and record both reflected light energy and emitted thermal energy from the earth's surface, whereas "active systems" utilise artificial energy sources such as radar pulses, photo flash-bombs and laser beams etc. (Figure 2). There are at present means of producing electro-magnetic radiation of almost any desired wavelength for use in active remote reconnaissance systems.

For the preparation of thematic maps, Earth Resources Technology Satellite Imageries (now renamed as Landsat) of four spectral bands are mostly used. Band 4 (0.5 to 0.6 micrometres) is found to be most useful for discriminating quantitatively the depth and turbidity of standing water bodies. Band 5 is suitable for showing topographic and cultural features such as drainage patterns, roads, towns, etc. Band 6 shows best tonal contrasts that reflect various land use practices and Band 7 is best for land-water discrimination (Figure 3).

Landsat Spacecraft.

By the launching of unmanned satellites ERTS-1, and ERTS-2, on 23rd July 1972, and 22nd January 1975, respectively, the supply of remotely sensed data about the earth has greatly increased. The satellite circles the earth in a near polar orbit at an altitude of about 910 km. It carries imaging systems and acquire images of about 188

scenes per day. The butterfly shaped space-craft weighing about 891 kgs. views large areas in a fraction of a second. The satellite orbit takes 103 minutes to go round the earth once. Landsat makes 14 orbits a day. Every equatorial crossing occurs at approximately the same local time each day about 9.30 a.m. The orbit is adjusted so that a strip observed on one given day in one given location advances Westward by about 159 km. on the next day. In this way, the sensors of the space-craft view the entire world between 80°N and 80°S once in every 18 days.

The Landsat pay load consists of 3 major elements as described below:—

(a) *Return Beam Vidicon (RBV)*.—Consists of 3 Cameras. Each camera is sensitive to a different colour band in the electromagnetic spectrum—green, red and near infrared with the smallest feature identifiable being about 90 metres (300 feet). The three cameras simultaneously photographs the area of 185×185 km. square and take overlapping pictures as space-craft travels. But due to electrical malfunction, the RBV cameras did not work in the Landsat flights.

(b) *Multispectral scanner sub-system (MSS)*.—The other sensor sensitive to 4 spectral bands is the line scanning device. This scans horizontally along with orbital tract and gathers data by imaging the surface of the earth in four spectral bands simultaneously through the same optical system. The space-craft scans across an area of about 185×185 km. square (100 n.mi.²). If a ground station is in sight, the space-craft transmits the data from the sensors immediately. Otherwise the data is stored on tape for transmission later. This data when processed is useful in many studies such as agriculture, forestry, water resources, marine resources and biology, Land use, Geology, air and water pollution.

(c) *Data Collection System (DCS)*.—The DCS is a communication system which collects information from about 150 remote ground platforms and relays the information to NASA ground stations for delivery to the users.

Landsat-2 contains the same payload as that of Landsat-1, excepting that a fifth channel to the scanner has been added which is measuring the heat energy radiated both day and night from land and water surfaces.

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Analysis of Data

(a) *Principal of image analysis.*—Photo-interpretation can be defined as "the act of examining photographic images of objects for the purpose of identifying the objects and judging their significance". Only recently, within the last two decades, man has been able to produce photo-like images by using radiant energy from the infrared, microwave and ultraviolet parts of the spectrum other than that contained in the visible light. These photo-like images are named as 'imageries' and the act of examining the imagery for the purpose of identifying the objects and judging their significance is termed as 'image analysis'.

Black and White aerial photo-interpretation techniques are much simpler as compared to the multispectral satellite imageries. For practical purposes, vertical air photos are mostly used in which stereoscopic study of the photographs and interpretations are easy. In the case of multispectral photos, while stereoscopic vision is possible, trouble arises from having more than one set of images with identical perspectives.

The volume of data generated by remote sensing systems is exceeding the capability of trained image interpreters. Landsat space-crafts alone generate numerous image of 10,000 sq. ml., areas in a single year. The analyst cannot hope to accomplish much in the way of interpreting the data. As the number of spectral bands used in remote sensing is increased, the task of analysing data also grows larger. It can become unmanageable unless he has equipment that helps him to correlate the multiband images.

The best means of accomplishing this is to set up a test site in which each type of feature that is to be identified by remote sensing is exhibited. By studying multiband images obtained from the test site the analyst will equip himself to recognise, by their unique spectral response patterns, the features that are of interest to him in a sensing mission. One such test should be included in each sensing flight for calibration purposes.

Apart from the interpretation on different bands of images, two or more images can be combined by projecting them one over the other either optically or electronically. For example, when red, green and blue light are projected together so that these impinge upon one another the result is white light. These are the primary additive colours. By making exposures through blue, green and red filters, one may obtain colour positive transparencies for projection. Using different projectors the images may be superimposed upon one another.

Instead of making these combinations optically, one can use an array of TV Camera—monitor systems to scan each of the multispectral pictures, code them according to tonal density in specific colours and superpose the resultant color images with Geometric fidelity. This technique is known as electronic colour coding. Though the human eye can distinguish only a maximum of 30 levels of grey (in black and white picture), with the introduction of colour enhancement technique, the number of categories increases to over 200. Colour coding thus enhances the discrimination potential considerably.

Similar to these methods is density slicing (delineating areas falling within specific narrow ranges of tonal density), which is found to be useful in the study of coastal tracts. For, e.g. water on a near infrared black and white photograph may be emphasised. Since water absorbs infrared radiation, it is normally the blackest item on a

near infrared photograph. Through exposure control, one may photographically clip out all grey tones lighter than those of water. One would thus obtain a photograph in which water bodies appear as black and everything else as white.

The multiband sensing system records on magnetic tape, rather than on photographic film. The sensors on board record degrees of brightness. For each part scanned, the sensors automatically determine a tone signature which will be identified with some signature established from the site.

Remotely sensed multispectral data recorded in magnetic tapes are retrieved by special as well as general purpose computers. With the use of programmes, like CBSER (Pennsylvania State University), LARS (Purdue University), BENDIX (Michigan University), Image 100 (General Electric Co.) etc., or with our own programmes, different thematic maps can be printed not using modern third generation computers.

Thermal infrared radiation of the objects on the earth is measured for resource inventory. Earth is an excellent energy source for a passive sensing device operating in the far infrared wavelengths. All objects above absolute zero which absorb the sun's radiant energy tend to increase in temperature and re emit the energy basically in the infrared portion of the spectrum. This is known as 'radiant energy'. Thermal infrared sensors like optical Mechanical scanner, images such emitted radiation although reflected radiation may also be recorded.

Radar.—

Radar is an active remote sensing system which operates in the microwave portion of the electromagnetic spectrum. Side-Looking Airborne Radar imagery (SLAR) is a type of remote sensing device, which scans the path to one side of the air craft's flight path. A pulse of energy is transmitted from the radar antenna and the relative intensity of the reflections from objects being sensed produce an image. On the next transmitted pulse, the air craft as moved forward a small distance and a slightly different strip of terrain is imaged.

SLAR produces a continuous strip image that is similar to an aerial photo. However, the area imaged is not below the aircraft, as in a photograph but lies to the side of the aircraft. SLAR is an attractive tool for the making of broad reconnaissance resource inventories. It is sensitive to changes in slope of the land surface roughness and is able to rapidly acquire photo like imagery of large areas with relatively good resolution. It has the ability to penetrate clouds. In areas that have high rainfall or are normally cloud covered, SLAR may be the only means of acquiring imagery of the ground. In areas of low relief or uniform ground covers SLAR often yields more information about subtle details of geomorphology than can be obtained from normal aerial photography which is acquired under conditions of high sun illumination.

SLAR imagery can be applied to the solution of a wide variety of resource inventory and terrain evaluation problems. Geomorphologists have used SLAR for many purposes including the analysis of stream networks, regional slopes, meandering streams, etc. SLAR is a very good tool for geologic mapping and particularly for recognising major fracture patterns and identifying regional structural features.

Applications of Remote Sensing systems.—

To meet the accelerated demands for resources, we must find means to accelerate our acquisition of knowledge concerning them. Aerial photography and airborne geophysical surveying techniques have already increased the rate at which new knowledge of the resources can be acquired. The use of remote sensing devices mounted in earth-orbiting satellites has further increased the capability of acquiring knowledge of the earth resources.

Remote sensing systems is capable of providing more comprehensive and accurate surveys of earth, hydrologic and oceanographic resources, a better control of environmental and ecological conditions, particularly pollution, and the monitoring of agricultural resources management and productivity

Water Resources.—

Water management activities include the mapping of water, studying its properties, predicting its behaviour, impounding it, diverting it and using it to serve agricultural industrial and municipal needs and to create electric energy. Hydrological data are to be collected through rain gauge/seam gauge stations and by observing water levels in observation wells meteorological stations etc. over a wide area if the performance of water management functions is to be satisfactory. Remote sensing techniques using satellite imageries can provide a satisfactory solution for the data collection problem. They can provide large scale repetitive imagery for water systems significantly supplementing data taken at individual points.

The available water in an entire river, lake or tanks can be mapped repeatedly. Various land uses related to water resources management can be easily identified and mapped. Sources of water pollution, increasing sediment load and changing water yield can also be delineated using different bands of satellite imageries.

In general, topographic maps do not possess the kind of dynamic hydrologic information available from the repetitive coverage of landsat. With satellite imageries, stream channel development and net works, stream length etc. can be mapped.

In addition to water inventories, remote sensing may help to reduce water losses. Using thermal infrared imageries, it is possible to locate the areas where underground fresh water flows to the sea.

Mapping of vegetation and weeds using satellite imageries will help in estimating the evaporation and transpiration of water.

Surface water bodies as small as one hectare can be found and courses of rivers as narrow as 70 meters can be easily mapped. So also mapping of floods including mapping the physiographic characteristics, channel configuration soil and vegetation differences, agricultural patterns, etc. can be done using satellite imageries.

Geological applications.—

Remote sensing has played a key role in geological exploration because it is the most practical method of measuring many pertinent physical properties of large and generally inaccessible areas. The information derived

provides a means for studying regional features for extrapolating local measurements to regional scales and for identifying critical areas for subsequent detailed studies.

In regions where rock exposures are good because of thin vegetation, major geologic features such as folds, faults, intrusion outlines, volcanic flows, contacts between distinctly different thick rock units and many land form types can be mapped using satellite images in conjunction with Aerial photo study.

The best achievement of Landsat imagery analysis is the direct identification of linear features between tonally contrasted surfaces or indirect alignments of topography stream segments and identification of circular features. These linear features vary in scale from a few kilometres to regional or subcontinental dimensions. Certain linear features may be known and studied in detail but unknown features could be studied for mineral deposits or groundwater resources. Some of the deposits are mostly controlled by or associated with lineaments or circular structures. Recognition of inter-section of lineaments provides new targets for mineral prospecting. Fracture zones and joints and major faults are frequently avenues of groundwater flow and storage.

In some locations, lineaments are found to be active faults and hence sources of destructive earthquakes. Study of land forms and dynamic surface processes is effectively done using satellite imageries. Satellite imageries have provided scientists an unexcelled opportunity to study volcanoes and their effects on surrounding areas.

In regions for which only poor quality maps are available landsat image offers an excellent method of generating good maps at small scales.

Agriculture.—

Application of remote sensing techniques to agriculture is large and appealing. For any agricultural management system, the availability of timely information on agricultural conditions is most essential. Repetitive aerial surveys and satellite imagery during the vegetative growth and harvest times of a crop can provide reliable inventories of the size of the harvest.

Use of multispectral, especially infrared band imagery is expected to be of great help in the identification of crops and timber species, in the analysis of crop vigour, in the early detection of crop diseases and other forms of crop stress (for example, that due to deficient water-supply). The valuation of the large scale effects of different kinds of fertilization and irrigation practices on agricultural land can be carried out more satisfactorily by remote sensing techniques than through isolated conventional ground measurements. Remote sensing is the only technique capable of achieving repetitive observations of large agricultural areas over a short period.

Conclusion.—

Remote Sensing Technique is not an end in itself for earth resources survey. 'Ground Truth' or 'on-site' verification is also a must. Therefore, in conclusion, it must be stressed that these data have their own limitations and are subject to careful interpretations supported by adequate ground truth verification.

FIG. 1

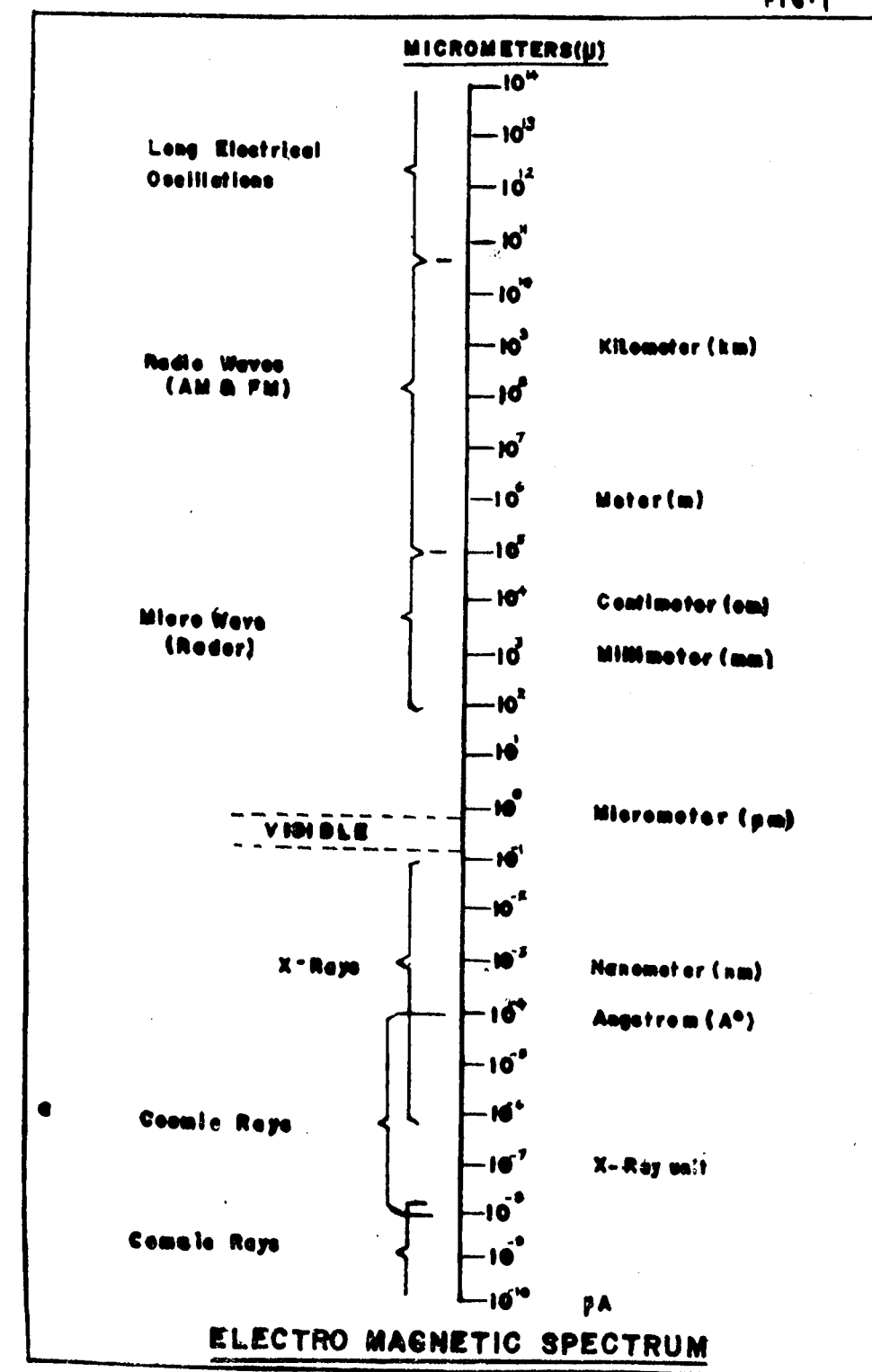
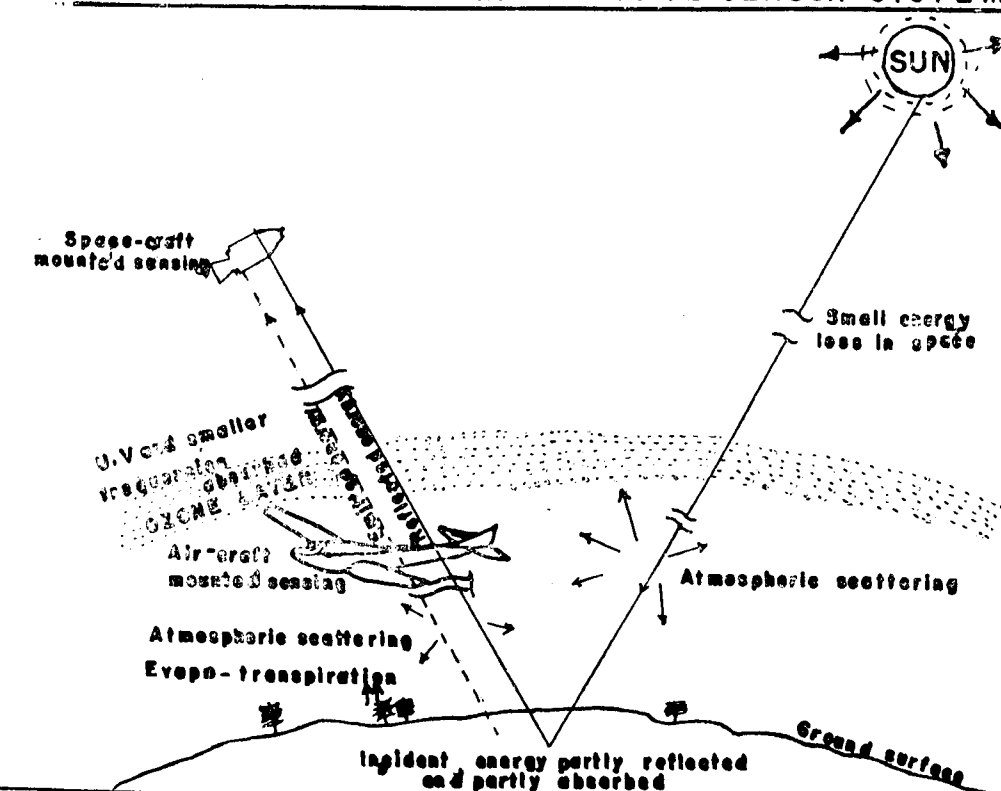


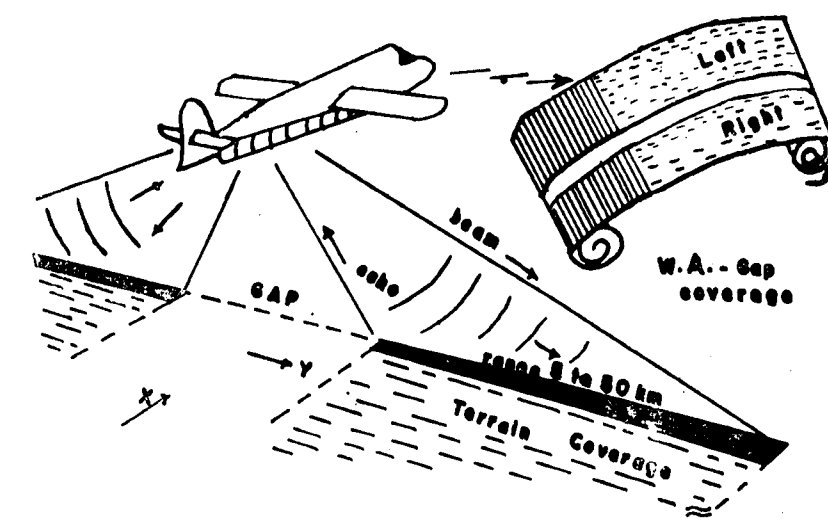
FIG. 2.

