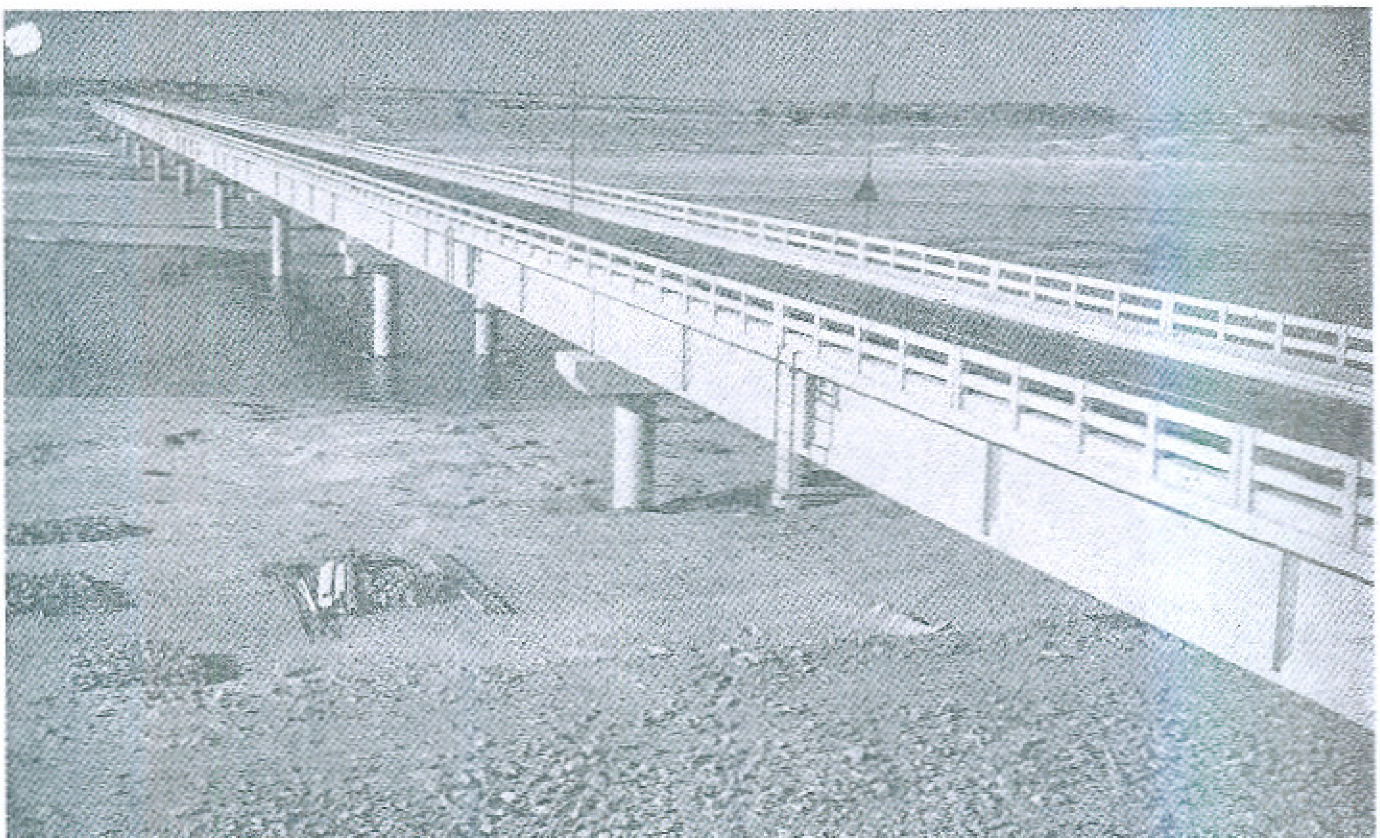
ENGINEERING NEWS

Vol. 14, Nos. 1 & 2, March-June 1969



New Bridge over River Sutlej near Bahawalpur

QUARTERLY JOURNAL OF THE WEST PAKISTAN ENGINEERING CONGRESS

• All communications should be addressed to the Editor, *Engineering News*, P. W. D. Secretariat, Lahore (W. Pak.)

• Price Rs. 2.50 per copy. Rs. 10.00 a year in advance. Free to members of the West Pakistan Engineering Congress. Change of address should be intimated promptly giving old as well as new address along with membership number.

• Contributions to this journal in the form of articles, news of engineering works, news about engineers, photographs and technical data etc. are cordially invited.

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Price of this Issue : Rs. 5.00

FOURTEENTH YEAR OF PUBLICATION

ENGINEERING NEWS

Quarterly Journal of the West Pakistan Engineering Congress

Vol. XIV MARCH—JUNE 1969 No. 1 & 2

In this issue

Printed by Mirza Muhammad Sadiq at Ripon Printing Press Ltd., Bull Road, Lahore.

The Two Research Veterans

The retirement of Dr. Mushtaq Ahmad and Dr. Nazir Ahmad marks the end of long association of two devoted scientists who have been connected with the Irrigation Research Institute ever since its inception.

Both entered the hydraulic Laboratory of the Institute about 36 years ago during 1933-34, when the Science of hydraulic investigation was just in its infancy.

The research in Irrigation Engineering was forced as a necessity on the department when problems of water and soil had become so acute as to undo the marvels which the master minds of Irrigation Engineers have conceived and created with great success.

Few could imagine that this marvellous achievement which brought prosperity and plenty to the country will start getting obliterated in the very life time of its builders.

Public Works Department of Irrigation had many eminent engineers. Those who could complete triple canals project consisting of Upper Jhelum, Upper Chanab and Lower Bari Doab Canals including their headworks in a short period of eight to ten years during the most difficult days of 1912 to 1915, under the shadow of the First World War which were consuming all the resources of the British Government. These engineers had also completed the Sutlej Valley Project consisting of four barrages and eleven canals in about eight years between 1921 to 1929 in spite of the economic depression and the after-effects of the war.

These eminent engineers found no difficulty too great in their professional attainments but were helpless to solve problems of land and water which needed a different type at training and experience of laboratory techniques and knowledge of basic sciences as possessed by Physicists, Chemists, Mathematicians, Biologists and Agriculturists. Persons with this type of training were advocated by all the experts called in by the British Government. Even the Irrigation Engineers on the platform of the Engineering Congress and in their own notes on files urgently moved for the help of scientists.

In keeping with these ideas Dr. E. Mckenzie Taylor, Ph.D., D.Sc., was the first Agricultural Chemist who was entrusted in 1931 to organize research on the Irrigation problems. He collected scientists from all over India, to head the various research divisions. Dr. V. I. Vaidianthan D.Sc., came from Madras to take up the assignment of Soil Physicist, Dr. N. K. Bose, Ph.D., came from Calcutta to head the Mathematical section, Dr. A. N. Puri, Ph.D., D.Sc., left the Pusa Research Institute to become Physical Chemist and so were the other heads of Sections. Even their Assistants were selected from amongst those who had the highest attainments in educational records: men like J. K. Malhotra, A. G. Asghar, R. C. Hoon, Hans Raj Luthra and so on.

The research on experimental hydraulic in those days was still in a very elementary stage. American Engineers and Scientists had just started to publish lecture notes of their German teachers. Freeman's Hydraulic Laboratory Practice was the first gospel which introduced experimental hydraulic investigations in America. Irrigation Engineers had not yet a clear conception about the sub-soil flow under weirs, energy dissipation below falls, training of rivers, and their control, sediment movement into the canals and several such intricate problems which were as important to the Irrigation Engineers as were the problems of Land and Water use.

The two scientists, Mushtaq and Nazir, in 1933-34, undertook the study of uplift pressure on structures founded on sand by means of hydraulic models and within a few years all aspects on the function of sheet piles, their positions and lengths with respect to floor, effects of silt blanket, scour both up stream and down stream, seasonal changes of temperature of flowing water etc., were investigated. A new technique for study of sub-soil flow phenomena by viscous flow of water, was perfected. On the results of these investigations was based the famous volume on Design of Weirs on Sand Foundation, in 1938. Within a few years many aspects of energy dissipation below weirs and falls, river training by spurs and its control, silt exclusion and ejection etc., were investigated.

Research was completed to establish rules and limits for reproduction of model results on prototype. The basis of model scale, its distortion, variation of slope, discharge, bed materials and time scales were also established by these workers. The future hydraulic investigations were thus made perfect and based upon sound Scientific principles.

In fact in between the years 1932 to 1943, due to the work of these Scientists, the science of hydraulic models was brought to its present pitch of perfection to predict with confidence the conditions on the prototype. The other divisions of the Institute headed by physical chemists, soil physicist, mathematical officer, land reclamation officer, soil and water analysist, investigated and elucidated the intricate interrelations of soil and water, salinity and alkalinity, waterlogging and reclamation, etc.

The Institute became a Premier Research Organization of India. Its standard of work was recognized Internationally. Every year the Institute produced two or three Ph.D's. It was set on scientific footing with its own standards of investigations and its work was reproduced in foreign publications.