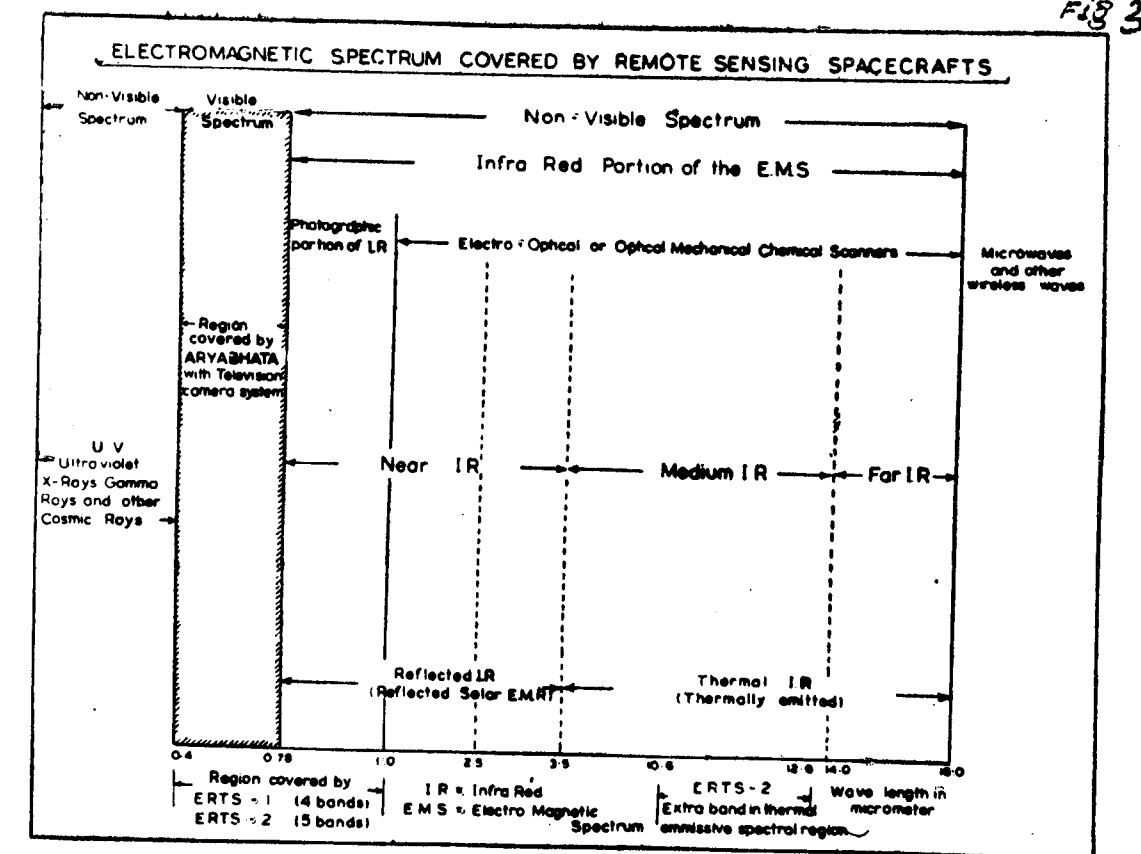
ENERGY FLOW PROFILE IN A PASSIVE SENSOR SYSTEM



SIDE LOOKING AIRBORNE RADAR : SLAR ACTIVE SYSTEM

Long Antenna alongside of Aircraft concentrates pulsed, narrow (in X = azimuth) radar beam side-way oblique.

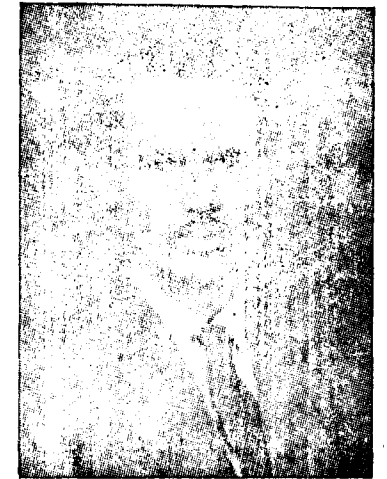




DROP IRRIGATION

By

THIRU R. K. SIVANAPPAN*



1. Introduction.

Irrigation is an age old art and it is as old as civilization. It is stated that the irrigation has been a major instrument in the advancement of ancient civilization. However, it is a fact that though there are immense advancement in all the fields of man's life there is no advance or improved practices in irrigation. We are witnessing many improved high yielding varieties of seeds and also implements for various operations including tractors, but the irrigation practices followed in India today is the same old practice followed thousands of year ago. In fact, there is no difference between the irrigation in ancient time and at present in our country. The progress in modernising irrigation has been rather very slow.

In Western countries, improvements were made in surface methods to find out the optimum size for the furrow and border irrigation so that the water will store only in the root zone. Even this cannot be attributed to a great improvement in irrigation practices. Mr. Velh Meyer of U.S.A. and his followers have studied the proper time to supply water to the crops and the same has been questioned in the later studies by various authors. A very remarkable change in the approach to irrigation came about in the later part of the last century and the earlier part of this century with (1) the development of pumping and power facilities; (2) the better understanding of the soil plant water relationships and (3) the development of modern equipments for irrigation.

In Tamil Nadu, irrigation is done for all kinds of crops. The total sown area is 7.5 m. ha. and the gross irrigated area is about 3.2 m. ha. which works out to about 40 per cent. We have already harnessed about 95 per cent of the surface water and nearly 60 per cent of the ground water. To bring more land under irrigation, we have to make a breakthrough in saving water by conservation and improved methods of irrigation practices.

2. Methods of irrigation.

The common method of irrigation practised throughout the world is gravity irrigation and it covers about 95 per cent of the world irrigation. In this method water is diverted into the canals from the rivers and tanks to supply individual lands. The irrigation is done in furrows in borders, in basins or in corrugations; all are the same in principle. In this way, water is flooded in the field and leads to the low efficiency which is inherent in gravity flow. The excess water delivered to the field is the cause for water logging and salinization or alkalination of the soil.

The studies conducted at Tamil Nadu Agricultural University Coimbatore and elsewhere have shown that the efficiency of irrigation never exceeds 50 per cent. Lower efficiencies are obtained in less favourable instances. This method of irrigation is also having the following disadvantages—:

1. Water used is more per unit area since light application is not practicable.
2. Causes water logging and salinity.
3. Drainage may be needed extensively.
4. The land has to be levelled which is costly.

Next improvement in irrigation is by using sprinkler. In U.S.A. sprinkler method is resorted to extensively to save labour. In Israel almost all crops are irrigated and over 90 per cent of them by sprinklers. But in India, this method is not popular as it is very costly. In recent years, the Israeli scientists have developed a new method of irrigation which is known as drip irrigation or trickle irrigation or daily flow irrigation. This is going to be a significant advance in the science of irrigation in the world. Work is taken up at Tamil Nadu Agricultural University, Coimbatore also to evaluate the drip irrigation system for various crops.

3. Drip irrigation.

Drip irrigation in Agriculture is relatively new, but it is used mostly in Israel, Australia and U.S.A. The development of drip irrigation was started by Shmcha Blass, a water engineer in Israel during 1959. The idea has spread all over the world and much work is in progress on the drip irrigation research.

This method has the following merits besides effecting increased fertilizer efficiency.

- (a) Increased yield.
- (b) Decreased water use.
- (c) Decreased tillage.
- (d) Higher quality.
- (e) Reduced disease incidence.
- (f) Less moving parts.
- (g) Shorter growing season.
- (h) Reduced labour cost.
- (i) Versatility in undulating land.
- (j) Utility under poor water quality.

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Working of this system

The irrigation method is based on the conveyance of water with little pressure (1.2 metre head) until it reaches points of dispersal and whereupon the water leaves the system through drip nozzles or holes with socket under no pressure. Drip irrigation generally wets a much smaller volume of soil than surface or sprinkler method and causes plants to have smaller root systems. The areas watered in the 3 main types of irrigation systems are illustrated in Figure 1.

Two conditions help compensate for this. The smaller root zone is kept at a higher soil moisture level so that rapid absorption can help balance the smaller absorbing area of root system. It is also reported that in some cases drip irrigation produces faster than the other methods.

Drip irrigation wets only part of soil surface and the crop is located in this wetted area. The width of the wetted area is a function of the soil type and the depth of wetting is a function of the ratio between rate of water application and evapotranspiration and of the soil type. The discharge of the regular drip nozzles or holes ranges from 1 to 10 litre per hour. The arrangement of drip irrigation is shown in Figure 2.

The work done at Tamil Nadu Agricultural University Coimbatore on tomato, bendai, brinjal, sweet potato, Banana, Cotton and Chilly has proved that by using only $\frac{1}{3}$ to $\frac{1}{4}$ of the water utilised by the conventional method (surface) we can raise these crops and at the same time the yield is also increased by 10-30 per cent. The table 1 below gives the water use and yield of various crops in drip as well as control (surface irrigation).

TABLE 1.

WATER USED AND YIELD IN DRIP AND CONTROL METHODS.

Serial number crops.	Water used in cms.		Yield in Kg/ha		Rainfall during the period in cms.	Remarks.
	Drip plot.	Control plot.	Drip plot.	Control plot.		
1. Tomato	10.76	49.80	8,872	6,187	24.18	
2. Bhendi	8.60	53.53	11,310	10,000	24.18	
3. Beetroot	17.73	85.76	887	571	Nil.	
4. Radish	10.81	46.41	1,186	1,045	Nil.	
5. Chilly	41.77	109.71	6,080	4,233	20.75	
6. Brinjal	24.47	69.18	12,300	12,400	17.18	
7. Banana	58.00	243.00	15.31 kg. plant	15.95 kg. plant.	34.00	
8. Sugarcane	72.90	131.86	75,000	86,000	33.50	
9. Sweet potato	25.20	63.14	5,888	4,224	12.12	

4. Conclusion

The drip irrigation is an important advance in the world of agriculture. The results surveyed in various places indicated that there are not only savings of water consumption on drip irrigation but also increase in yields than the surface irrigation methods. The design of drip irrigation unit has not reached its final stage and there are still problems. Research on improving the system is in progress all over the world including at Tamil Nadu Agricultural University, Coimbatore. It is clear that the trickle irrigation can play a considerable part in the nation's agricultural economy and at the same time help

us to use our limited water resources more efficiently. The cost of the unit per hectare is about Rs. 10,000.

Reference.—

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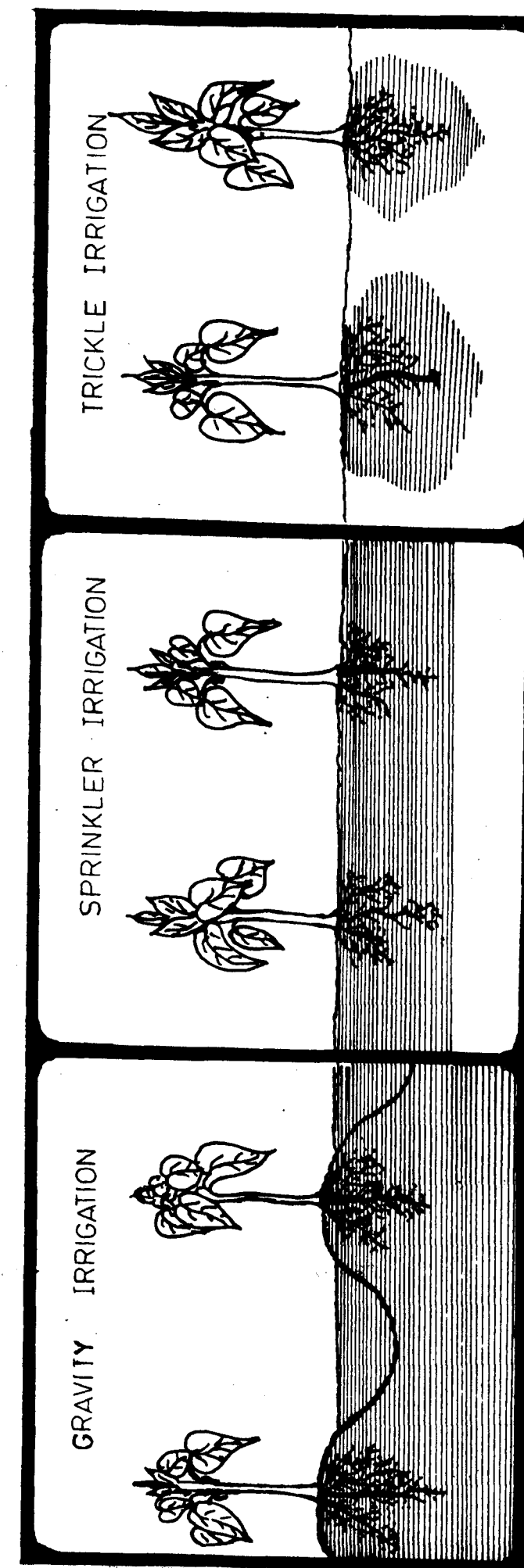


Fig.1. Areas watered by three methods of irrigation

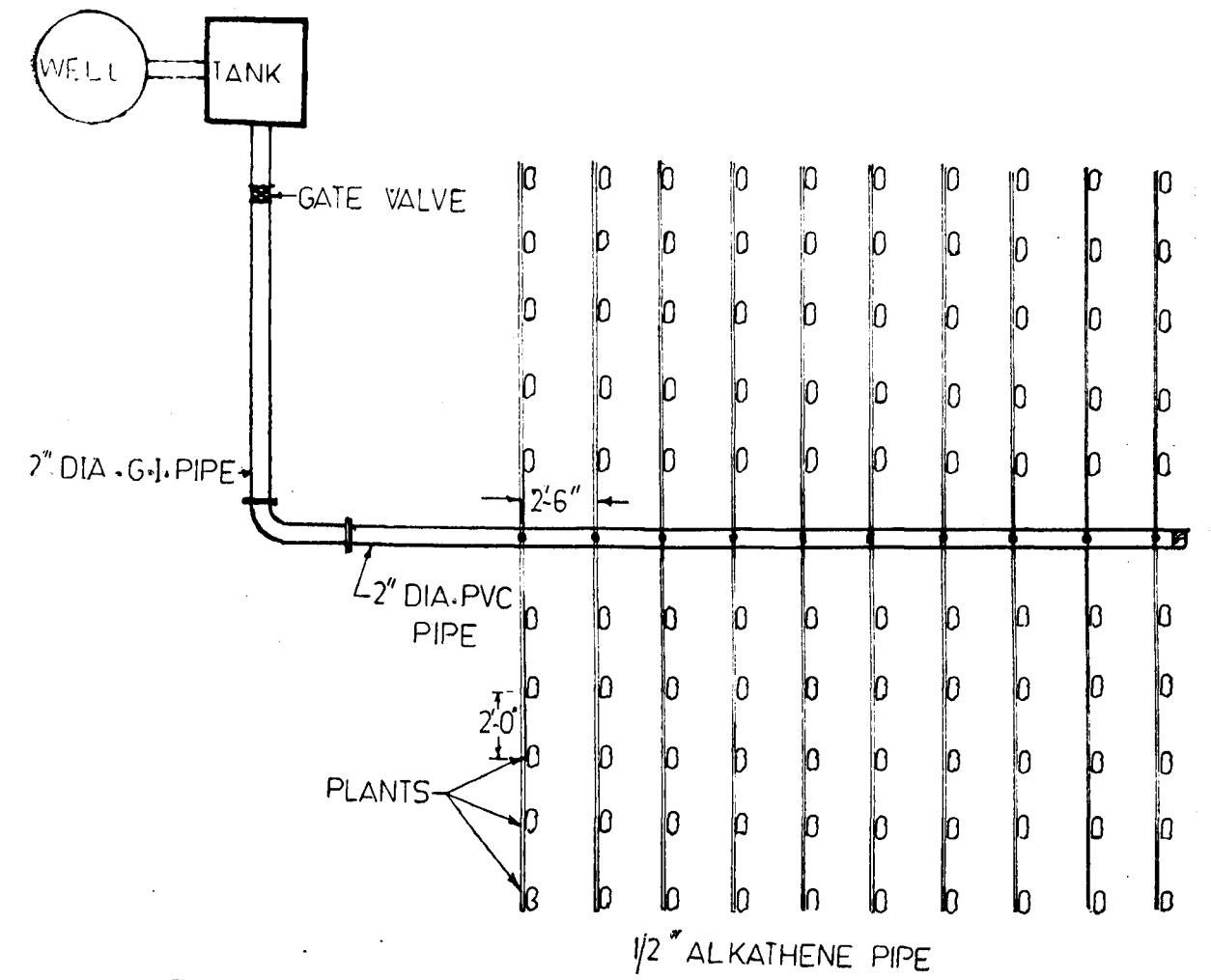
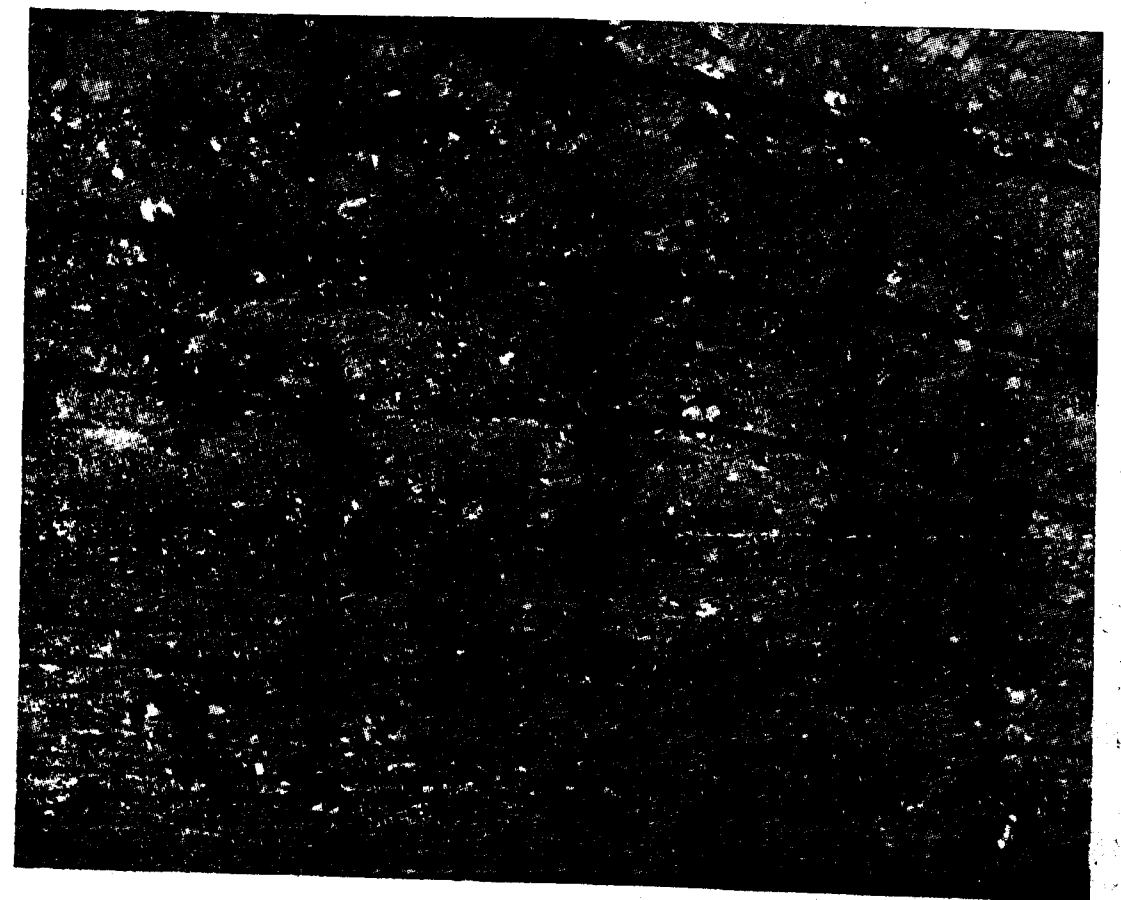


FIG.2. DRIP IRRIGATION LAYOUT

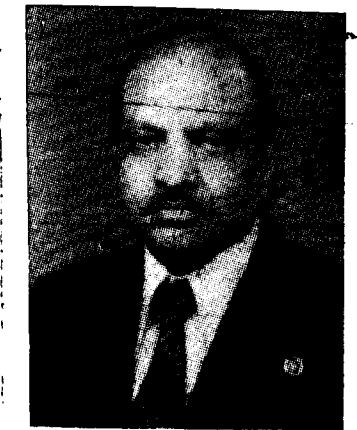


Drip irrigation for Chilly

INTEGRATED DEVELOPMENT OF WATER RESOURCES FOR IRRIGATION

By

THIRU J. K. JAIN.*



1. Introduction :

The importance of integrated development of water resources is now fully recognised. A major factor responsible for this realisation has been the massive development of ground water for irrigation in the recent years resulting not only in augmenting the totality of irrigation supply but also in several other advantages providing a basic infrastructure of assured irrigation for modern agriculture controlling water logging salinsation, etc. The other reason is the anticipation that with further population growth and technological advances, the water will tend to become a scarce and a critical resource and that as it happens, there will be increasing need for taking an integrated view of the various demands, available resources, and the problems involved including pollution hazards, when planning further development of the water resources. There are also a number of other special advantages that accrue from and underline the need for integrated development.

Water is a complex and a dynamic resource and its occurrence and distribution cannot be predicted in a deterministic manner. Apart from regional variations, there are wide variations from day-to-day, season to season and from year to year, in the availability of water. Moreover, development of water resources on a comprehensive basis, would always involve several competing alternatives with numerous possible variations in capacity and operating policies. Increasing attempts have therefore been made in recent years to apply computer based modern system analysis and mathematical model techniques in the field of planning and development of water resources. These techniques, however, are in a developing stage. Fortunately, we need not wait for perfection of these techniques, because experience has shown that fairly sensible decisions can be taken over without their aid. Moreover, it has yet to be seen how far the optional solutions based on these sophisticated techniques can be applied advantageously in actual practice in the face of socio-economic institutional, managerial and other inherent constraints which are equally numerous as the variables and the alternatives involved. No doubt, as the indications are, these techniques would certainly improve the planning process but it is doubtful if they ever replace the role played by sound engineering judgment borne from long varied experience in the field.