In 1947 came theIndependence. All the non-Muslims migrated to India. The Institute was left with only three scientists, Dr. A. G. Asghar, Dr. Mushtaq and Dr. Nazir who had 14 to 15 years' experience of research in the Institute. Dr. Asghar took over as head of the Land Reclamation Department and the vast organization of the Research Institute was left to the control of Mushtaq and Nazir who had now to organize every thing from a scrap. Mushtaq took over the hydraulics, and surface flow problems whereas Nazir interested himself in groundwater hydrology soil mechanics and foundation and such other subjects of Irrigation Engineering. The work of organization in those unsettled days was a difficult job. Qualified persons were not available. Every person had to be initiated in the technique of research on Irrigation problems. In spite of all handicaps and difficulties those who had seen the Institute before Independence and now when the two scientific workers have laid down their charge in 1969, can see the vast development in research facilities and contribution to the science of Hydraulics and Irrigation Engineering. During these years the Institute has established a grand Hydraulics Research Station at Nandipur, where men of International fame had worked and have been happy to take guidance at all points from Dr. Mushtaq. It was the scientific attainment of Mushtaq and his standard of work which won the confidence of International consultants to entrust all Hydraulic Model Investigations of Indus Basin works to the Research Institute. Nandipur Hydraulic Research Station became as much well established as any Research Organization of the world. It will ever remain a landmark in the history of research on the subject in this country.

The Science of soil physics, tubewells, canal lining, sediment estimations, evaporation and evapo-transpiration and its control etc. needed a field experimental set-up. This was established at Niazbeg by Dr. Nazir. The Research work of this station is known in the world and referred to in the International Publications. During these years, the research organization at Hyderabad, at Karachi and at many field sites and the grand three-storey new wing of the research Institute at Lahore with all facilities to conduct research on Irrigation Engineering, Soil and Water is just one example of the achievements of the devoted workers. The output of work, published papers, hundred of technical reports, speak for the scientific work of this Institute between these twenty-two years.

Dr. Mckenzie Taylor started in 1935 the publication of Annual Reports of the work done in the Institute. There were very few individual reports on particular investigations. A few research notes remained in files and that became difficult for the workers to locate. The sectional heads, however, published some research papers in different journals and some memoirs of the Institute. Except for the published work, the main technical reports became unavailable. The two scientists after independence, introduced the publication of technical reports, on the completion of a study. These were numbered and copies were made available to the library, to the office of all Chief Engineers besides the organizations which initiated the studies. Technical reports on various aspects of Hydraulic, river flow, canals, falls, dams etc., on tubewells, ground water, canal lining, stress analysis, sediment, soil mechanics and foundation etc. have all been numbered and are made available for all investigations.

The research contributions and papers after independence run into hundreds. Practically every engineering journal of the country, the West Pakistan Engineering Congress, the Institute of Engineers, Pakistan, the University of Engineering and Technology, the Pakistan Association for Advancement of Science etc., contain contributions of these selfless scientists. Their contributions kept the name of the Institute amongst the scientific organizations of the world. Every international conference pertaining to hydraulic model research, groundwater, tubewells, canal lining, waterlogging and salinity received contributions from the Research Institute.

It was for the first time during these twenty-two years that solution to a problem had always been made available to designers and construction engineers from the Institute before they took their field construction.

Field and design engineers would walk in with their problems, and would come out always enlightened with a solution.

Every foreign engineer, professor or scientist visiting the country would take pleasure to go round the activities of the Institute. It always presented something original, some new idea, new methods and new results.

The Publications of the Institute have always remained in great demand all over the world. In fact the Institute library receives innumerable publications on excharge basis.

The two scientists have retired. They have left the Institute with the fame well established in the world. Its research laboratories are well equipped, with several scientific persons trained for years on different aspect of irrigation problems.

It is a different Research Institute as it was twenty-two years hence at the time of Independence and thirty-six years hence when it started on its path of progress.

Let this concern, this symbol of hard work of two devoted scientists, develop and prosper in the coming years and be a source of happiness to its past and present builders !—Amen.

Superelevation on Highway Curves

MOHAMMAD IDRIS RAJPUT
S.D.O., Kalat.

The article of Mr. Mohammad Idris Rajput contains basic data, tables and graphs for designing superelevation in the design of curves in Highways. Mian Saeed Ahmed, Director-General Highways, has been sending instructions of Design to Engineers in the field. Mr. Idris has tried to work out the basis of the design from ab initio and given the whole theory which is generally not available to the field engineers. The article contains fundamental and basic information on the subject.

Necessity

When any vehicle negotiates a horizontal curve, it experiences two types of accelerations, the tangential and the normal (directed towards centre).

The tangential acceleration helps in forward motion and the normal acts towards the centre, causes it to move along a curve. At every instant the tangential acceleration tends the body to move in a straight line whereas the normal acceleration pulls the body towards the centre of the curve and the net result on the body is the resultant effect of the two forces.

The normal acceleration causes an imbalance in the body so that there is a tendency to skid towards the centre. The skidding is opposed by the frictional forces of the tyres of the vehicle.

An excess of the friction force overcomes the skidding. This can happen if the radius of curvature is long and the speed of the vehicle is low.

An example for such a condition is as under. Suppose a vehicle is moving at a speed of 30 M.P.H. around a circular curve of 1500 ft. radius.

The frictional force F is (see Fig. 1)

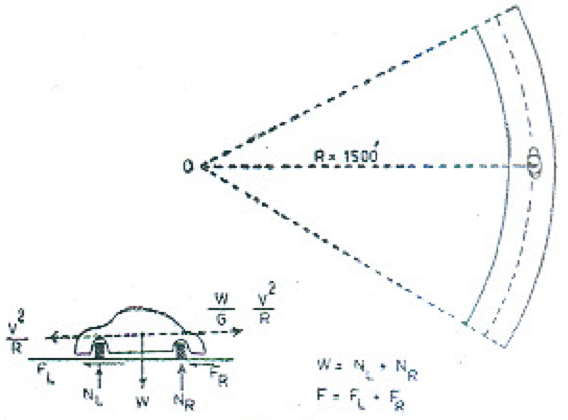


Fig. 1

$$F=\frac{W}{g}\times\frac{V^2}{R}=\frac{W}{32.2}\times\frac{(44)^2}{1500}=0.04W$$

Normally the safe coefficient of friction between the tyres and the road surface is 0.15. Therefore the friction force opposing skidding is 0.15 W. This value being more than 0.04 W. the vehicle will not skid.

When the speed of a vehicle increases and the curve becomes sharp, the frictional force becomes insufficient to counteract skidding. This is explained from another example. Refering to Fig. 2, suppose the vehicle is moving

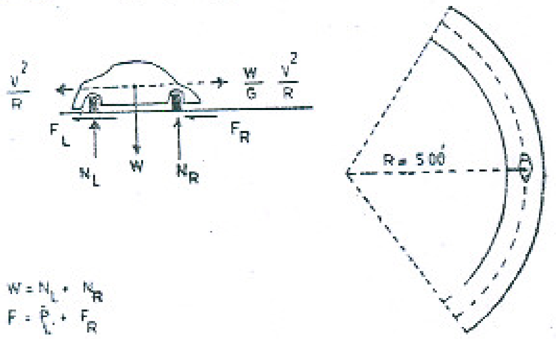


Fig. 2

at a speed of 60 m.p.h. around a circular curve of 500 ft. radius, the frictional force is

$$F=\frac{W}{g}\times\frac{V2}{R}=\frac{W}{32.2}\times\frac{(88)^2}{500}=0.48W$$

The friction force available for a coefficient of friction of 0.15 is 0.15 W. This frictional force is more than 0.15 W, required to avoid skidding and hence the skidding will take place.

The skidding can be avoided when the outer edge of the pavement is elevated with respect to the inner edge. This raising of outer edge of pavement with respect to the inner edge is known as superelevation.* In this case the component of this weight of the vehicle parallel to the inclination assists the frictional force to overcome skidding.

Calculation For Superelevation

Suppose car (see Fig. 3*a*) is moving along a superelevated circular curve of radius R ft., with a velocity of v ft./sec. The weight "W" of the car including the occupants is acting vertically downwards. The outer edge of pavement of width "B" is elevated a vertical distance 'h' from the inner edge.

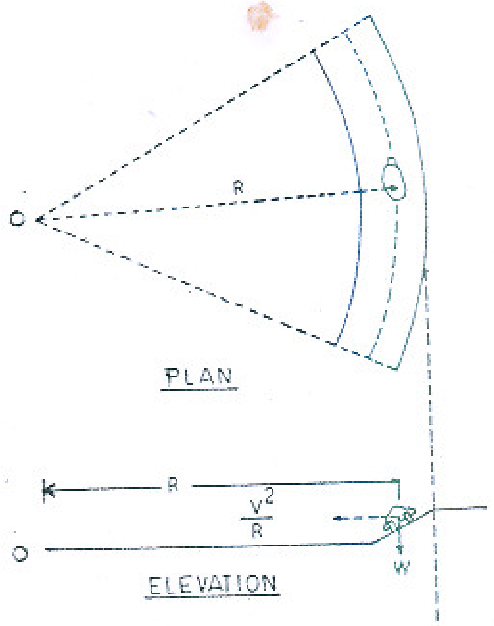


Fig. 3 (*a*)

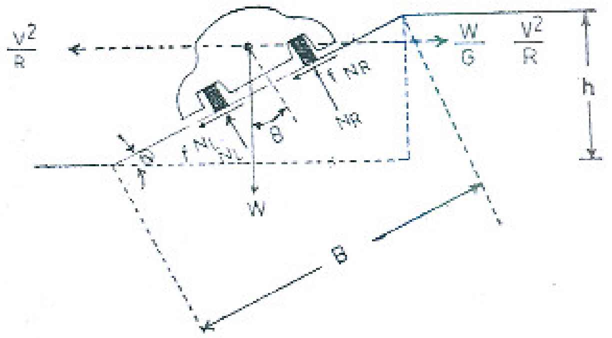


Fig. 3 (*b*)

The forces acting on the body are shown in the Fig. 3*b*. The body is moving with an acceleration of $\frac{V^2}{R}$ towards the centre.