Water is controlled and regulated to serve a wide variety of purposes. Water supply, irrigation, hydro-electric power generation, navigation, industrial uses, development of recreation facilities, etc., are examples of utilisation of water for beneficial purposes. Integrated development of water resources implied that the water resources development planned for a region should take note of all the realistic demands for water for these various purposes. Irrigation alone, however, at present accounts for more than 90 per cent of the total withdrawal of water resources for various purposes. The subject of our lecture today will be confined to the integrated development of water resources for irrigation only.

It is proposed to cover the subject matter of this lecture in five parts. In the first part an idea will be given about, the different categories of water resources, how they are formed and what is the inter-relation between them. In the second, the nature, salient technical features and the limitations of the various types of irrigation systems structures, in vogue, to tap the available water resources for irrigation purposes will be described. Subsequently in the third part an effort would be made to indicate what actually the term "integrated utilisation of water resources" means. The focus in part four will be on spelling out certain specific objectives that cannot be accomplished without resorting to integrated planning and development of water resources. Lastly, in part five, it is proposed to concentrate on the manner in which the integrated utilisation of water resources is or can be arranged in actual practice for servicing particular goals. Implications and limitations of the various possibilities for such development will be discussed. Illustrative examples will be given indicating how and to what extent the various approaches have actually been put into practice in India and elsewhere.

2. Water resources—Types of and inter-relations between them.

Water resources are divisible into two distinct categories. the surface water resources and the ground water resources. Each of these categories is a part of the earth's circulatory system, called the hydrologic cycle, and is water ultimately derived from precipitation, that is rainfall, plus snow. They are inter-dependent and frequently loss of one is the gain of the other. The brief description of the run-off cycle, which is a part of the hydrologic cycle, will be helpful in understanding the origin and the inter-dependence of these two categories of water resources.

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The precipitation that falls upon land and is the ultimate source for both the categories of water resources is dispersed in several ways. A sizeable portion is intercepted by the vegetal cover or temporarily detained in surface depression. Most of it is latter lost by evaporation. When the available interception or the depression storage are completely exhausted and when the rainfall intensity at the soil surface exceeds the infiltration capacity of the soil, overland flow begins. Once the overland flow reaches a stream channel, it is called surface run-off, which together with other components of flow, forms total run-off.

Part of the water that infiltrates into the surface soil may continue to move laterally at shallow depths as inter flow, owing to the presence of relatively impervious lenses just below the soil surface and may eventually reach the stream channel when it is called the sub-surface run-off. A part of the sub-surface run-off may enter the stream promptly while the remaining part may take a long time before joining the stream flow.

A second part of the precipitation which infiltrates is lost by evapo-transpiration via plant roots and thermal gradients just below the soil surface. A third part may remain above the water table in the zone of unsaturated flow. A fourth remaining part percolates deeply to the ground water table and becomes ground water. Part of this ground water may eventually reach the stream channel and become base flow of the stream. This portion is termed ground water run-off or ground water flow.

The total run-off in the stream channel, which includes the snow melt, the surface run-off, the sub-surface run-off, the ground water run-off and the channel precipitation, i.e. the precipitation falling directly on the water surfaces of streams, lakes, etc., constitutes what is known as the surface water resources. The portion of precipitation which after infiltration reaches the ground water table, together with the contribution made to ground water from the neighbouring basin, influent rivers, natural lakes, ponds, artificial storage reservoirs, canals, irrigation, constitutes the ground water resources. The quantity of water in the ground water reservoir which is not annually replenishable is not taken into account as it is a sort of dead storage which cannot be used on a continuing basis from year to year.

The above phase of the run-off cycle pin-points the in-flow components for the surface as well as ground water resources. It has to be appreciated that there is always a balance between the in-flow factors making up water resources of a region, whether surface of ground and the out-flow components. The surface water resource of a given basin, in excess of the withdrawal use is accounted for, on the out-flow side, by one or more of the following factors:—

- (i) Stream out-flow from the basin;
- (ii) Loss by evaporation; and
- (iii) Influent recharge to the ground water.

Similarly, the unutilised ground water resource of a basin is accounted for by the following out-flow factors:—

- (i) Evapo-transpiration from the ground water table;
- (ii) Out-flow to neighbouring ground water basin;
- (iii) Effluent discharge to the streams; and
- (iv) Addition to the ground water storage.

The inter-relationship between the surface water and the ground water resources is evident from the above analysis. The surface water resources contribute to ground water recharge in various ways: (i) by influent recharge from the streams; (ii) by seepage from natural lakes, ponds, etc.; (iii) seepage from artificial storage reservoirs, canal systems, etc.; and (iv) return flow from irrigation. It is roughly assessed that the above factors contribute to about 25 per cent of the total country's ground water resources which are roughly estimated as 600 million cubic metres. In addition, there are also possibilities of artificial recharge or induced recharge from surface water resources. The dependency of ground water resources to an appreciable extent, on the surface water development, is thus obvious.

On the other hand, the bulk of the base flow in the rivers which represents the sustained fair weather run-off, is contributed by ground water resources. It is roughly estimated that the base flow contributed by ground water accounts for about 25 per cent of the total surface water resources of the country roughly estimated 1,700 million cubic metres. It is therefore obvious that the uncontrolled development of ground water may lead, apart from other hazards, to depletion of the stream flow, which is already committed for the existing withdrawal uses.

3. Irrigation Systems/Structures-Type, Salient Technical Features and Limitations.—

Surface water resources are usually tapped by three types of irrigation systems:

(i) *Storage Projects*.—These projects include storage reservoirs and tanks which impound stream flow for irrigation purposes. These comprise a bund or dam which is generally of earth but also sometimes partly or fully of masonry or concrete, anicuts and feeder channels to divert water from adjoining catchments, a water-weir/spill-way to dispose of surplus flood water, sluice or sluices to let out for irrigation and the conveyance and the distribution systems. These projects vary in size and scope from major multi-purpose river valley projects on one extreme, to small micors to age works providing very little direct irrigation and mostly either improving the moisture regime or replenishing ground water, on the other extreme. These are usually executed and maintained as public works.

(ii) *Diversion schemes*.—These schemes aim at providing gravity flow irrigation by mere diversion of stream flow without arranging any storage and thus depend on the run-off the river supply. They consist of a weir constructed across the stream for raising and diverting water to the fields. They also vary considerably in magnitude, ranging from large canal systems as in the north to very small diversion channels, constructed in the hilly areas. These schemes are generally executed as public works.

(iii) *Lift Irrigation Schemes*.—In regions where the topography does not permit direct flow irrigation from rivers, streams, lakes, etc., water has to be lifted through pumping. The pumping plants are either installed on the river banks or on the barges. Pumped water is carried by a gravity flow conveyance and distribution system. Big schemes benefiting large commands usually have a battery of pumpsets including a few spare ones. These are generally executed and operated as public or co-operative schemes. Farmers also put in their own pumping installations on individual basis for lift irrigation purposes.

In general, storage and lift irrigation projects provide more assured irrigation. On storage projects supply of irrigation water is flexible and can be varied to an appreciable extent in a season according to the actual crop requirement. In the case of lift irrigation schemes, the irrigation supply is usually assured, particularly when installed on the perennial streams, because the water pumped at the source normally comprises only a small proportion of the total available flow. On run-off-the river scheme, the irrigation supply at any time is dependent on the actual flow of the river at that time and is therefore inflexible. Moreover, there are wide fluctuations in the flow of the river and this necessitates rotational closure and opening of the distribution system, thus imposing a constraint in the availability of irrigation water at quick intervals.

Structures, i.e., wells and tube-wells, for tapping ground water resources are of the following types:—

(i) *Dug wells*.—Dugwells comprise open surface wells of varying dimensions dug sunk from the ground surface into the water bearing stratum to extract water for irrigation purposes. Usually two types of wells are constructed (a) masonry wells; (b) wells in rocky sub-strata. The masonry wells have a (masonry) steining wall usually sunk in sub-soil by applying static weight of sand bags and simultaneously scooping out of earth from inside. In locations, where it is not possible to sink masonry steining by ordinary methods due to presence of hard clay or boulders etc., it is built up in a dug pit from the bottom upwards. The rock wells are usually open excavated pits through top soil mantle and soft rock in the hard rock areas. These wells in the hard rock portion are generally deepened with the help of blasting through use of explosives. Persian wheels or rope-and-bucket lifts and sometimes counterpoise lifts are used to lift water from dugwells. Present trend, however, is in favour of using power pumps, both electric and diesel.

(ii) *Dug-cum-bore wells*.—Dugwells are frequently bored through the bottom to augment their water output. In the alluvial areas boring essentially consists drilling of small size bores of diameter usually ranging from 3" to 6" in the bottom of the well and extending the bore upto layer or layers of good water bearing medium lying underneath the bottom of the well with a view to tapping these aquifers. The bore may be of two types, according to whether the tap the water bearing medium through the cavity formed below a hard impermeable strata or through strainer or screens provided opposite the vertical depths of the water bearing stram/strata. In the first type the bore is installed with plain pipe extending up to the cavity; in the second type, with pipe assembly having screens opposite the water bearing media and blind pipes opposite impermeable strata. The first type of boring is cheaper but is not feasible at all locations.

In hard rock areas, the earlier practice had been to bore a hole (ranging from 6" to 16") at the centre. This requires use of percussion rigs or caylx rigs which can be lowered down to the bottom of the well. Drilling progress of these rigs is very slow. Lately boring of slim holes, 1½ to 2" diameter in various directions, by using rock drills with extension equipment which drill these holes at a very fast rate, has been found effective in increasing the discharge and is coming in vogue.

(iii) *Tubewells*.—Tubewells essentially consist of a deep bore drilled into ground with the purpose of tapping ground water through one or series of permeable layers of water

bearing strata. The bore is installed with an assembly of blind (unperforated) pipes and strainers, such that the former comes opposite the non-water bearing strata and the latter opposite the water bearing media. In the cavity type tubewells, no strainers are provided and the water is directly pumped from the cavity formed at the bottom end of the boring which is provided only with blind (unperforated) pipes. The water is pumped through centrifugal turbine or submersible pumps installed on the top of the tube.

Tubewells drilled in the predominantly hard rock areas, where the bores can stand on their own and lining by blind pipes is not necessary are called bore wells. Generally strainers are not provided in bore wells.

Small diameter shallow tubewells installed in the soft alluvial formations or the coastal regions are called filter points.

Deep tubewells are generally constructed and maintained as public works. Shallow tubewells including filter points and bore wells are usually constructed as private works.

In alluvial and soft sedimentary formations, usually tubewells, dugwells as well as dug-cum-bore wells are feasible. Tubewells in such areas are generally cheaper than dugwells in term of cost per unit of water produced. Dugwells, however, have the advantage that they permit phased development—a farmer in the first instance gets in only for a well and then after earning some money he gets it bored and subsequently gets it fitted with a pump-set. In the hard rock formations which comprise about 2/3rd of the country, dugwells/dug-cum-bore wells are the two types of ground water structures that are usually feasible. Borewells also have established their merit by producing drinking water, supply and at some locations they are able to even yield enough water for irrigation. Tubewells generally yield a sustained supply but in the case of dugwells, particularly in the low rainfall areas the water output tends to dwindle down during the summer months, and in some drought years they become completely dry.

4. Integrated development of water resources—What it means.

Now we are in a position to define what we understand by integrated development of water resources for irrigation. It essentially means simultaneous utilisation of the surface and the ground water resources through a judicious combination of surface irrigation projects and ground water schemes, keeping in view the overall estimate of available water resources, the infra-structure of irrigation facilities already available, agricultural setting and potentialities of the region and the long-term needs for irrigation and other competitive uses, and to serve one or more of the important objectives discussed in the next section. Planning for integrated development will include decision making in regard to:

(i) nature and the types of projects to be included in the irrigation complex of the basin;

(ii) location and capacities of the different works;

(iii) time phasing of the projects for their initiation and completion; and

(iv) integrated schedules, if any, for operation and management of the projects.

5. Objectives behind integrated utilisation.

The next question to be answered is why an integrated development is necessary? What are the special advantages or benefits that accrue from such development and are not normally possible under a laissez-faire approach towards development? As mentioned earlier, there are certain vitally important objectives which can only be realised by an integrated approach. These include:

(i) *Maximising agricultural production.*—For achieving this objective it is necessary that the irrigation complex, representing the totality of works in a basin, should be such that it enables maximum tapping of the available water resources, both surface and ground, on economic lines. This would mean that the out going unusable runoff from the basin will be reduced to the minimum. Secondly, it would be necessary that the irrigation complex should be of a type that provides irrigation of an optimal quality in an efficient and sustained manner with least risks for untoward hazards, and incurs minimum evaporation and seepage losses from the reservoir areas or the conveyance and the distribution systems. It will be impossible to achieve these goals without adopting an integrated approach, in development of water resources.

(ii) *Augmenting Resources.*—There are numerous possibilities for augmenting quantum of usable water resources through re-cycling of water, induced recharge artificial recharge and even the use of highly saline water, which cannot be used directly for irrigation. These possibilities can be explored and opened up only through an integrated approach and would normally not come under the realm of practicability under a laissez-faire approach for development.

(iii) *More economic utilisation of water resources.*—Keeping in view the overall availability of water resources and the totality of demands for various competitive uses, and subject to certain accepted socio-economic objectives, undoubtedly the most important consideration in the water resource development of a region would be to have maximum economic return not only in the form of agricultural production but also other economic benefits such as hydro-electric generation, reclamation or protection of vulnerable areas through flood control measures, industrial and domestic uses etc. that form an integral part of any programme for water resources development in a region. When several alternatives for development with numerous variations are available, the particular complex of works that would fulfil this basic economic objective can be decided only through an integrated approach of an high order.

(iv) *Improving the status of irrigation supply on existing project.*—This is one of the most important objectives that are attainable by conjunctive use of water resources and underlines the need for an integrated approach. On several existing irrigation projects, particularly the one that depend on the run-of-the-river flows the present irrigation supply is chequered or sub-optimal due to various reasons. In some cases the old irrigation systems were designed to provide protective extensive irrigation to large areas. On many old projects the areas presently under irrigation are for more than what the projects were originally constructed to cater for. A major constraint in some of the existing canal systems is that the distributory channels are able to run only in a rotation of 1:3 or 1:4, i.e. they run in rotation for one week and then remain closed for two-three weeks, during the

periods of keen irrigation demands. This rotational system of operation becomes imperative during the periods of lean flow in the river because continuous running of the distributory channels with low discharges during these periods will result in large scale siltation of the channels apart from causing multi-farious problems in equitable water distribution through the channel outlets.

For modern productive agriculture based on fertilizer responsive high-yielding varieties of crops, it is extremely necessary to pin-point these constraints, and to undertake measures for their removal. In this context, the provision of supplemental irrigation through integrated utilisation of surface and ground waters will be the only effective manner for removing these constraints.

(v) *Bringing more sophistication in Irrigation Planning and Design.*—Irrigation Planning and design for a project concerns with decision making in regard to the size of the command area and proposed intensity of irrigation, cropping pattern and rotations, water allowances, outlet factors, duty, irrigation requirement etc., full supply-discharge and capacity factors, channel capacity at different stages of the conveyance system and channel rotation and schedule of irrigation deliveries. There is usually sharp difference of opinion on these matters between experts and their views are governed more by professional prejudices than by a correct appreciation of the techno-socio-economic considerations. While some old-timers still insist on thin spreading of irrigation water over large areas, some of the new enthusiasts of modern agriculture advocate average intensities of irrigation as high as 250 to 300 per cent. For sound decision making in these matters what is essential is that apart from certain accepted socio-economic considerations such as balanced regional growth, dispersal of benefits among as large a section of community as possible etc. the primary principle governing these decisions should be the achievement of maximum agricultural production from the combined totality of land and water resources in the region. The focus has to be on taking an integrated view of the combined resources and their development for optimal results, and if this is done, correct decisions in all these controversial matters will flow automatically.

(vi) *Removing or Controlling hazards of water-logging salinisation and local infestation.*—This is again a field where the conjunctive use of surface and ground water plays a crucial role. Surface water development, in isolation of ground water development, is known to have created serious problems of water logging, salinisation etc. in large many areas of the country, particularly in the northern parts. Even in lands which were salt-free initially, excessive surface water irrigation resulted in accumulation of salts in the root zones thus rendering these lands unproductive. Once this happens the only remedial measure available is the leaching down of the salts with excess water and this process has to be preceded by soil amendment through the use of gypsum or some other available alternative, if alkalinity is involved. The leaching, however, requires not only additional supply of water but also provision of intensive and expensive drainage system. Experience, nevertheless, has shown that conjunctive use of ground water in such areas, provided the ground water is of a good quality and hard pan at shallow depths or other similar hazards are not encountered, provides the most effective and economic alternative. Not only it provides an important additional source for irrigation of a high quality, but also the vertical drainage which

relieves water logging as well as enables the leaching operation to be performed. Subject to the conditions mentioned ground water development may or may not completely eliminate the need for surface and sub-surface drainage but it certainly reduces the requirement for such drainage drastically. In areas where ground water is saline and there is water logging, leaching down of the salts from the root zones will not be possible even though adequate drainage is provided, unless the water table is lowered by pumping of saline water.

In arid, semi-arid and coastal regions, there is always a hazard involved that excessive pumping of fresh water in pockets where it is available, may invite saline infestation from the adjacent saline water zones or the sea water. This, however, can be controlled at some locations by simultaneous pumping of the water from the saline zones also.

It would, thus appear that the control of water logging and salinisation hazards seriously underlines the need for an integrated approach in the water resources development.

(vii) *Control of encroachment on committed uses.*—An encroachment on committed uses is an attendant hazard always present with isolated development of water resources. Cases have already started coming to notice where intensive ground water development in the basins is feared to have reduced the river committed downstream on the existing surface water projects. In some cases construction of heavy duty deep tubewells is reported to have reduced the discharge of existing shallow tubewells and dugwells. The risk of mutual hydraulic interference and lowering of water table leading to depletion of supplies on existing dugwells tubewells are always present with intensive ground water development, that is currently in vogue. These risks involving possibilities of large scale infructuous expenditure can be effectively controlled only through an integrated approach emphasising a careful water budgeting before undertaking any large scale programme of development.

(viii) *Control of sedimentation in reservoirs.*—A sizeable amount of storage capacity is annually lost in the surface water storage projects due to reservoir sedimentation. Some studies have indicated that due to excessive erosion in the catchment areas, reservoir sedimentation on several projects is taking place at a much higher rate than was envisaged when these project were constructed. Integrated development of water resources in the basin, aiming at balanced network of storage points, covering upper valleys as well as the head water regions, and including storage projects of varying sizes ranging from major river valley projects to micro storage works (sediment basins) can go a long way in reducing the sedimentation rate, apart from fulfilling the accepted socio-economic objective of dispersing benefits to different sections of the community. An integrated storage complex of this type will also provide opportunities to influence sediment control through co-ordinated procedures for reservoir operations.

(ix) *Satisfying accepted socio-economic considerations.*

The accepted socio-economic considerations include:—

(a) balanced regional development giving priority to backward areas;

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(b) dispersal of benefits as large a section of community as possible, particularly including the weaker sections; and

(c) providing employment opportunities in the rural areas.

Fulfilment of these objectives in conjunction with basic techno-economic considerations can be possible only under integrated planning and development of water resources.

6 Possibilities for integrated development illustrative example.

There are always possibilities for undertaking integrated projects for serving multiple purposes irrigation, hydro-electric generation, navigation, flood control etc. In our present subject-matter, however, we will be concerned with possibilities for integrated development of water resources for irrigation only. The broad possible approaches include—

(i) *Conjunctive use through direct irrigation public tubewells.*—As mentioned earlier, there are several big canal systems in the country in the Indo-Gangetic basins and also elsewhere which suffer from chronic shortage of irrigation supplies, particularly in the tail reaches. Sufficiently thick water bearing aquifers are available in most of the areas covered under the command of these projects in the Indo-Gangetic and some other inland or coastal basins. One manner of removing the shortage in these canal systems can be to construct public tubewells at suitable locations in the command area and to cut-off the canal supply to such areas that can be served with tubewells water. The part of the canal system existing in the region would still be used, with some modifications, for distribution of the tubewell water. It may even be possible in this manner to bring at some locations the whole area of one or more distributory channels under tubewell command by constructing a battery of tubewells.

This method of conjunctive use, however, has been applied in practice to a very limited extent perhaps in U.P. only in some pockets in the command of the existing canals which had received practically no supply during the previous several years, were identified and public tubewells were constructed to serve these pockets. The same were then excluded from the canal command.

A World Bank Group of Consultants, after a thorough study of the water and power resources of West Pakistan, had strongly advocated construction of public tubewells for supplemental irrigation in this manner. The point was made that as compared to private tubewells, public tubewells would provide greater flexibility in tackling difficult ground-water aquifers and would also enable better management of the irrigation complex as a whole for water table control and other desired objectives. The top brass in the World Bank Group, however, while agreeing that the arguments in favour of public tubewells were weighty, held the view that preservation of private exploitation would be worthwhile and public tubewell development should not be undertaken in any area where private tubewells were spreading rapidly.

Nevertheless, there appears to be a positive case for undertaking public tubewell projects on this pattern in any areas where holdings are small, ground-water

aquifers are difficult and consequently private tube-well development activity is not likely to show much promise. There should be no opposition from the cultivators to this arrangement if the rates for the canal and the tube-well supply are pooled and made uniform.

(ii) *Conjunctive use through augmentation tubewells.*—An alternative to supplement irrigation from public tube-wells can be that the water from the tube-wells may be delivered in the canal system at suitable points instead of doing direct irrigation in exclusive pockets detached from the canal system. A snag in this approach is that if the augmentation tubewells are constructed too close to the canal system, there may be excessive induced seepage from the canals. On the other hand, if they are located sufficiently away from the canals, long and expensive delivery channels would be needed. This difficulty, however, would not exist if the canal is lined.

A typical successful example of this approach is the Augmentation Canal Project, recently executed in Haryana. This Project comprises a lined carrier channel, which transmits about 3,000 cusecs diverted from the existing Western Jamuna Canal, in order to cut down the seepage losses by an extent of about 500 cusecs. These losses occur at present as the discharge is carried through the Western Jamuna Canal which is an unlined Canal. About 160 public tubewells have been constructed along the lined carrier canal to deliver an additional discharge of about 500 cusecs in the canal. Since the canal is lined, there is no question of their drawing induced seepage from the canal.

(iii) *Conjunctive use through construction of private tubewells and dugwells.*—A method of conjunctive use having much wider applicability and utility is the construction of dugwells and shallow tubewells in the command of surface Water Projects. Both these are generally private works. While shallow tube-wells are possible in the alluvial and other soft formations having aquifers at shallow depths, dugwells are feasible almost everywhere except where the water table is extremely deep or rocks are exposed at the ground surface. A network of these ground-water structures desirable not only to meet the inadequacy or to further extend irrigation but also to minimise the danger of water logging and salinisation, that might arise with continuous surface water irrigation over the course of years.

Conjunctive use in this manner is coming in vogue in the country in large many areas and particularly on a large scale on the canal systems in Punjab, Haryana and U.P. Cauvery Delta in Tamil Nadu, Krishna and Godavari Deltas in Andhra Pradesh and the Godavari and Pravara Canal systems in Maharashtra. In the northern canal systems the conjunctive use, apart from bringing other advantages, has also been helping in promoting irrigated rice as an additional crop. Supply in the canal systems is particularly low in these areas in the month of May when water is needed for nursery raising for rice. What the farmers now do is that they raise nursery on the assured supply of dugwells/tubewells. Transplantation is later carried out with the help of rain, canal water as well as well/tube-well water.

In certain parts of Cauvery Delta construction of filter points has enabled the farmers to raise paddy seedlings for the first rice crop called Kuruvai, early in June

before the canal system can be opened. This has been helping in two ways: firstly, the Kuruvai crop is harvested early by the end of September so that it is not prone to damage by the North-East monsoon during October-November as was the case earlier; secondly, the raising of a second irrigated crop called Thaladi in the same area becomes possible. Besides, filterpoints are also expected to relieve the drainage congestion which is a serious problem in parts of this tract, by lowering the water table.

Conjunctive use of ground water, more or less in a similar manner, is also being met in the Krishna and Godavari Deltas of Andhra Pradesh. Under the Pravara and Godavari Canal systems in Maharashtra a number of farmers have constructed Masosary Wells and installed diesel or electrical Pump sets to supplement land supplies for growing sugarcane.

There is yet another direction in which the conjunctive use in this manner can greatly help. The main cause of the drought situation that frequently arises in the eastern rice belt, particularly in East Uttar Pradesh and Bihar is the failure of rice nursery due to delay in the break of monsoon or a long dry spell in June-July. Transplantation of rice could, however, be delayed even till the end of August, if the dry spell continues, without much harm, the only bottleneck being the non-availability of seedlings. What therefore, needs to be encouraged is that rice nursery should be raised as a commercial venture in this tract on wells/tubewells which have assured supply of water. If this is ensured, re-occurrence of droughts in these areas can be considerably minimised.

There, however, are some inherent drawbacks in the conjunctive use through private wells and tubewells. Ground-water in an area is limited; it is usually sufficient for providing irrigation to hardly 20 to 40 per cent of the total area. It is therefore imperative that a large number of farmers would not be able to own wells/tubewells. This results in the creation of a privileged class having the facilities of both the canal and the ground water supply, and it is usually the small farmers who come in the list of 'have nots'. There are three measures that may remedy the situation to some extent and need consideration:—

(a) Canal supply may be cut off or at least reduced in quantum to the owners of private tube-wells/dugwells. This will, however, be greatly resented by the privileged farmers who form a powerful group, as the canal water is highly subsidized and therefore extremely cheap.

(b) Irrigation rate for canal water may be substantially increased to the level of an economic self-paying to. If this is done the well owner may not seriously resent deprivation of the canal supply.

(c) A special cess may be levied on all owners in lieu of the use of ground-water which is a national asset and for which there is no prescriptive right in our country.

There is also some element of over-capitalisation in the case of private tube-wells. These tube-wells usually run for 600 to 1,200 hours on the average in a year against the corresponding average figures of 2,000 to 3,000 hours for public tube-wells. It is obvious that private tube-wells are capable of irrigating much larger areas than they actually do at present. There is need that the

tube well owners should be encouraged to sell water to the neighbouring farmers at reasonable rates. The best alternative, of course, would be to encourage co-operative or community tube-wells, and it would be even desirable to offer some special financial inducement for this activity.

(iv) *Conjunctive use through Lift Irrigation Projects.*—River pumping schemes are a potential source for conjunctive use. Such schemes have been successfully completed in East Uttar Pradesh to supplement irrigation in the tail commands of the existing Sarda Canal system, which suffers from a chronic shortage. The existing part of the canal system in the area is utilised for conveyance and distribution of water and further construction involves only the feeder canal besides the pumping station.

(v) *Integrated use through backing-up Storage Reservoirs.*—Creation of storage reservoirs at suitable sites higher-up the river is always an important possibility worth while exploring, to improve inadequacies on the existing run-of-the-river systems, through integrated use of surface waters.

An example of such use is the Sardar Sagar constructed in Uttar Pradesh to augment the supply of water in the existing Sarda System. This has been formed by constructing an embankment around a natural depression lying between the main Sarda Canal and the river to more excess monsoon supplies. During the kharif it is filled by the surplus canal water which is then made use of during the rabi. The Mettur Dam constructed in 1930 on the Cauvery serves the same purpose. Similarly, the Krishna Delta System in Andhra Pradesh and the Mahanadi Delta System in Orissa have all benefited from reservoirs in the upper reaches of the rivers.

(vi) *Inter-basin Transfer of Surface Waters.*—In some cases it may be possible to transfer water to existing deficient irrigation system from the adjacent basin where there is a surplus. The Sarda Sahayak Project (called the 'Project Assist') presently under execution in East Uttar Pradesh is an example of such development. It will transfer about 1,300 cusecs of water from the Chagga Basin to the existing Sarda Canal System, in its tail reach. The Western Jamuna Canal is expected to receive supplies from the Ravi-Beas-Sutlej Complex in a similar manner. The Periyar Project in Tamil Nadu and the Rajasthan Canal and the Parambikulam-Aliyar Project, presently under construction are also based on inter-basin transfer of waters. The formulation of the famous Ganga-Cauvery Link Project is based on the same concept.

(vii) *Setting up an Integrated Complex of Surface Water Projects.*—There are numerous possibilities for such development particularly in the undulating hard rock areas of the country with significant resulting benefits. A unique example of such development in the past in South India is the "Chain System" of tanks under which a number of tanks are constructed in a series by bunding up the same valley in succession at several points. The command area of the upper tank thus becomes a part of the catchment area of the lower tank and so on. A system of this type results in dispersal of benefits, saves more expensive land from submergence, helps sedimentation control and achieves re-use of the irrigation water to sizeable extent. There is

one drawback which has to be safeguarded. If the upstream tank breaches it is likely that it may lead to breaching of several tanks downstream. Hence it becomes necessary that the spill-way capacity should be properly designed and adequate breaching sections emergency spillways, also provided.

Construction of anicuts and feeder channels to bring supply to the existing tanks, in addition to what they get from their own catchments, is another feature of integrated development of this type in vogue in south India. In some cases, an existing diversion system is used to divert any excess supply whenever available for storage in the available tanks in the region.

There is need as well as scope for giving further stress on this type of development through an integrated complex of surface water projects which would include works ranging, according to feasibility, from sediment basins (micro storage works) on one end, minor irrigation works of various sizes in the middle, and major or medium projects on the other end.

(viii) *Conjunctive Development of Public and Private Tubewells.*—A judicious combination of public tube-wells, private tube-wells and dugwells, based on integrated planning is highly essential for optimal results. It is true that public tube-wells entail a lot of management problems and do not provide the desired satisfaction to the cultivators. Hence, ordinarily they need not be encouraged in areas where private development activity through shallow tube-wells and dugwells is possible and is coming in vogue, although even in such areas public tube-wells may be required to some extent to provide irrigation pockets dominated by small farmers who cannot own wells/tube-wells of their own. There are, however, several tracts and fairly extensive sometimes where either water table is deep or aquifers are deep seated or otherwise difficult. Construction of public tube-wells will be necessary in such areas as private development activity will, by and large, be absent. Also, public tube-wells will be necessary for development of deep confined aquifers which would otherwise remain untapped if activity is restricted only to dugwells and shallow tubewells.

(ix) *Integrated Development for inducing Groundwater Recharge.*—All surface water irrigation projects are potent sources of ground-water recharge as already discussed. About 25 per cent of the total groundwater resources in the country are assessed to be derived from these sources. Special measures, exclusively for the purpose of inducing recharge would include: (a) surface spreading/ponding; (b) surface ponding with injection tube-wells; (c) intensive development of groundwater in and along river beds to induce influent recharge and bank storage during the monsoon season.

The first type of development is already in vogue in the country to some extent. Percolation tanks are being constructed in Maharashtra, Tamil Nadu and Gujarat to improve the supply of water within their zones of recharge. In Gujarat and Rajasthan construction of check-dams on streams and riverlets is achieving the same purpose.

Injection wells are costly and have not yet been tried in our country. They are expensive and may be feasible only under special conditions. Undertaking of pilot projects is called for to try out this method.

The main idea behind alternative three above is to create space for groundwater recharge and storage in the flood season, by lowering the water table in the flood and the adjoining zone through intensive purposeful development of groundwater. The method seems to hold promise in selected particular areas and deserves to be tried on a pilot scale as quickly as possible to assess the feasibility for large scale application.

x. Integrated Operations for Tackling Salinity Problems.—There are three types of possible developments which seem to hold promise and deserve consideration in this context. These have been tried successfully in other countries and also to some extent in our own country.

The first is the use of saline groundwaters for irrigation after diluting the salinity with surface water. There are some crops which can tolerate a fairly high degree of salinity in water and the water resources particularly in arid and semi-arid tracts, where ground water is frequently saline, can to some extent be augmented in these areas by the combined use of surface waters and saline

ground waters. The mixing can be done by pumping saline groundwater in the canal system. The method has been successfully tried in Israel, U.S.A. and Pakistan and can be considered for application in India, particularly in the States of Gujarat, Rajasthan, Haryana and Punjab, where saline groundwaters are encountered in fairly large quantities.

The second would cover the reclamation of saline lands where the ground water is also saline by undertaking two integrated operations: (a) pumping out the saline ground water and using it for irrigation with or without mixing or allowing it to be drained away, if it is extremely saline; and (b) leaching down the salts, which would now be possible after the water table has been lowered through operation (a) with the help of surface water.

The third possibility would cover the situations where fresh and saline water zones exist in close vicinity. The operation would essentially consist of simultaneously pumping the water from the saline comes along with the withdrawal of fresh water in the adjoining zones for beneficial purposes.

CONCEPTS AND PRACTICE OF CONCRETE MIX DESIGN.

By

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Preface:

The modern specification for concrete defines the quality of concrete in terms of strength rather than the stated mix proportions. This has heightened the interest in studying the properties of concrete and in designing the most economical mix proportion.

This monograph is brought out to translate the concrete proportioning knowledge developed in this laboratory to benefit the practising engineers. Along with the stepwise presentation of mix design, the underlying principles are also explained at all stages of mix design.

There are two distinct schools of thought regarding the design of concrete mixes. The first, which might be called the "empirical" or "pragmatic" school hold that the mix design is a matter of trial and error and any mix design calculations are really the means for making an intelligent guess to start with the first trial. This approach considers mix design mostly as an art than a science.

The British Road Note 4 approach is an outstanding example of empirical approach, which presents the mix designers with a wealth of tables to serve as ready reckoners for a variety of conditions. The difficulty with the British Road Note 4 method is that it is more restrictive in use and applies mainly to the British Conditions. Also the mix designer has to handle a multiplicity of tables to arrive at trial proportions.

The other school is the theoretical school which considers that the mix design is an exact science and that precise formula can be derived for arriving at the proportions of concrete ingredients. Notable contributions have been made by Hughes (5) and Whymouth (6) in this direction. Theoretical approach to mix design is generally cumbersome for ordinary applications because of the involvement of large variables.

The American Concrete Institute System of concrete mix design amounts to a consensus of both theoretical and empirical approach. It adopts firm scientific concepts but supported by empirical data in a set of tables.

In this laboratory, considerable progress has been made in evolving a rational method of mix design adopting sound-theoretical promises. The mix design procedure here adopted is an outcome of such an attempt.

The approach to mix design is evolved specially to suit compaction by vibration and necessary corrections are to be made for manual compaction. Ordinarily only one trial will be required in producing a concrete of predicted workability and strength in the fresh as well as in the hardened state provided the strength of cement conforms to I. S. Specification.

The formulae to be adopted for arriving at different proportions are laborious for ordinary application. Hence no formulas have been designed to reduce calculations. The description is lengthy because the monograph covers the underlying principles at all stages of mix design. But it is no measure of the time taken to design a mix. After some experience the mix can be designed in 20 minutes.

The mix design here evolved is based on the two research papers published in the proceedings of the Forty-second and Forty-fourth annual research sessions held at Madras and Chandigarh (4) (18) respectively.

I. Introduction:

The design of concrete mixes is the determination of the most economical and practical combination of concrete ingredients, that is workable in its plastic state and that will develop the required qualities when hardened. This properly designed mixes achieve three objectives:—

- (a) Required quality of hardened concrete.
- (b) Workability of fresh concrete.
- (c) Economy.

1.1. Properties of concrete in the hardened state:

The usual primary requirement of concrete in the hardened state is its compressive strength. The other desirable properties are density, durability, tensile strength, impermeability, resistance to abrasion and resistance to sulphate attack, etc. These properties of hardened concrete depend on the mix proportions especially water cement ratio and being compacted well. For these reasons the water cement ratio has been regarded as a major factor in the design of concrete mixes.

1.2. Workability of concrete:

Workability of concrete is a complex concept and is difficult to define. It is a combination of a group of fundamental properties of fresh concrete. It should reflect at least three separate properties.

(a) Compactability:

The ease with which the concrete can be compacted and air void is removed.

(b) Mobility:

The ability of the concrete to remain a coherent homogeneous mass during handling and vibration without constituents segregating.

(c) *Workability:*

The workability is also defined as the amount of useful internal work necessary to produce full compaction.

No one test gives complete guidance on the degree to which these properties are developed in a mix. The slump test, the compacting factor test, and V.B. seconds test provide the most general guide at present. For the field, the slump test, augmented by the observation of the behaviour of the concrete offers the best means of evaluating workability.

1. 3. *Economy:*

To achieve economy, the aim of concrete mix design should be to minimise the amount of cement required without sacrificing concrete quality. Since the quality is primarily dependent upon water cement ratio, the water requirement should be minimised to reduce cement content. Steps to minimise water and cement requirement include the use of—

- Stiffest practical mix.
- The largest possible size of aggregate.
- Optimum ratios of fine and coarse aggregate.

2. *Water Cement Ratio and Strength:*

The strength of concrete is commonly considered the most valuable property. Strength gives an overall picture of the quality of concrete. The best known fundamental property of concrete is the relation between concrete strength and water cement ratio. The water cement ratio determines the porosity of cement paste. A low water cement ratio leads to low porosity and more

strength and vice versa. The practical implication of this relationship was recognised by Duff Abram and he stated that, for any given conditions of test, the strength of any workable concrete is inversely proportional to the water cement ratio. Subsequent work has shown that the concrete can be considered workable (for the purpose of applying this rule) if it can be compacted reducing air void to less than 2 per cent.

Duff Abram expressed this relationship in the form of the following equation:

$$P = \frac{A}{(B)q} \dots \dots (1)$$

where p is the compressive strength of concrete A and B are constants, and q is the water cement ratio by weight. The approximate relationship between water cement ratio and compressive strength for the type of cement in the southern region is given in fig. 1. The equation of strength for the cement in this region is also expressed in the following relationship.—

$$f = \frac{1000}{14q} \quad (2)$$

where f : cube strength expressed in kg/cm²

Table 1 presents the relationship between water cement ratio and strength in the form of statement. These relationships are approximate and are based on several laboratory data accumulated over years in this laboratory using cement from southern region, artificially broken metal and natural river sand.

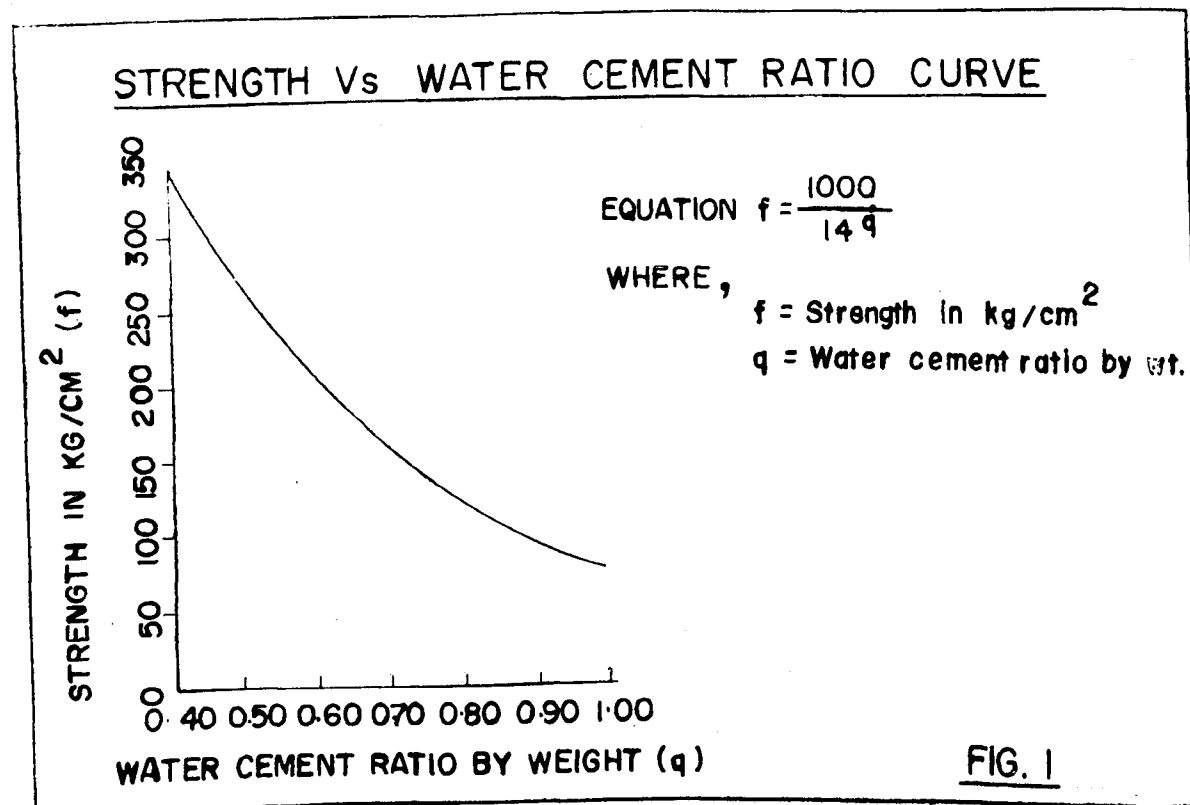


TABLE I.

COMPRESSIVE STRENGTH OF CONCRETE FOR VARIOUS WATER CEMENT RATIOS.