*It should actually be called elevation, but in order to avoid confusion with elevation of a point above sea level, it is termed superelevation *i.e.* the vertical distance of outer side of the road pavement to the inner ratio or percentage is another way of expressing superelevation.

Let us bring the body to rest by applying an imaginary opposing acceleration $\frac{V^2}{R}$, the imaginary opposing force is $\frac{W}{g} \cdot \frac{V^2}{R}$ which is termed as the "Reversed Effective Force". It is sometimes termed the "Centrifugal Force" and is assumed to be an actual force acting on the body. This concept is not true. There is no such force acting on the body.

For equilibrium of forces along the inclination:

$$\frac{W}{g} \cdot \frac{V^2}{R} \text{Cos } \theta = f\left(N_R + N_L\right) + W \text{ Sin } \theta$$

But $N_R + N_L = W \text{ Cos } \theta$

$$\therefore \quad \frac{W}{g} \cdot \frac{V^2}{R} \text{Cos } \theta = f\, W \text{ Cos } \theta + W \text{ Sin } \theta$$

$$\therefore \quad \frac{V^2}{gR} = f + \tan \theta$$

$\therefore \quad \tan \theta = \frac{V^2}{gR} - f$; since θ is small $\sin \theta = \tan \theta$

(This is true upto about 6°, giving a value of 0.105 which is O.K. because superelevation generally does not exceed this limit.)

$\therefore$ Sin $\theta = \frac{V^2}{gR} - f$ and $\sin \theta = \frac{h}{B}$ = Superelevation = e

$$\therefore \quad e = \frac{V^2}{gR} - f$$

If we convert velocity v (in ft./sec.) to velocity V (in m.p.h.)

$$\frac{V^2}{gR} = \frac{(5280/3600\ V)^2}{gR} = \frac{2.15\ V^2}{32.2\ R} = \frac{V^2}{15\ R}$$

$$\therefore\ e = \frac{V^2}{15R} - f \text{ ———— (A)}$$

Where

e = Superelevation in ft./ft.
V = Velocity in m.p.h.
R = Radius in ft. &
f = Coefficient of friction.

If we express R in terms of D, the formula becomes

$$D = \frac{85900\ (e + f)}{V^2} \text{ ———— (B)}$$

where D = Degree of the curve.

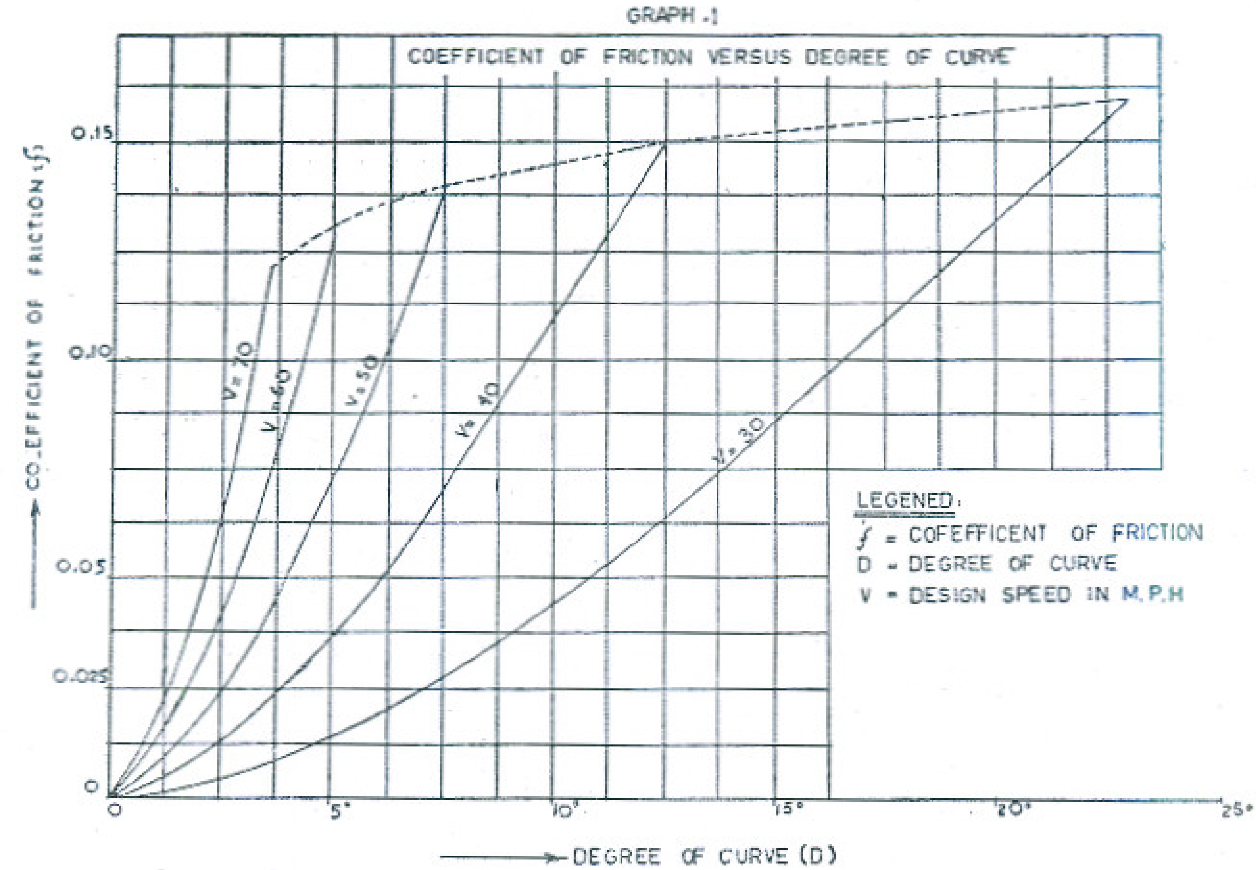
Safe Co-efficient of friction (f)

The co-efficient of friction "f" at the point of skidding depends upon the speed of the vehicle, the type and condition of the road surface, the type and condition of tyres and finally the degree of curve.

The maximum value of 'f' for good, dry pavement varies from 0.5 at low speeds to 0.35 at high speeds. For wet and slippery pavement the value is as low as 0.2. These are the maximum values encountered while skidding is imminent. For safety, much lower values are adopted. The criterion of design for safe friction factor is the point at which the driver recognises a feeling of discomfort and instinctively acts to avoid higher speeds. The maximum safe frictional-factor for different speeds is as under:

Design Speed in M. P. H.	30	40	50	60	70
Maximum Safe Friction Factor, 'f'	0.16	0.15	0.14	0.13	0.12

On a flat curve, at a constant speed, the friction force does not come into play and all centrifugal force is reacted by the superelevation. As the degree of curve increases for a constant speed, the friction force gradually comes into play and goes on increasing as degree of the curve increases and up to the safe limit beyond which the driver recognises a feeling of discomfort. The variation of friction factor for various degrees of curvature, speeds and a maximum superelevation of 0.08 is shown in Table I and the Graph-I.



Maximum Superelevation

Superelevation depends upon the velocity, radius and degree of the curve and the coefficient of friction. Greater the velocity and lesser the radius, greater will be the superelevation. If superelevation is excessive, even a slow moving vehicles stand the chance of slipping down. Also in rainy areas and at places where snowfall occurs, excessive superelevation is dangerous for fast moving vehicles also. Taking all these things into consideration, a maximum value of 0.8 has been found satisfactory.

The value imposes restriction on the radius of the curve for various design speeds. For a speed of 70 M.P.H., a superelevation of 0.08 and for f = 0.12 the radius R is as under:

$$0.08 = \frac{70^2}{15R} = 0.12 \therefore R = 1633 \text{ ft.}$$

This is the maximum value of the radius. Below are worked out the degree of the curve for a constant superelevation and for different speeds and radius.

TABLE 1

Coefficient of Friction for Various Design Speeds and Degrees of Curvature

D	R	Assumed Design Speed M.P.H. (V)				
		30	40	50	60	70
		f	f	f	f	f
00°-15′	22918	0	0	0	0	0
00°-30′	11459	0	0	0	0	0
00°-45′	7639	0	0	0	.009	.014
01°-00′	5730	0	0	.0081	.013	019
01 -30′	3820	0	.007	.0136	.023	.033
02°-00′	2865	0	.0102	.0202	.033	.049
02°-30′	2292	.0052	.0136	.0268	.045	.0695
03°-00′	1910	.0064	.0178	.0344	.059	.093
03°-30′	1637	.0087	.0222	.044	.074	.120
04°-00′	1432	.0099	.0275	.0535	.091	D max. = 3.5°
05°-00′	1146	.0143	.0382	.0745	.130	f max. = 0.12
06°-00′	955	.0198	.051	.098	D max. = 5°	
					f max. = 0.13	
07°-00′	819	.0253	.063	.125		
08 -00′	716	.0318	.078	D max. = 7.5°		
09 -00′	637	.0382	.092	f max. = 0.14		e max. 0.08
10°-00′	573	.046	0.109			
11 -00′	521	.052	0.125			
12°-00′	477	.058	0.143			
13°-00′	441	.068	D max. = 12.5°			
14°-00′	409	.077	f max. = 0.15			
16°-00′	358	.094				
18°-00′	318	0.11				
20°-00′	286	0.131				
22°-00′	260	0.15				
23°-00′	250	0.16				
		D Max. = 23°				
		F Max. = 0.16				

D = Degree of curve
R = Radius of curve
V = Assumed Design Speed
f = Safe coefficient of friction.