Water cement ratio by weight (q)	Probable compressive strength at 28 days (cube strength) in kg/cm ²
0.40	340
0.45	300
0.50	270
0.55	235
0.60	205
0.65	180
0.70	160
0.75	140
0.80	120
1.00	70
1.10	55
1.20	40

2.1. *Validity of water cement ratio law:*

Duff Abram rule of water cement ratio is an over simplification. The rule is valid only when the concrete strength is controlled solely by the cement paste. This can be achieved only when the following five conditions are satisfied:—

- The aggregate is stronger than the cement paste.
- The bond between the hardened cement paste and the aggregate is adequate.
- There is no significant chemical reaction between the paste and aggregate.
- The contribution of aggregate skeleton to strength of concrete is the same in various concrete specimens.
- Uniform compaction—that is air should be expelled to the same degree.

In spite of these limitations, the strength versus water cement ratio relationship is used in the design of concrete mixes for medium strength concrete up to 350 kg/cm²

3. *Effect of Imperfect consolidation on the strength of concrete.*

The greatest single factor causing maximum deviation from Abram's rule and consequent fall in strength is the presence of accidentally entrapped air in concrete due to poor consolidation. A good numerical approximation of this effect is provided by the formulae:

$$fr = \frac{1}{0.035 V} \dots (3)$$

Where fr: Compressive strength of concrete with air content divided by the compressive strength of air free concrete.

V = entrapped air content of concrete in per cent due to incomplete consolidation. Hence the percentage decrease in strength due to entrapped air is equal to.

$$(1 - fr) 100 \dots \dots (4)$$

According to this equation the fall in strength due to 1, 2, 5 and 8.5 per cent entrapped air is 7.7, 15.1, 33.0, and 50 per cent respectively. But the corresponding fall in strength due to lapse in controlling water cement ratio varies linearly; that is 1, 2, 5 and 8.5 per cent increase in water cement ratio decrease the strength only by 1, 2, 5 and 8.5 per cent. For these reasons the present day concrete technologists are less dogmatic in insisting the water cement ratio at site if slight increase in water could ensure cent per cent consolidation.

4. *Durability of concrete and water cement ratio.*

The concrete must be able to endure the exposures which may affect its serviceability and durability. The ability of the concrete to resist the aggressive environment depends upon the constituents of the concrete.

An impermeable concrete reduces the penetration of aggressive liquids and prolongs the life of concrete. Hence the durability of concrete is assumed to be an inverse function of permeability of concrete. A concrete with low water cement ratio is less permeable and hence more durable. Many specification therefore relate durability to the maximum permissible water cement ratio.

Table II is guide for selecting maximum permissible water cement ratio for various exposure conditions.

'Severe exposure indicates, wide temperature range

'Fresh water and sea water' assumes regular wetting and drying.

For concrete deposited by tremie, under water, water cement ratio should not be more than 0.45.

5. *Aggregates.*

Natural sand and gravel (pebbles) are usually the most economic source of aggregates and are commonly obtained from stream deposits. The aggregates obtained from streams are rounded. Yet they make good aggregate for medium strength concrete. In this stage, river sand (Fine aggregate) in the natural state and artificially broken metal (coarse aggregate) are used in concrete making. Artificially broken aggregates are costly compared with natural aggregates.

TABLE II.

MAXIMUM PERMISSIBLE WATER CEMENT RATIOS FOR DIFFERENT TYPES OF STRUCTURES AND DEGREES OF EXPOSURES.

	Severe exposure.			Mild exposure.		
	Air.	Fresh water.	Sea water.	Air.	Fresh water.	Sea water.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Road slabs, thin sections or less than 25 mm. cover to reinforcement.	0.55	0.50	0.45	0.60	0.50	0.45
Moderate sections, beams retaining walls, etc. ..	0.60	0.55	0.50	0.65	0.60	0.50
Exterior portion of mass concrete or more than 30 mm. cover.	0.65	0.55	0.50	0.70	0.60	0.55

5.1 Continuous graded aggregates.

The aggregate passing 4.75 mm sieve is classified as fine aggregate and that retained in 4.75 mm sieve as coarse aggregate. However the splitting of the concrete aggregate as coarse and fine is arbitrary. When fine and coarse aggregates are considered together, it is referred as "combined" or "all in" aggregates.

Early attempts to make concrete stressed the importance of grading of aggregates (both fine coarse aggregates). Several theoretical works have developed ideal grading curves for maximum density in the dry state with minimum voids. But this ideal grading concepts were developed divorced from workability requirement. Hence the resulting concrete was harsh and unworkable.

The "Road Note 4" method of mix design, suggests four types of grading curves for aggregates. These grading curves are by no means ideal and do not import an special property to concrete. Though these gradings were popular in U.K. for over 15 years, it is now considered that any locally available aggregate can be used to make good concrete by proper mix design without forcing aggregate to any arbitrary grading curve.

5.2 Gap graded aggregate

The gap graded aggregate is defined as an aggregate in which one or more intermediate sizes are omitted.

On a grading curve gap grading is represented by a horizontal line over the range of sizes omitted. As per this definition, the combination of single size artificially broken coarse aggregate and natural river sand and popularly used in this State may be considered as "gap graded" aggregate.

Both gap graded and continuously graded aggregates or any locally available aggregates can be used for making good concrete by proper mix design.

The I.S. code 383-1970 covers the requirement of aggregate for concrete-making.

6. Fineness Modulus.

Sedimentary petrologists introduced several statistical indices to describe and classify natural sediments. On similar lines Duff Abram, introduced the fineness modulus concept for characterising the grading of aggregate in concrete technology. Fineness modulus is not an empirical index as popularly understood, but is proportional to the logarithmic mean diameter of particles size distribution. In practice the fineness modulus is obtained by adding the cumulative percentage of fractions retained in a set of sieve divided by 100. But it is convenient to calculate the fineness modulus of aggregates, from the individual fineness modulus of different size group shown in Table III:—

TABLE III.

FINENESS MODULUS OF INDIVIDUAL SIEVE GROUP.

Size Group.	Sieve fraction for.		Fineness modulus of individual size group.
	Passing.	Retained.	
(1)	(2)	(3)	(4)
I	150 micron ..	..	..
II	300 micron ..	.. 150 micron	1
III	600 micron ..	.. 300 micron.	2
IV	1.18 mm ..	.. 600 micron.	3
V	2.36mm ..	.. 1.18 mm.	4
VI	4.75 mm ..	.. 2.36 mm.	5
VII	10 mm ..	.. 4.75 mm.	6
VIII	20 mm ..	.. 10 mm.	7
IX	40 mm ..	.. 20 mm.	8
X	80 mm ..	.. 40 mm.	9
XI	160 mm ..	.. 80 mm.	10

Using Table III and from the sieve analysis, the F.M. of aggregates can be calculated using equation 5

$$F.M. = \frac{100}{P_1 + 10P_2 + 10P_3 + 10P_4 + \dots} \quad (5)$$

where P_1, P_2, P_3 etc. are the fractions retained in size groups I, II, III, etc., in table III Examples of computation of F.M. of aggregates are given in Annexure I.

Official documents of Indian and British codes do not accept the fineness modulus for characterising the grading of aggregates as it gives no idea of particle size distribution. But in scientific mix design, there is a need for such a parameter to represent grading of aggregates in the equations. Hence in the present mix design the fineness modulus has been used, as it takes care of grading in a practical way.

7. Quality of mixing water.

In many a specification, the quality of water is covered by a clause that the water should be fit for drinking but while the use of potable water is safe, water not fit for drinking has been found satisfactory for concrete making. As a rule, water which does not taste saline or brackish is suitable. Water containing large quantities of chlorides tends to cause persistent dampness and surface efflorescence. In practice, it is generally, considered inadvisable to use sea water for mixing unless this is unavoidable.

The water used for mixing should also be free from injurious amount of deleterious materials.

As far as the curing of concrete is concerned, water satisfactory for mixing is also suitable for curing.

8. Selecting mix Characteristics.

Before designing concrete mixes certain characteristics of the mixes should be known or fixed in advance. They are:

- Water cement ratio.
- The maximum size of aggregate.
- The maximum permissible air content.
- Slump range.

The guide lines for fixing the above characteristics are explained below:—

8.1. Water Cement ratio.

The water cement ratio is selected primarily from the criteria of strength. While selecting water cement from the compressive strength requirement, the relationship between target strength and specified minimum strength should be noted. Most codes and standards require that the concrete should be designed to have a target mean strength greater than the specified minimum strength. However the manner in which the over design factor is allowed differs from one code to another.

The I.S. code 456-1964 refers to the target mean strength as "Preliminary test strength" and the specified minimum strength as "Works test strength" and presents a table connecting these two strengths (Table F O.F.I.S. Code 456-1964). This table is reproduced below Table IV here. The full implication of this "margin" or over design factor" in designing concrete mixes will be explained in a later section on "variability of concrete strength"

TABLE IV.

RELATION BETWEEN TARGET MEAN STRENGTH AND SPECIFIED MINIMUM STRENGTH.

Grade of Concrete.	Compressive strength of 15 cm. cubes at 28 days after mixing conducted in accordance with I.S. 516-1259.	
	Target mean strength (Preliminary test) in kg/cm ² .	Specified minimum strength (Works test) in kg/cm ² .
(1)	(2)	(3)
M. 100	135	100
M. 150	200	150
M. 200	250	200
M. 250	320	250
M. 300	380	300
M. 350	440	350
M. 400	500	400

Suppose it is required to design a concrete of M. 200 grade from table IV, the specified minimum strength is 200 kg./cm² and the target mean strength is 260 kg./cm². The mix should be designed for target mean strength of 260 kg./cm².

Referring to Table I, the water cement ratio of 0.51 will give this strength.

In certain circumstances the exposure conditions of concrete are prescribed. In such cases Table II is a guide for selecting maximum permissible water cement ratios. If the exposure conditions and strength must both be considered, the lower of the two indicated water cement ratios should be used.

8.2. Choice of maximum of size aggregate:

Generally, the maximum size of aggregate should be the largest that is economically available consistent with the dimensions of structures. Some of the requirements of I.S. code 456-1964 (Art. 4.2) is furnished here regarding the selection of the maximum size of aggregate.

(a) The maximum size of aggregate should not be greater than one fourth of the minimum thickness of members.

(b) For heavily reinforced sections, the nominal maximum size of aggregate should be usually restricted to 5 mm less than the minimum clear distance between the main bars or 5 mm less than the minimum cover to reinforcement whichever is smaller.

(c) Where the reinforcement is widely spaced as in slabs, limitations of the size of aggregate may not be so important and the nominal maximum size may sometimes be as great as or greater than the minimum cover.

(d) For reinforced concrete work aggregate having maximum size of 20 mm are generally considered satisfactory.

(e) In the design of high strength concrete exceeding 350 kg/cm² reduced maximum size below 12 mm gives better result for a given water cement ratio.

(f) Plums above 160 mm and up to any reasonable size may be used in plain concrete work upto a maximum limit of 20 per cent by volume of concrete.

8.3. The maximum permissible air content

It is customary to use the word "entrapped air" when the air is introduced accidentally due to poor consolidation. The allowance for entrapped air in concrete can be estimated from Table V which varies with the maximum size of aggregate.

TABLE V.

APPROXIMATE AMOUNT OF ENTRAPPED AIR IN NON-AIR ENTRAINED CONCRETE.							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Maximum size of aggregate.	10 mm.	12.5 mm.	20 mm.	25 mm.	40 mm.	50 mm.	70 mm.
Air entrapped percent.	3	2.5	2.15			10.5	0.3

When air is purposely introduced into concrete using air entraining agent it is called air entrained concrete. The entrained air is said to affect the strength by a lesser degree than entrapped air. The beneficial effect of air entrainment is due to the reduction in water cement ratio for the same workability. Design of air entrained concrete is outside the scope of this monograph.

8.4. Choice of slump range :

To achieve full compaction the proper selection of wetness of mix is very essential. Stiffest practical mix, which will suit the method of compaction available should be chosen. However the effect of a slight excess mixing water is usually less severe, than a lack of it. In the field slump augmented by the observation of the behaviour of concrete offers the best means of evaluating workability. Different ranges of slump are specified in Table VI for different types of construction using mechanical vibrations for the compaction of concrete. For manual compaction the slump should be increased by 25 mm (1 in.).

TABLE VI.

RECOMMENDED SLUMP FOR VARIOUS TYPES OF CONSTRUCTION.

Types of construction.	Slump in mm.	
	Maximum.	Minimum.
(1)	(2)	(3)
Reinforced foundation walls and footings.	75 mm. (3 in.)	25 mm. (1 in.)
Plain footing caissons sub-structure walls.	75 mm. (3 in.)	25 mm. (1 in.)
Beams and reinforced walls ..	100 mm. (4 in.)	25 mm. (1 in.)
Building columns	100 mm. (4 in.)	25 mm. (1 in.)
Pavements and slabs	75 mm. (3 in.)	25 mm. (1 in.)
Mass concrete	50 mm. (2 in.)	25 mm. (1 in.)

Note.—The slump may be increased to 25 mm (1 in.) for method of consolidation other than vibration.

9. Optimum proportion of fine and coarse aggregate:

After determining the mix characteristics viz. water cement ratio, maximum size of aggregate, air content and range of slump, the next step is the determination of optimum proportions of F.A. and C.A. from the consideration of workability and economy.

9.1. Optimum proportions defined.

The concrete containing the highest proportion of coarse aggregate is fundamentally the best. The high proportion of C.A. lowers shrinkage and creep, increases elastic modulus and strength and also effects economy in cement.

The highest theoretical limit for C.A. proportion is attained when the void in the dry rodded state is just filled with mortar. In this condition, there is no dispersion of C.A. from its dry rodded condition and the density of C.A. in concrete is equal to the dry rodded density. But in actual practice for satisfactory workability the C.A. should be dispersed in the matrix of mortar, causing the separation of the individual C.A. particles, thus altering the jammed dry rodded state.

An optimum conditions, the C.A. should be just sufficiently separated by the matrix of mortar, to ensure adequate workability. Hence the optimum C.A. proportion may be defined as the maximum limit of C.A. giving acceptable workability.

9.2. Optimising concepts.

The concrete technologists have postulated different theories for optimising aggregates. The aim is to predict the optimum proportions with no laboratory trials. There are

several optimising concepts in vogue. Duffs Abram's (19) fineness modulus method and Kennedy's (24) excess paste, theories are examples of such an attempt. The optimising concept here followed is based on the theories of particle interferences postulated by Waymouth (6) and Huges (2).

In this concept, the optimum C.A. proportion is assumed to occur when the interstices of C.A. are just sufficiently large to readily accept the fine aggregate, especially the coarser fraction of F.A. When the interstices are not large, the coarser fraction of F.A. cannot infiltrate into the void in C.A. causing segregation and loss of workability. Thus the workability requirement causes dilation of C.A. structure in concrete which is caused by the coarser fraction of F.A. and also by the smaller fraction of C.A. The cement and water do not contribute to the dilation of C.A.

Hence the optimum C.A. is a function of the fineness moduli of F.A. and C.A. and dry rodded or loose bulk density of C.A. but independent of cement and water content. Nomogram I is designed to evaluate the optimum C.A. as a function of fineness moduli of F.A. and C.A. and the loose bulk density of C.A. and is an outcome of this theory.

9.3. Oversanded mixes.

The optimum proportion of F.A. is intrinsically the best. But there are situations in which over sanded mix is to be preferred. For concreting cast in-situ piles and for under water concreting by tremie, over sanded mix is good. In small concrete members high sand content is required for better finish. Generally when the surface to volume of structure is increased, an increase in sand content is necessary. Manual compaction requires more sand than concrete using vibrator for compaction.

9.4. Under sanded mixes.

In the case of mass concrete works a slight reduction in sand is preferable as the surface to volume ratio is negligible.

10. Estimation of mixing water.

After determining the optimum proportions of C.A. and F.A. the next step is the estimation of mixing water. The greatest single factor affecting the workability is the amount of mixing water in the mix. The requirement of mixing water largely depends upon the maximum size of aggregates, grading and angularity of aggregates and slump. The influence of cement content on the mixing water requirement is not much. Hence for all practical purposes the mixing water requirement for producing a particular slump may be held constant irrespective of cement content.

In scientific mix designs equations are derived taking into account all the factors affecting the water demand including the cement. Such equations are cumbersome for ordinary applications because of the involvement of large variables. The equations derived in this laboratory are simplified to suit the materials in the region. Nomogram II is based on this equation which gives the cement content directly. Water content can be calculated from the water cement ratio.

10.1. Correction for moisture in aggregate.

It is usually assumed in the mix design that the aggregates both coarse and fine, are in saturated and surface dry condition (or shortly in S.S.D. condition). In this condition, the aggregates are fully absorbed with moisture while the surface is apparently dry.

If bone dry samples of C.A. and F.A. are supplied an extra allowance of water for bringing the aggregate to the S.S.D. state should be made. Ordinarily for the aggregate of the type available in this region, an allowance of 0.5 per cent by weight of coarse aggregate and 1 per cent by weight of fine aggregate is sufficient and should be added to the water already calculated for mix design purpose and should be deducted from the respective aggregate weight. The rigorous method is to determine S.S.D. moisture absorptivity by test prescribed in I.S. code 2386 (Part III) 1963.

If the surface moisture is in excess of S.S.D. condition, this also should be determined in accordance with I.S. code 2386 (Part III) 1963 and should be duly deducted from the estimated water requirement for mix design.

11. Proportioning by solid volume.

In the scientific mix designs, the ingredients of concrete viz. coarse aggregate, fine aggregate, cement and water are discussed in solid volume basis, instead of by the conventional parametric ratios like aggregate cement ratio, F.A. and C.A. ratio, etc. This approach eliminates complexities in computation and streamlines steps in the mix design. The principle is explained below :—

Assume a unit quantity of fresh concrete, containing C.A., F.A. cement, water and air voids. Let us assume that C.A., F.A. and cement melt down to voidless solids. Then the sum total of solid volumes of C.A., F.A. and cement together with the volume of water and air must be equal to unit. That is,

$$a + b + c + w + n = 1 \quad \dots (6)$$

Where a, b and c are the solid volume fractions of C.A., F.A. and cement and w and n are the volumes of water and air voids.

11.1 Picture of concrete.

Some of the features of mix design reported in earlier of section is depicted in figure 2. It is observed from the figure that :

(2) (i) 'a' the solid volume fraction of metal, w, the volume of water for the specified consistency are held constant in respective of content.

(ii) The sum total of solid volume of F.A. (b) and the solid volume of cement (c) are maintained constant.

(iii) The solid volume of F.A. (b) and the solid volume of cement (c) exchange each other depending upon the richness of mix shown by the inclined line BB.

(iv) The accidentally entrapped air "n" is assumed constant.

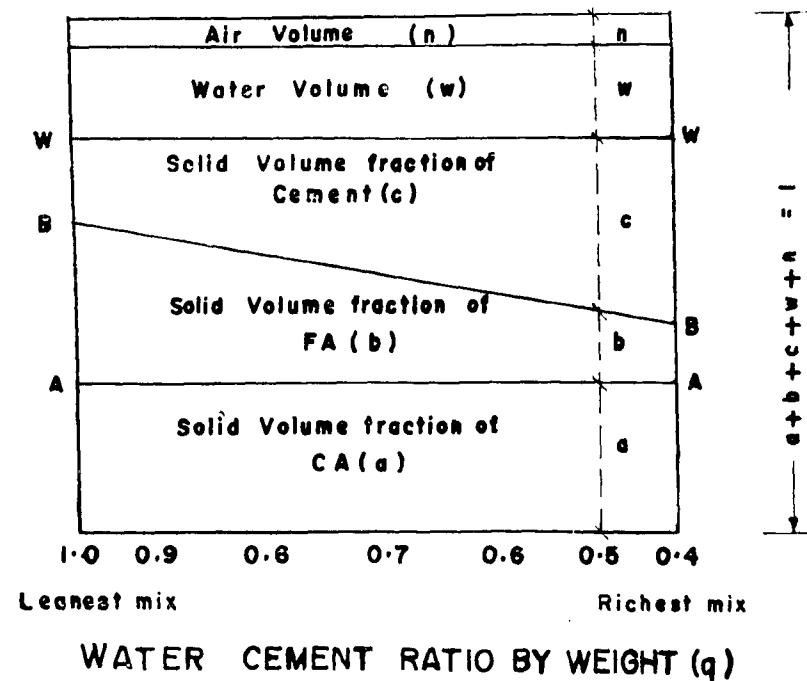


FIG. 2. PICTURE OF CONCRETE

12. Determination of the solid Volume Fractions of the Ingredients of concrete.

The mix design involves the determination of solid volume fractions of C.A., F.A. cement and the volume of water and air void.

12.1. Determination of 'a' the solid volume fraction of C.A. For determining the solid volume fraction of coarse aggregate, the following data are required.

- The fineness modulus of C.A. (ma)
- The fineness modulus of F.A. (mB)
- The solid volume of C.A. per unit volume contains as determined by loose bulk density test (aB).

The fineness modulus of C.A. and F.A. is determined from the sieve analysis as shown in Annexure 1. The (aB) can be determined by loose bulk density test as described in Annexure 2. Using the above data in Nomogram I 'a' the solid volume fraction of C.A., in concrete can be determined. The Nomogram I is designed to furnish solid volume fraction of C.A. suitable for vibratory compaction. For manual compaction a 5 per cent reduction may be made if needed.