Design Speed in M. P. H.	Maximum Superelevation	Minimum Radius in ft.	Maximum Degree of curve
30	.08	250	23.5
40	.08	464	12.5
50	.08	758	7.5
60	.08	1143	5.0
70	.08	1633	3.5

If the speed is low and the radius of curve is large, no superelevation is necessary. A normal crown section can be provided.

The minimum radius for Normal Crown Section for various speed limits are as under:

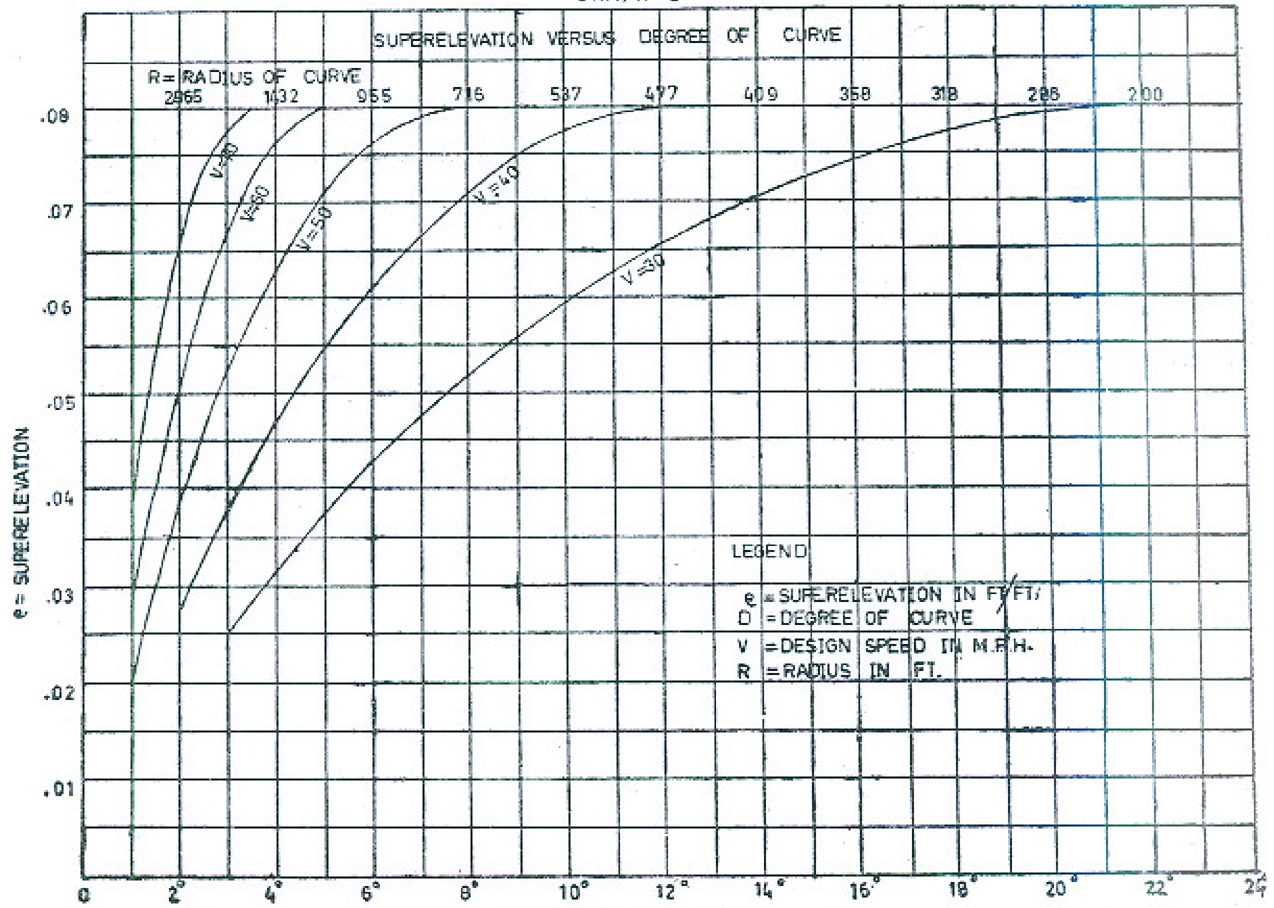
Design Speed in M.P.H.	Maximum Degree of of Curve	Minimum Curve Radius in Ft.
30	1°-30′	3,800
40	0 -45′	7,600
50	0°-30′	11,450
60	0°-20′	17,200
70	0°-15′	22,900

The variation of superelevation *e*, for various speeds and degrees of curves is shown in Table 2 and Graph 2. The calculations are for the safe coefficient of friction as given in the Table 1. For design purposes, this table and graph will be used.