12.2. Determination of 'c' the solid volume fraction of cement,

The 'c' the solid volume fraction of cement content can be directly found out from Nomogram II. The following background data is required from finding out 'c'.

- The fineness modulus of F.A. (Annexure I).
- The fineness modulus of C.A. (Annexure I).
- The water cement ratio by weight (q).
- The slump range (Section 8.4).

12.3. Determination of 'w' the volume fraction of water.

The water cement ratio (c) is known (Section 8.1). The volume fraction of water 'w' can be directly computed from equation (7).

$$w : 3.15 q c \dots \dots (7)$$

where q is the water cement ratio by weight and 'c' is the solid volume fraction of cement as determined in section 12.2.

12.4. Allowance for air entrapment (n).

The allowance for air entrapment is taken from Table V (Section 8.3).

12.5. Determination of 'b' the solid volume fraction of F.A.

The values of a, c, w and n are known. Hence 'b' can be calculated from equation 6 section 11. That is

$$b : 1 - (a + c + w + n).$$

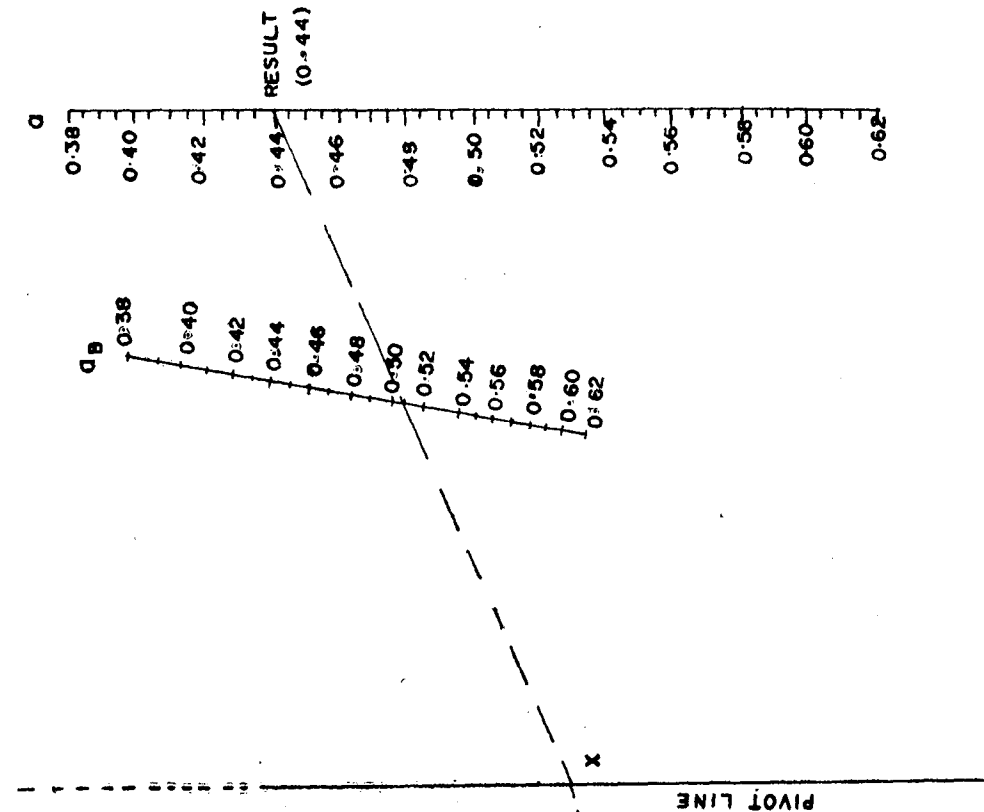
12.6. Determination of unit weight of ingredients per cubic metre of fresh concrete.

The unit weight of ingredients per cubic metre of fresh concrete is determined by multiplying the respective solid volume by thousand times the respective specific gravity as demonstrated in sample computation.

12.7. Correction for moisture in aggregate.

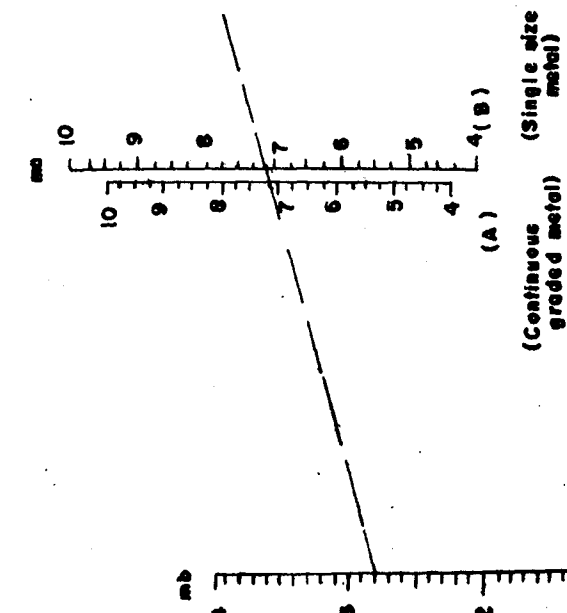
Correction for moisture in aggregates should be allowed as indicated in section 10.1.

NOMOGRAM I :- DETERMINATION OF 'a' THE SOLID VOLUME FRACTION OF METAL



1) JOIN 'ma' AND 'mB' AND PRODUCE TO MEET THE PIVOT LINE IN 'X' (USE SCALE 'A' FOR CONTINUOUS GRADED METAL AS PER IS 383-1970 AND SCALE 'B' FOR SINGLE SIZE METAL AS PER IS 383-1970)

2) JOIN 'X' AND 'aB' AND PRODUCE TO MEET 'a' AND GET THE RESULTS



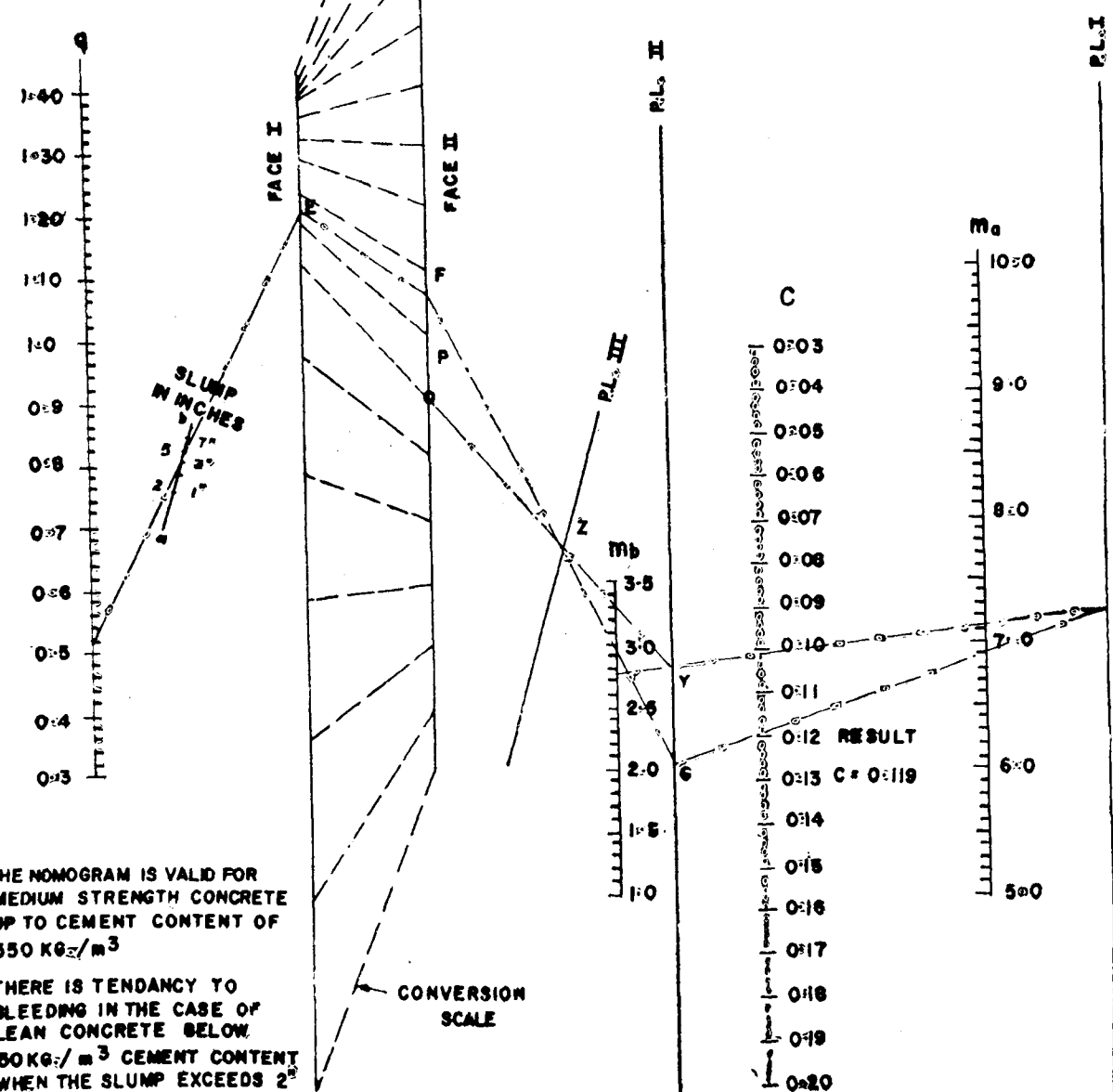
NOTE :- 1. IN THE RANGE SHOWN DOTTED IN THE PIVOT LINE 'a' EXCEEDS 'aB'. HENCE THE MAXIMUM OF 'a' SHOULD BE LIMITED TO 'aB' EXCEPT IN MASS CONCRETE 2. THE VALUE OF 'a' GIVEN BY THE NOMOGRAM IS FOR MECHANICAL COMPACTION FOR MANUAL COMPACTION 5% REDUCTION SHOULD BE MADE.

NOTATION :-
ma F.M. OF SAND
mB F.M. OF METAL
aB SOLID VOLUME FRACTION OF METAL DETERMINED BY LOOSE BULK DENSITY TEST
a SOLID VOLUME FRACTION OF METAL IN CONCRETE

NOMOGRAM II - DETERMINATION OF 'C' THE SOLID VOLUME FRACTION OF CEMENT

NOTATION

m_s F.M. OF SAND
 m_b F.M. OF METAL
 C THE SOLID VOLUME FRACTION OF CEMENT
 q WATER CEMENT RATIO BY WT.
 PL PIVOT LINE



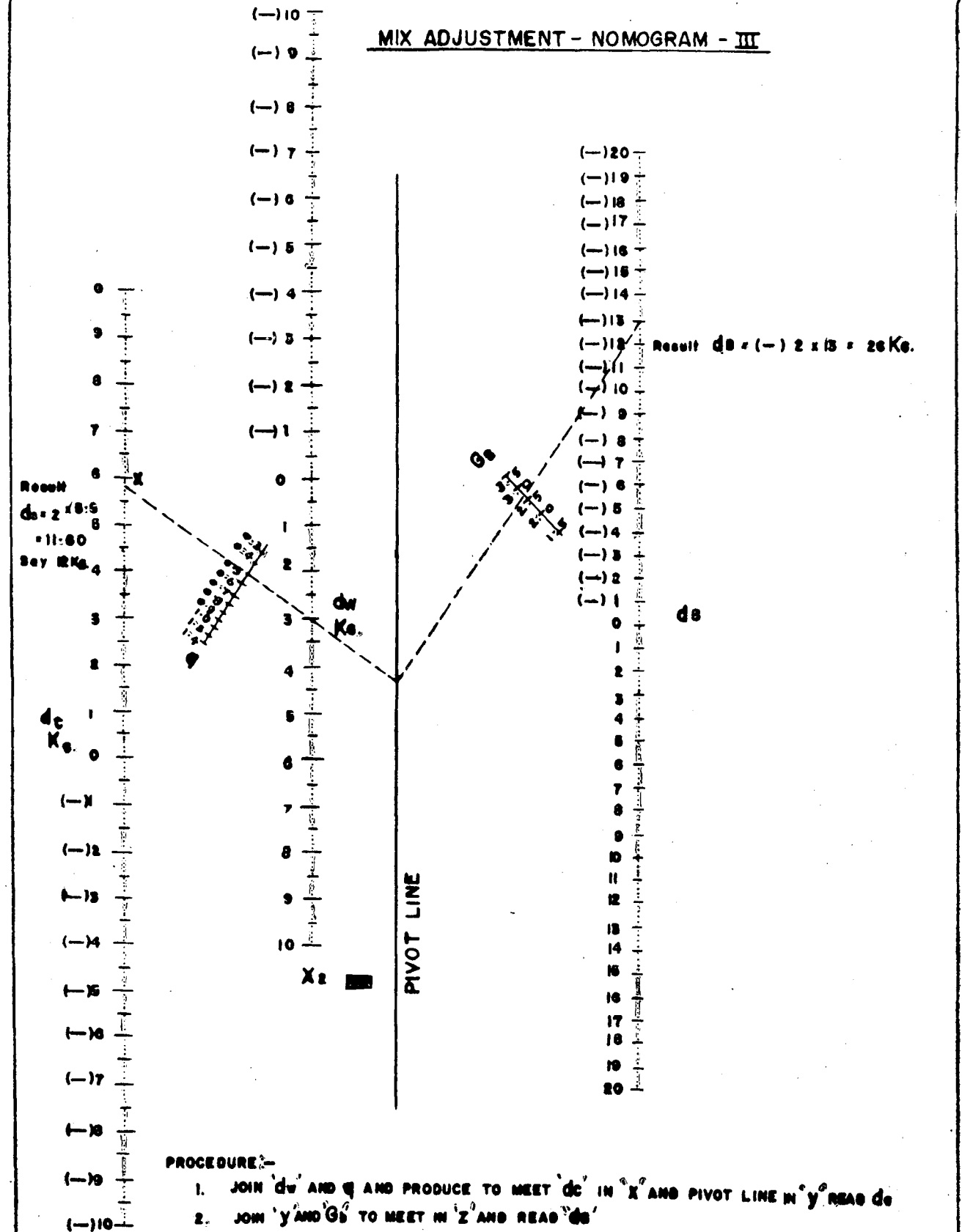
NOTE:

- 1) THE NOMOGRAM IS VALID FOR MEDIUM STRENGTH CONCRETE UP TO CEMENT CONTENT OF 550 Kg/m^3
- 2) THERE IS TENDANCY TO BLEEDING IN THE CASE OF LEAN CONCRETE BELOW 150 Kg/m^3 CEMENT CONTENT WHEN THE SLUMP EXCEEDS 2"

PROCEDURE

- OPERATION I
- 1) JOIN m_s AND m_b LET IT CUT $PL. I$ IN X $PL. II$ IN Y
 - 2) JOIN Y AND P THE POLE IN $FACE II$ OF CONVERSION SCALE, LET IT CUT THE INCLINED $PL. III$ IN Z
- OPERATION II
- 1) JOIN q AND SLUMP AND PRODUCE TO MEET THE $FACE I$ OF CONVERSION SCALE IN E
 - 2) FROM E PROCEED TO $FACE II$, FOLLOWING THE NEAREST INCLINED LINE TO MEET $FACE II$ IN F
- OPERATION III
- 1) JOIN F AND Z AND PRODUCE TO MEET $PL. II$ IN G
 - 2) JOIN G AND X TO CUT C -SCALE. READ THE RESULT FROM C -SCALE.

MIX ADJUSTMENT - NOMOGRAM - III



PROCEDURE:-

1. JOIN dw AND q AND PRODUCE TO MEET dc IN X AND PIVOT LINE IN Y READ ds
2. JOIN Y AND G_s TO MEET IN Z AND READ ds

NOTE:-

1. dw , dc , AND ds SCALES CAN BE USED FOR ANY RANGE OF VALUE, BY SUITABLY MULTIPLYING THE SCALES BY A CONSTANT FACTOR.
2. IN THE PRESENT EXAMPLE EACH VIZ. dw , dc AND ds IS MULTIPLIED BY 2 TO COVER THE REQUIRED RANGE

NOTATION:-

dw WATER ADJUSTMENT PER M^3 OF CONCRETE IN KG. (+ OR -)
 dc CEMENT ADJUSTMENT PER M^3 OF CONCRETE IN KG. (+ OR -)
 ds F.A. OR SAND ADJUSTMENT PER M^3 OF CONCRETE IN KG. (- OR +)
 q WATER CEMENT RATIO BY WEIGHT.
 G_s SPECIFIC GRAVITY OF F.A. (SAND)

12.8. Field trial.—

The calculated mix proportions should be checked in the field by small scale trials. The ingredients to produce 1/100th cubic metre of concrete is mixed and the mix should be carefully observed for proper workability, freedom from segregation and finishing properties.

Adjustment for workability if necessary may be made by regulating water. No change in C.A. and F.A. proportion is necessary. The increase or decrease in water content from the computed quantity per cubic metre of concrete is noted. As the change in water will affect the solid volume fraction of F.A. and cement, as per the concept pictured in figure 2, readjustment in quantities of cement and F.A. is necessary. This is easily done using Nomogram III and the corrected mix proportion is arrived at.

Ten cubes may be cast as per I.S. 516-1959 and the 7 and 28 days strength checked for compliance with the acceptance criteria in Table V of I.S. code 456-1964.

12.9. Scope of the mix design.—

The mix design here explained applies only to the normal weight, non-air entrained, medium strength concrete using ordinary portland cement. Design of air entrained concrete, light weight concrete, high strength concrete, no fines concrete and sulphate resistance concrete are outside the scope of this monograph.

For producing high density concrete, wear resistance concrete, under water concrete, precast concrete, concrete for piles (cast in-situ) and concrete to resist flexural stress additional specification for making concrete as per relevant code should be incorporated in the mix design.

12.10. Applicability of this mix design to different regions.

The Nomogram II is designed to suit the material in this region, viz., river sand, artificially broken metal and ordinary portland cement. If the angularity of the aggregates and the characteristics of Cement are different in other regions, the slump scale of Nomogram II should be suitably adjusted along the lines "b" by conducting few mix design trials.

13. Variation of concrete strength and quality control.

Variation of concrete strength results from different factors such as strength of cement, water cement ratio, changes in grading, air voids, curing, temperature, and testing errors. Some of these factors will tend to increase the strength, some to reduce the strength.

13.1. Measurement of variability.—

Statistical parameters are used to measure the variability of concrete strength and is expressed either as a "standard deviation" or as "Coefficient of variation" and are expressed numerically by equation 8 and 9.

S :
$$\sqrt{\frac{\sum (x - \bar{x})^2}{n-1}} \quad (8)$$

V :
$$\frac{S}{\bar{x}} \quad (9)$$

MS7A-2-8A

Where "S" is the standard deviation, 'X' is the individual test results, $\bar{x}$ is the mean of all results 'n' is the number of results and "V" is the coefficient of variation.

The Standard deviation 'S' is expressed in the same unit as the strength of concrete and the coefficient of variation "V" is expressed as a ratio.

13.2. Specifying concrete strength.—

Until recently many standards and codes have been based on minimum strength principles, with the implication that no test result should be obtained below this level. This way of specifying concrete strength has the merit of simplicity and is adequate for many jobs. But this system has a serious disadvantage in that, the greater the number of samples submitted for test, the greater the chance of test results falling below the specified minimum. Statistical theories consider this way of specifying concrete strength to be as illogical.

It is now found that the minimum strength can have significance only if it is related to the probability that a certain portion of result will fall below the minimum value. Hence the level of defective concrete that is permitted must also be specified along with the specified minimum strength so that the target mean strength can be calculated from the equation.

$$f_t = f_s + K_s$$

where f_t is the target mean strength, 'f_s' is the specified minimum strength, K is the constant depending upon the proportion of defective work permitted. Specifications have been written up allowing defective rate varying from 1 per cent to 20 per cent. European codes usually specify defective rates up to 5 per cent.

13.3 Values of 'K'

The value of "K" is a statistical constant and is furnished in Table VII for different proportions of defective rate.

TABLE VII.
VALUES OF PROBABILITY FACTOR 'K'
Proportion of cubes less than specified minimum strength.

1 in	Per cent.	K.
(1)	(2)	(3)
6	16	1.00
10	10	1.23
20	5	1.64
25	4	1.75
33	3	1.83
40	2.5	1.96
50	2	2.05
100	1	2.33

13.4 Standard deviation and quality control—

The value of 'S' the standard deviation is a function of quality control exercised. It varies usually between 35 kg/cm² to 75 kg/cm² and can even be greater for poor concrete. The approximate values of standard deviation for a given quality control is given in Table VIII. But it is better to base the choice of 'S' on the data collected from previous relevant projects.

TABLE VIII.

DEGREE OF CONTROL VS STANDARD DEVIATION.

Degree of control.	Standard deviation kg/cm ²
(1)	(2)
Laboratory control	20 to 35
Excellent site	25 to 45
Average site	50 to 60
Poor site	70 to 80

Once the concrete production is underway, it is important to obtain as quickly as possible, a reasonably reliable estimate of both mean strength and standard deviation. At least 40 cubes samples over a week should be tested. The causes of reduced average strength if noticed should be investigated and eliminated. If a consistent increased average strength together with the reduction in standard deviation is recorded economy in mix proportion may be affected. This is known as statistical control of concrete quality which applies only to large site.

14. Sample Computation.—

One example of mix design will be used to illustrate the application of proportioning procedure. The following data are assumed:—

(a) Ordinary portland cement will be used and its specific gravity (G) is 3.15.

(b) Coarse and fine aggregate are of satisfactory quality conforming to IS. 383-1970 and IS. 515-1959.

(c) The specific gravity of coarse aggregate (Ga) on S.S.D. basis is 2.87 and absorption is 0.5 per cent.

(d) The specific gravity of fine aggregate on S.S.D. basis is 2.67 and absorption is 1 per cent.

(e) The aggregates have the following sieve analysis:—

(i) Coarse aggregate—

Passing.	Retained.	Percentage retained.
(1)	(2)	(3)
20 mm	10 mm. ..	85 per cent.
40 mm.	20 mm. ..	15 per cent.

Fineness Modulus of C.A. : 7.15 (Annexure I).

(ii) Fine aggregate—

Passing.	Retained.	Percentage retained.
(1)	(2)	(3)
150 micron	Passing ..	0
300 micron	150 micron ..	12
600 micron	300 micron ..	48
1.18 mm.	600 micron ..	15
2.36 mm.	1.18 mm. ..	10
4.75 mm.	2.36 mm. ..	5
10 mm.	4.75 mm. ..	10

Fineness Modulus of F.A. : 2.78 (Annexure I).

The aggregates are available in bone dry state and allowance for S.S.D. should be made.

(f) Solid volume of C.A. per unit volumes of container as determined by the loose bulk density test (Annexure II).

$$^a B = 0.51$$

14.1. Determination of mix characteristics:—

a. Water cement ratio (q)—

Required minimum strength = 200 kg/cm²

Therefore target strength (Table IV = 260 kg/cm² —Section 8).

Corresponding water cement ratio } = 0.515
for 260 kg/cm² (Table I—Section 2).

From the criteria of durability for } = 0.65
mild exposure in air Table II—Section 4
maximum Water cement ratio. }

Hence water cement ratio selected is 0.515

b. Maximum size of coarse aggregate.—

The coarse aggregate predominantly contains 20 mm. aggregate. Hence it is suitable for R.C.C. work (Section 8.2-b).

c. Slump range.—

The slump range is selected from Table VI Section 8 with 2cm. extra allowance for hand compaction, i.e., 12cm. to 4 cm. (Average slump is about 8 cm. or 3 inches).

d. Air content.—

The maximum size of aggregate is 20 mm. and the corresponding allowance for air entrapment is 2 per cent (Table V).

14.2. Determination of the solid volume fraction of coarse aggregate (a).—

The value of 'a' is read from Nomogram I which comes to 0.44 (Using vibrator). This value should be reduced to 5 per cent for hand compaction. Hence the final value is 0.42 (0.44—0.02).

14.3. Determination of 'C' the solid volume fraction cement.

The 'C' is determined using Nomogram II and is read as 0.119.

14.4. Determination of 'W' the volume fraction of water.—

'W' is determined using the equation '7' section 12.3.

$$^a W = 3.15 \times 0.515 \times 0.119 = 0.193.$$

14.5. Determination of 'b' the solid volume fraction of F.A.—

This can be determined from the following relationship:

$$b = 1 - (a + c + W + n) \\ = 1 - (0.42 + 0.119 + 0.193 + 0.02) \\ = 0.248.$$

14.6. Tabulation of Concrete quantities.—

Constituents.	Volume fraction.	Specific gravity.	Density (kg per cubic metre).	Batch weight corrected for S.S.D.
(1)	(2)	(3)	(4)	(5)
Coarse aggregate.	0.420	2.87	1,205	1,199
Fine aggregate.	0.248	2.67	653	656
Cement ..	0.119	3.15	375	375
Water ..	0.193	1.00	193	206

NOTE:

$$\text{S.S.D. Correction for C.A.} = 1205 \times 0.5 = 6 \text{ kg.}$$

$$\text{S.S.D. Correction for F.A.} = 653 \times 1 = 7 \text{ kg (any)}$$

Therefore,

$$\text{Correction for C.A.} = 1205 - 6 : 1199 \text{ kg.}$$

$$\text{Correction for F.A.} = 653 - 7 : 656 \text{ kg.}$$

$$\text{Correction for water} = 193 + 13 : 206 \text{ kg.}$$

If the aggregates contain surface water in excess of S.S.D., the correction for water will be negative and for the aggregates, it is positive.

14.7. Field check and adjustment.—

The above quantities are sufficiently accurate. The field trial is required for checking purposes only and for making minor adjustment if necessary. The procedure for adjustment is explained below.

The following quantities of C.A., F.A. and cement required to produce 0.01 M³ of concrete are mixed in the dry state:—

C.A. : 11.90 kg.

F.A. : 6.56 kg.

Cement : 3.75 kg.

Water is progressively added observing the slump at intervals. The amount of water needed to produce a slump of 8 cm. (3 inches) is recorded which in this case comes to 2.09 kg. The difference between the observed and the computed water demand per cubic meter of concrete (dw) is noted which works out to 3 kg. (209—206).

Using Nomogram III the adjustment for cement and fine aggregate is carried out—

dc—Adjustment for cement } 12 kg.
in kg/3m (Plus or Minus)

db—Adjustment for F. A. } 26
in kg/3m (Minus or Plus)

14.8. Corrected mix proportion for one cubic metre of concrete.

Coarse aggregate	1199 kg.
Fine aggregate	630 kg. (656—26)
Cement	387 kg. (375+12)
Water	209 kg. (206+3)

14.9. Verifying the strength of cement.—

Ten number of test cubes of size 15 cm × 15 cm × 15 cm are to be prepared as per the corrected mix proportion in section 14.8 and in accordance with I. S. Code 516-1959. The strength of concrete should be checked as per the criteria in Table V of I. S. code 456-1964-at 7 days and 28 days.

15. References.—

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ANNEXURE I

Determination of the Fineness Modulus of fine Aggregate and Coarse Aggregate.

AI-1. The simplest and the most direct method of determining the fineness modulus is demonstrated using the Table III in section 6 for the aggregate used in the sample computation. The sieve analysis of aggregates is furnished in section 14.

AI-1. Determination of the fineness modulus of F. A.

Sieve Fraction.		(3)	(4)	(5)
Passing.	Retained.	P. M. of each size.	Fraction retained in each group.	F. M. of C.A.
(1)	(2)	(3)	(4)	(5)
150 micron	..	0	0	
300 micron	150 micron	1	0.12	0.12
600 micron	300 micron	2	0.48	0.96
1.18 mm	600 micron	3	0.15	0.45
2.36 mm	1.18 mm	4	0.10	0.40
4.75 mm	2.36 mm	5	0.05	0.25
10 mm	4.75 mm	6	0.10	0.60
		$\Sigma(4): 2.78$		

The fineness modulus of sand = 2.78.

AI-2. FINENESS MODULUS OF COARSE AGGREGATE.

Sieve Fraction.		(3)	(4)	(5)
Passing.	Retained.	F. M. of each size.	Fraction retained in each group.	F. M. of C.A.
(1)	(2)	(3)	(4)	(5)
20 mm	10 mm	7	0.85	5.95
40 mm	20 mm	8	0.15	1.20
		$\Sigma(4): 7.15$		

F. M. of C. A. : 7.15.

ANNEXURE II.

Determination of the solid volume of Coarse Aggregate per Unit volume of container (aB) as determined by loose bulk density test.

AII 1. Apparatus.

- A 15 cm x 30 cm deep cylinder (30 cm height).
- A Metal scoop.
- A balance accurate to weigh 5 gm.
- A straight edge (rule) (Approximately 30 cm. long 30 mm. wide and 3 mm. thick).
- A rod 12 mm dia. 30 cm long.

AII-2. Method—

The coarse aggregate is slowly poured into the cylinder from a scoop held 25 mm. above the level of the lip of the cylinder. The surface is struck off by a swift movement of 12 mm dia. rod, with rule held behind and slightly above the rod from being redeposited on the surface. The combined weight of coarse aggregate with container (W1) and the weight of empty container (W2) are separately found in Kilogram and the weight of the sample (W) is determined (W1-W2).

AII-3. Calculation.

The solid volume of loose aggregate per unit volume “aB” is calculated as below:—

Weight of sample .. W K.G.(1)

Volume of cylinder .. 5.3 litres

Specific gravity of coarse aggregate. Ga

Equivalent weight of cylindrical solid rock core of specific gravity Ga (Size 15 cm x 30 cm.). : 5.3 Ga(2)

Hence “aB” the solid volume fraction of loose aggregate per unit volume. (1) (2) $\frac{W}{5.3 Ga}$

x aB : $\frac{W}{5.3 Ga}$ (3)

Note.—In the determination of loose bulk density the container size provision prescribed in Table I of I. S. Cod 2386 (Part III), 1963 is not complied. This is delebrate.

AII-4. Determination of “aB” of C. A. in sample computation in section 14.

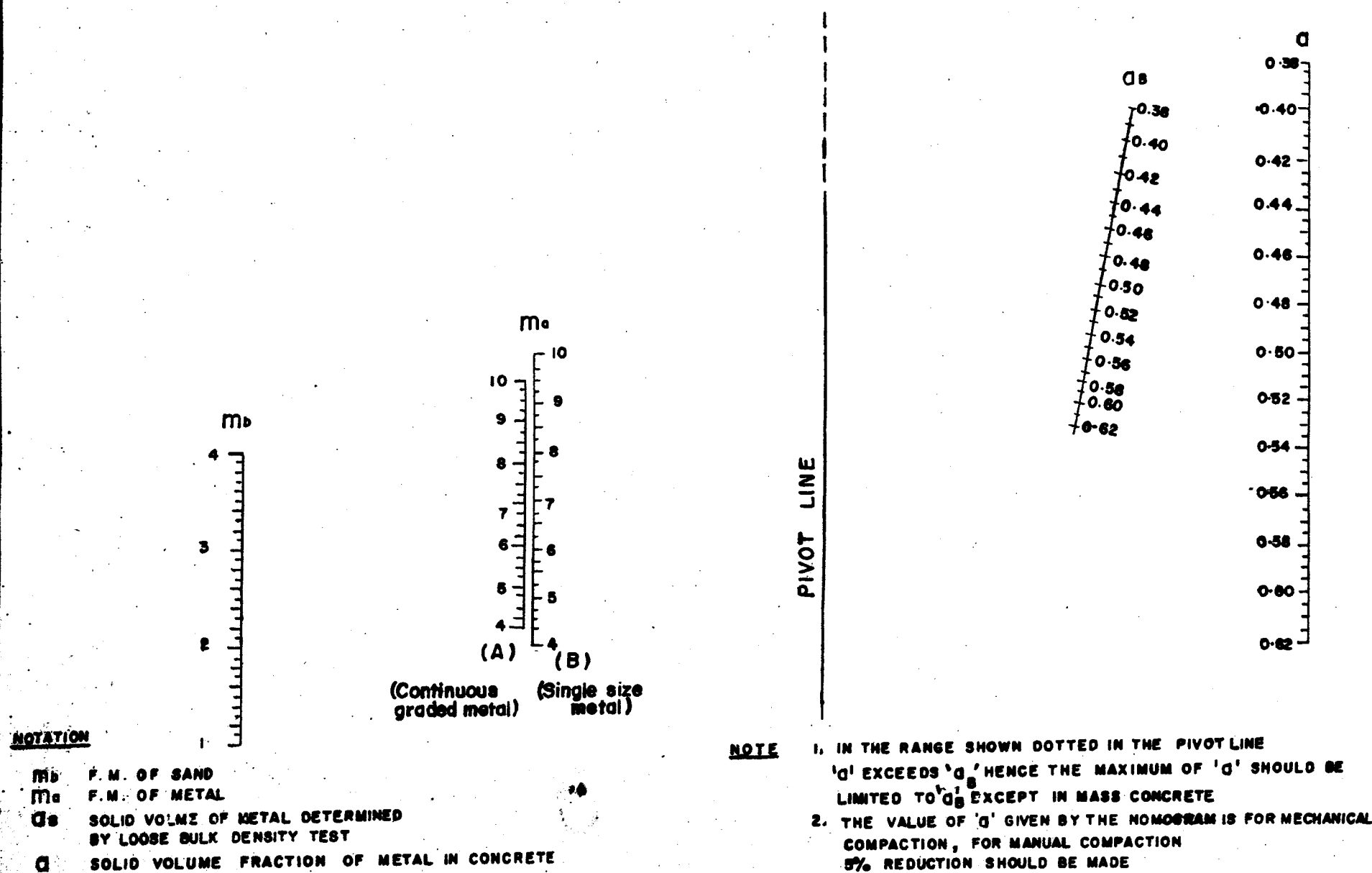
Loose weight of C.A. as determined by the above test using 15 cm. x 30 cm. cylinder. } (W) : 7.80 kg.

Specific gravity of C. A. (Ga) = 2.87

Therefore aB = $\frac{W}{5.3 Ga} = \frac{7.80}{5.3 \times 2.87} = 0.51$



NOMOGRAM I DETERMINATION OF 'q' THE SOLID VOLUME FRACTION OF METAL



NOMOGRAM II DETERMINATION OF 'C' THE SOLID VOLUME FRACTION OF CEMENT

NOTATION :-

M_b F.M. OF SAND

M_s F.M. OF METAL

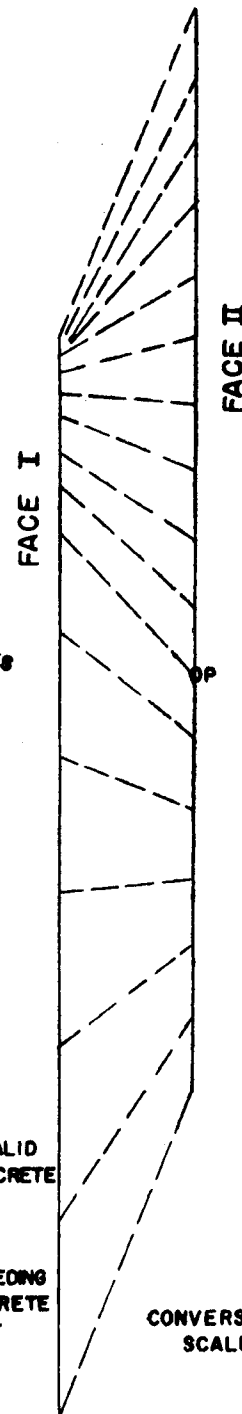
C THE SOLID VOLUME FRACTION OF CEMENT.

q WATER CEMENT RATIO BY WT.

P.L. PIVOT LINE

q
1.40
1.30
1.20
1.10
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3

SLUMP
IN INCHES
5" 7"
2" 3"
1"



CONVERSION
SCALE

M_b
3.5
3.0
2.5
2.0
1.5
1.0

C
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.18
0.19
0.20

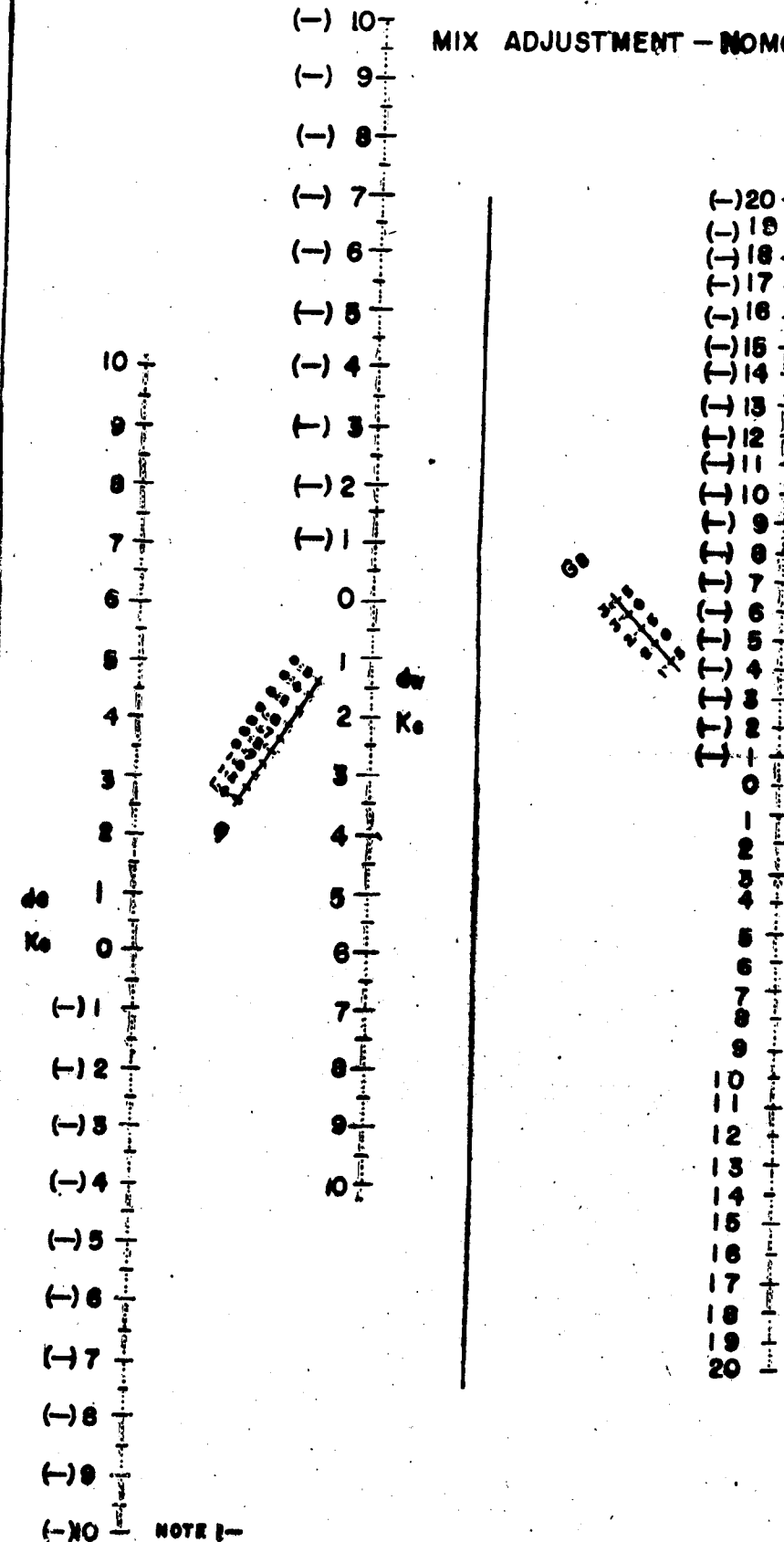
M_s
10.0
9.0
8.0
7.0
6.0
5.0

P.L.I

NOTE - THE NOMOGRAM IS VALID FOR MEDIUM STRENGTH CONCRETE UPTO CEMENT CONTENT OF 550 KGS/m³

2) THERE IS TENDENCY TO BLEEDING IN THE CASE OF LEAN CONCRETE BELOW 160 KG/m³ CEMENT CONTENT WHEN THE SLUMP EXCEEDS 2"

MIX ADJUSTMENT - NOMOGRAM III



NOTE :-

1. dw , dc , and ds SCALES CAN BE USED FOR ANY RANGE OF VALUE, BY SUITABLY MULTIPLYING THE SCALES BY A CONSTANT FACTOR.

NOTATION :-

dw WATER ADJUSTMENT PER M³ OF CONCRETE IN KGS (+ OR -)

dc CEMENT ADJUSTMENT PER M³ OF CONCRETE IN KGS (+ OR -)

ds F.A OR SAND ADJUSTMENT PER M³ OF CONCRETE IN KGS (+ OR -)

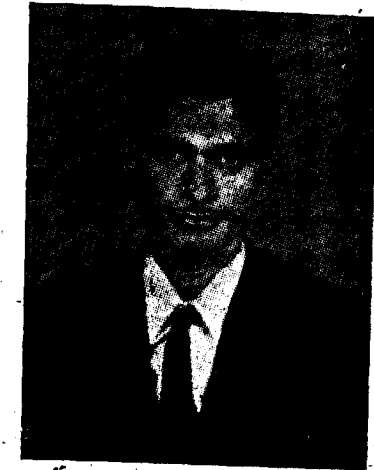
q WATER CEMENT RATIO BY WEIGHT.

G_s SPECIFIC GRAVITY OF F.A. (SAND)

EGGLIPSE : A NEW CURVE FOR ENGINEERS AND SCIENTISTS

By

ER. P. V. SAHADEVAN.*



Synopsis :

This article brings out the salient features on a NEW CURVE enshrined as EGGLIPSE, already published in the author's paper entitled "EVOLUTION OF 'N' POLAR CURVES BY EXTENSION OF FOCAL POINTS (BY MORE THAN TWO) OF AN ELLIPSE" (1). In addition, a method of describing the curve (Egglipse), using a THREAD AND PENCIL, is given. Possible places where Egglipse may be used in Engineering are also enumerated.

Introduction :

A mathematics teacher of the author made a casual statement to the following effect in one of his regular classes. "An Egg, even if it is pressed by an Elephant (ALONG ITS LONGER AXIS) cannot be broken". The author, then doing his 10th Standard, wondered "why should it be so", and later contended that the cause must be its CURVATURE. The search for finding such a curvature was thus started and the result is the invention of the NEW CURVE EGGLIPSE. A proper definition of the curve, its salient features, a method of describing the curve are given in the following paragraphs :—

Definition:

The locus of a point which moves such that its sum of its distance from THREE FIXED COLLINEAR POINTS remains a constant 'K', is defined as an EGGLIPSE (See Fig. 1).

The three fixed points are called FOCAL POINTS of the curve.

The form of an Egglipse obtained when the INTER-MEDIATE FOCAL POINT, F_2 , bisects the distance F_1F_3 (See Fig. 2) is defined as AN ABNORMAL EGGLIPSE.

The form of an Egglipse obtained when the intermediate focal point, F_2 , is shifted by a distance 'S' from the mid point of F_1F_3 is called a NORMAL EGGLIPSE (vide Fig. 1).

Basic equations :

In an Egglipse, the fundamental Equations is $r_1 + r_2 + r_3 = K$(1) (See Fig. 1 & 2)

The constant of the curve K is given by

$$K = \frac{3}{2}(a_1 + a_2) \dots \dots \text{for a Normal Egglipse (Fig. 1)} \dots \dots (2)$$

$$K = 3a \dots \dots \text{for an Abnormal Egglipse (Fig. 2)} \dots \dots (3)$$

The polar Equation of an Abnormal Egglipse with respect to F_3 as pole and F_3A as initial line (See Fig. 2) is given by :

$$16p^2r^2 \cos^2 \theta = (K-r)^2 [4(p^2+r^2) + (K-r^2)] \dots \dots (4)$$

The polar distance ['P' in an abnormal Egglipse (See Fig. 2)] is given by :

$$p^2 = \left[\left(\frac{k-b}{2} \right)^2 - h \right] \dots \dots (5)$$

The polar Equation of a Normal Egglipse with respect to F_3 as POLE and F_3A as INITIAL LINE is given by :

$$16p^2(s-r \cos \theta)^2 = (k-r^2) \{ 4(p^2+r^2+s^2) - 8Sr \cos \theta (k-r^2) \} \dots \dots (6)$$

Method of describing the curve Egglipse with thread and pencil.

One method of describing an Egglipse using a pencil and thread is detailed in Fig. 3. It employs an infinite thread for the purpose. The winding of the thread on the three pins nailed at the three focal points are shown

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in Fig. 3 to a exaggerated scale for the purpose of clarity. A step by step procedure is given below :—

(1) Take a graph sheet mounted on a card board and locate the three focal points. Nail one pin at each of the focal points.

(2) Wind the infinite thread over the pins as shown in the Fig. 3.

(3) Then, the pencil point can be moved to describe the curve Egglipse.

(4) Fig. 1 and 2 are described by the above methods and their coordinate can be computed analytically using Equations 5 and 4 respectively.

Possible uses for Egglipse :

1. One of the shapes presently used for TUNNEL SECTION is shown in Fig. 4. It is called an EGG-SHAPED section and is constituted by five different radii. The author had recently advocated an Egglipse (See Fig. 5) for the tunnel section. The author is glad to mention that the water Conductor System Sectional Committee BDC 58 meeting under the Chairmanship of Shri P.M. Mane had decided to include 'Egglipse' as one of the recommended shapes for tunnels in the Indian Statements.

2. An Egg-shaped section comprising of a few circular arcs is sometimes used as a SEWER SECTION to help maintain the velocity during low depths of flow in the sewer. This can now be replaced by an Eggliptic section to have better hydraulic and structural performance.

3. Elliptic transitions are already used in hydraulic structures. Egglipse might be better suited for some of the transition problems. Eggliptic spurdykes were tried while conducting model studies at our Instituto of Hydraulics and Hydrology, Poondi for the proposed skew type bridge across River Coleroon near Tiruchirapalli (I. H. H. Report No. 976).

Apart from these, the author expects, that the theots of Egglipse will find its use in the other branches of Science like Astromomy, Dynamics, etc. Being fundamental in concept, it is bound to expand its utility in due course.

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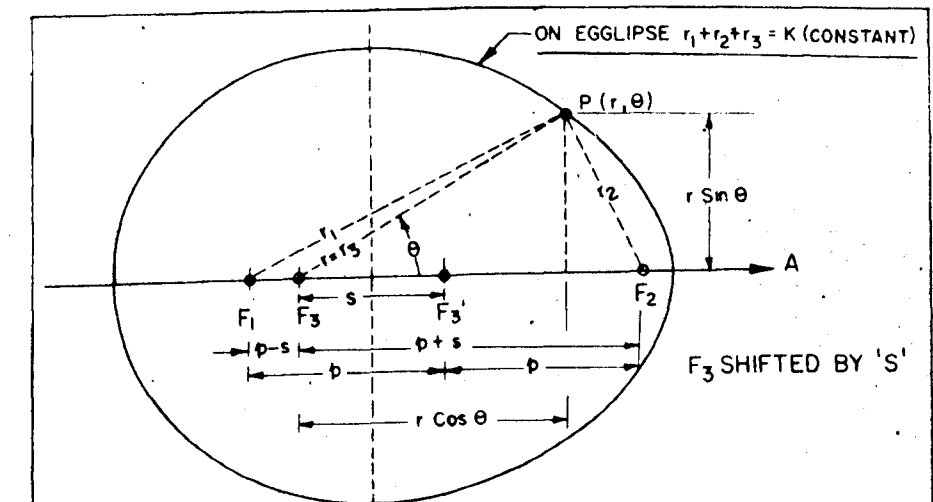


FIG. 1. NORMAL EGGIPSE

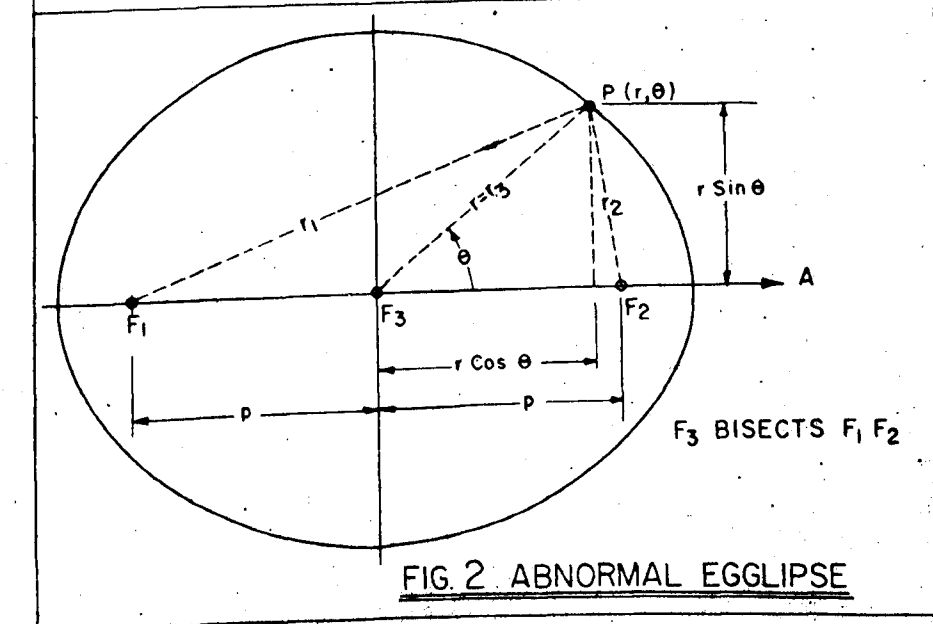
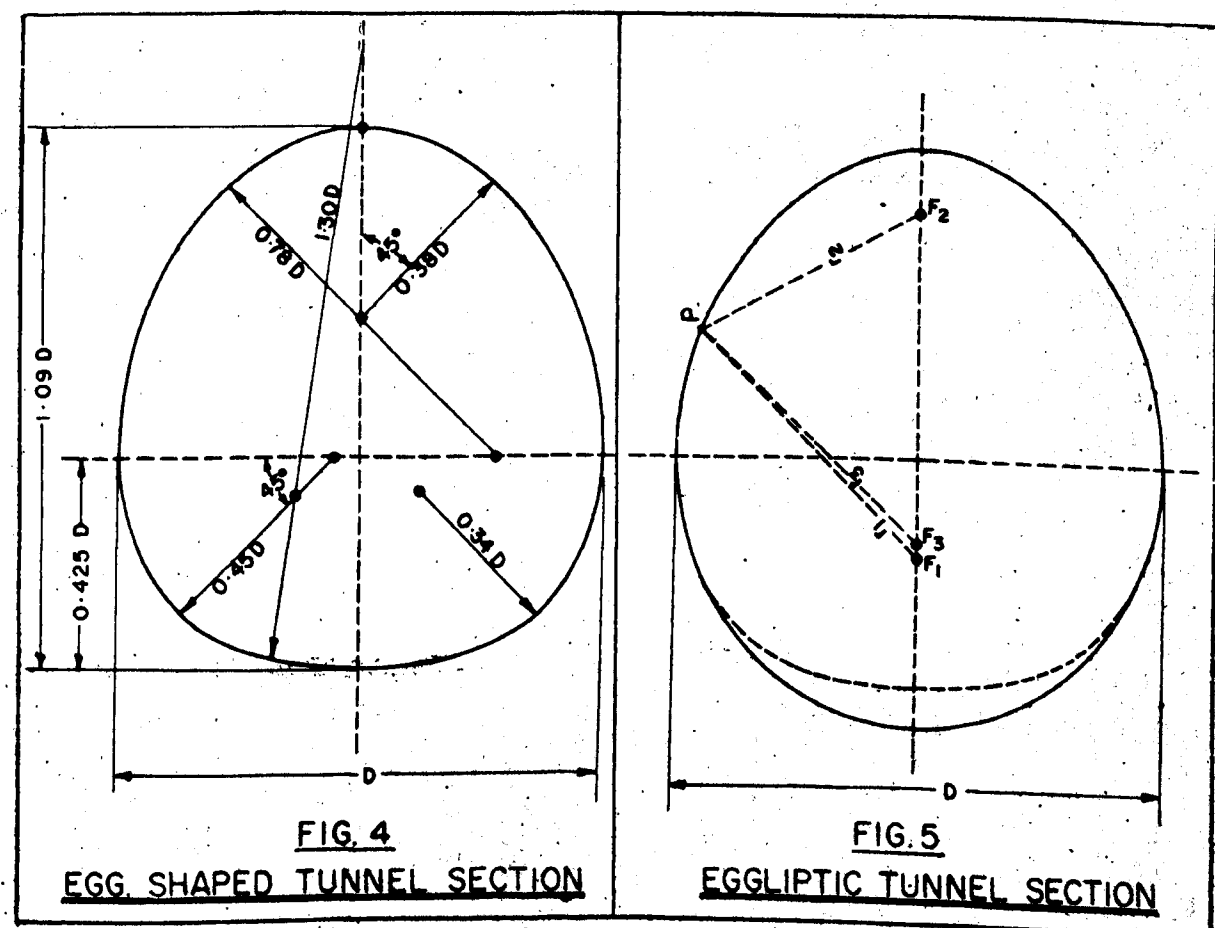
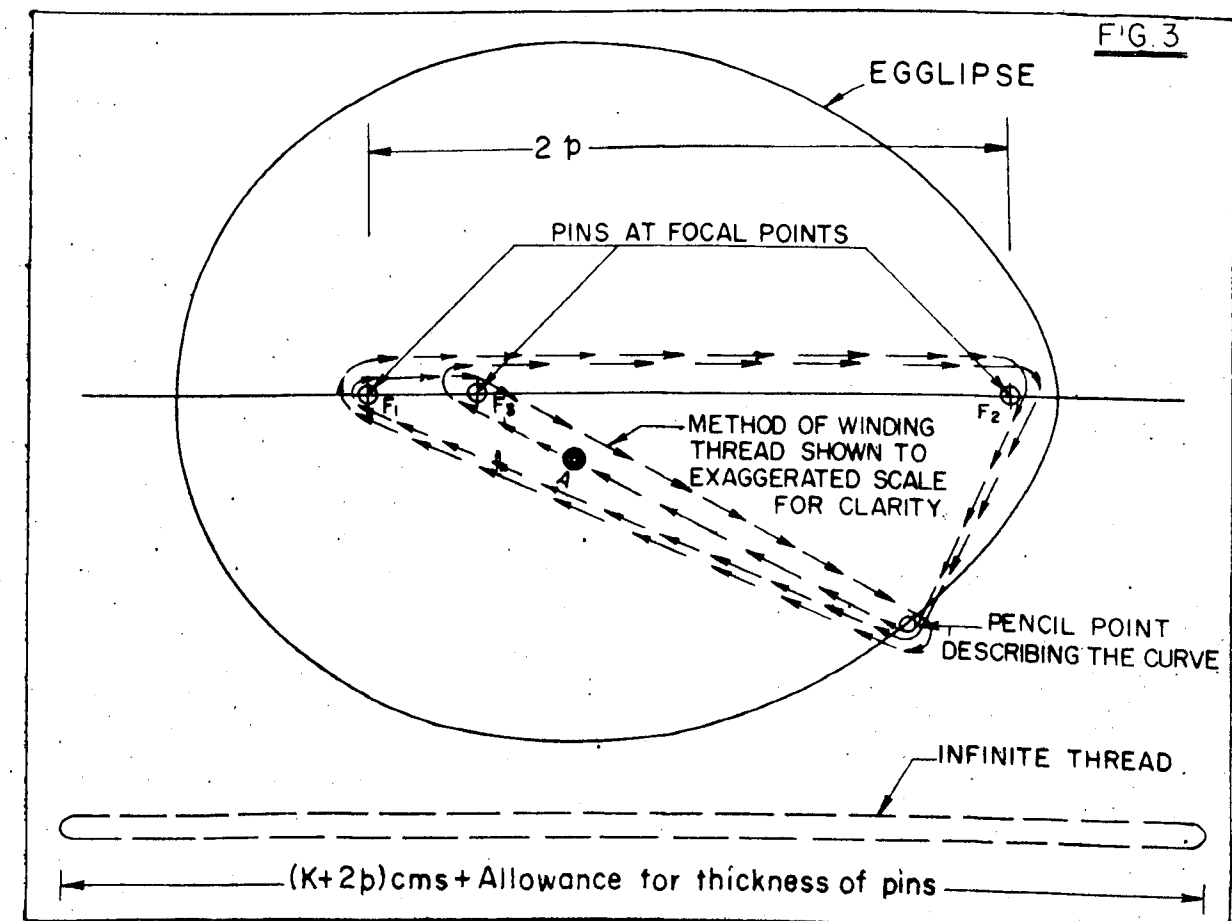
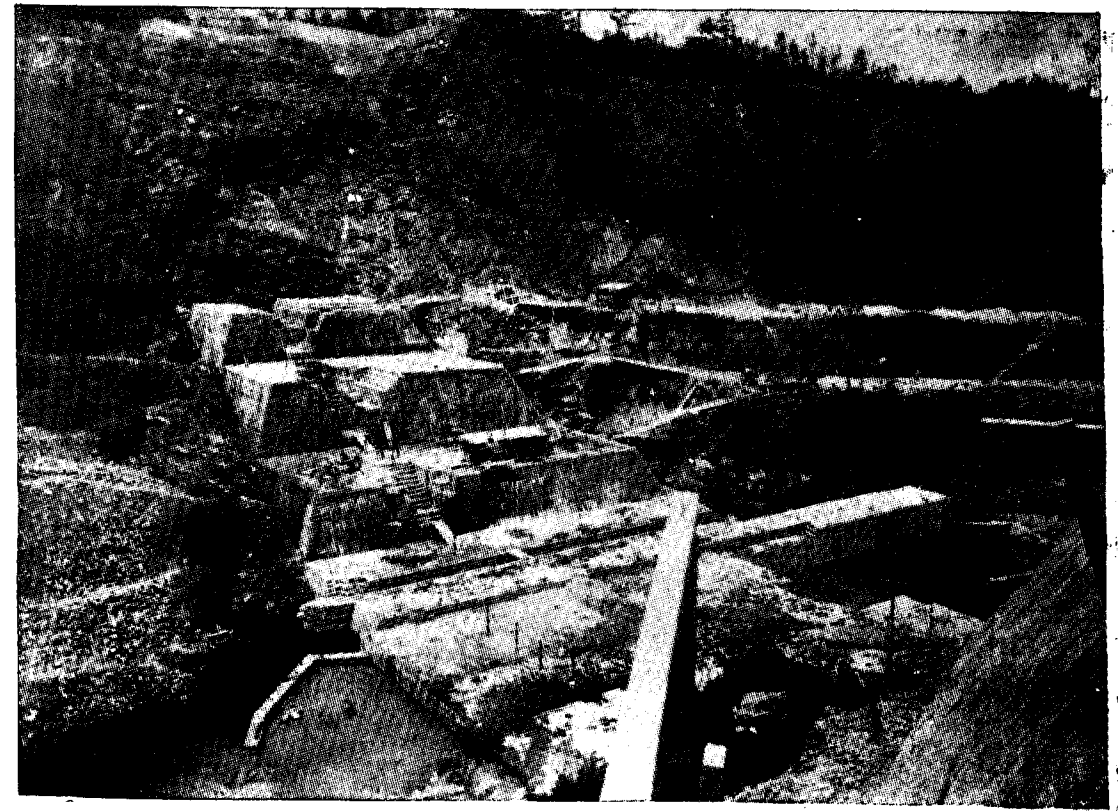
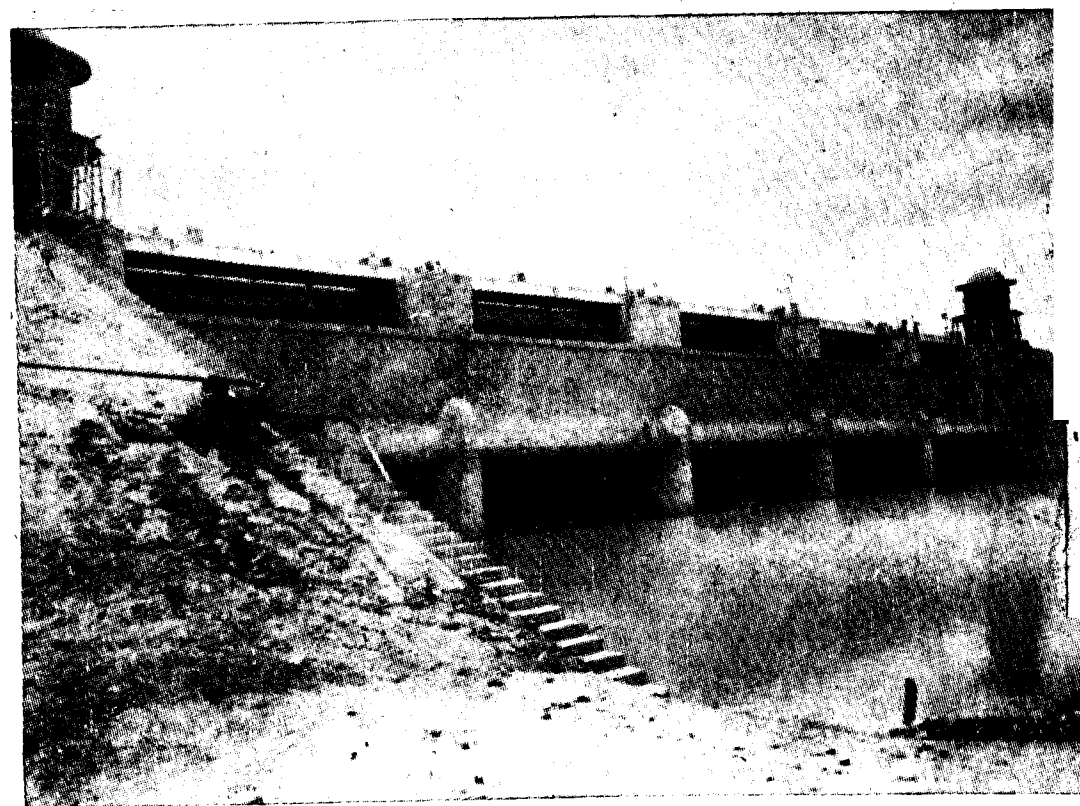


FIG. 2. ABNORMAL EGGIPSE





A view of lower Nirar Dam (Under Construction)



A view-Kodaganar Regulator