Superelevation Runoff (Lr)

Keeping in view the driver's comfort, safety and appearance of pavement edges, the superelevation should be effected in a suitable distance which is termed superelevation run off. This Superelevation runoff has been

GRAPH – 2



D= DEGREE OF CURVE

TABLE 2

Superelevation Rates For Various Design Speeds and Degrees of Curvature

		Assumed Design Speed M.P.H. (V)				
D	R	30	40	50	60	70
		e	e	e	e	e
00°-15′	22918′	N.C.	N.C.	N.C.	N.C.	N.C.
00°-30′	11459′	N.C.	N.C.	N.C.	R.C.	R.C.
00°-45′	7639′	N.C.	N.C.	R.C.	.022	.029
01°-00′	5730′	N.C.	R.C.	.021	.029	.038
01°-30′	3820′	R.C.	.021	.030	.040	.053
02°-00′	2865′	R.C.	.027	.038	.051	.065
02°-30′	2292′	.021	.033	.046	.060	.073
03°-00′	1910′	.025	.038	.053	.067	.078
03°-30′	1637′	.028	.043	.058	.073	.080
04°-00′	1432′	.032	.047	.063	.077	.080
05°-00′	1146′	.038	.055	.071	.08	D max. = 3.5°
06°-00′	955′	.043	.061	.077	.08	
07°-00′	819′	.048	.067	.079	D max. = 5°	
08°-00′	716′	.052	.071	.08		
09°-00′	637′	.056	.075	D max. — 7.5		
10°-00′	573′	.059	.077			
11°-00′	521′	.063	.079			
12°-00′	477′	.066	.08			
13°-00′	441′	.068	.08			
14°-00′	409′	.070	D max. = 12.5°			
16°-00′	358′	.074				
18°-00′	318′	.077				
20°-00′	286′	.079				
22°-00′	260′	.08				
23°-00′	250′	.08				
		D max. = 23°				

e Max. =0.08

D = Degree of curve
R = Radius of curve
V = Assumed Design speed
e = Rate of superelevation.
N.C.=Normal Crown Section
R.C. = Remove adverse crown, superelevate at normal crown slope.

worked out empirically in terms of slope of outside edge of pavement relative to the profile of the centre line.

For the above stated condition of driving the following relative slopes of outer edge o pavement to the centre line profile for a tw lane highway have been found satisfactory fo various design speeds:

Design Speed in M.P.H.	30	40	50	60	70
Relative Slope of Profile Edge to Centre Line Profile.	1:150	1:175	1:200	1:225	1:250

The length of run off is directly proportional to total superelevation which is a product of the lane width and the rate of superelevation. Thus if superelevation is 0.04, width of lane 12 feet and design speed 50 M.P.H.

Superelevation run off, Lr = B x e x 200
= 12 × .04 × 200
= 96' Say 100 ft.

The following table gives the superelevation run off lengths for 12 feet and 10 fee wide lanes of a two-lane highway.

SUPERELEVATION RUN OFF LENGTHS FOR TWO-LANE HIGHWAYS

Superelevation rate	Length of run off in ft. for design speeds in M. P. H.				
	30	40	50	60	70
	Lr.	Lr.	Lr.	Lr.	Lr.
		12' WIDE LANE			
.02	35	40	50	55	60
.04	70	85	95	110	120
.06	110	125	145	160	180
.08	145	170	190	215	240
		10' WIDE LANE			
.02	30	35	40	55	50
.04	60	70	80	90	100
.06	90	105	120	135	150
.08	120	140	160	180	200
Design minimum length, regardless of superelevation.	100'	125'	150'	175'	200'

NOTE 1.—There is no harm if for practical purposes design minimum run off lengths of Superelevation are used.

NOTE 2.—For 12 feet or 10 feet wide pavements (not lanes), as are common in West Pakistan, shorter run off lengths would result but for considerations of uniformity empirically derived values should be resorted to.

NOTE 3.—For curves of 2° or lower, no superelevation run off length is needed. Full superelevation can be provided directly at P.C. or P.T.

NOTE 4.—The angular breaks of profile grade such as at sections B.B., C.C., D.D., should be smoothed by small vertical curves to improve their appearance and make them easy to negotiate.

Attaining of Superelevation

Out of three methods of attaining superelevation such as Revolving pavement about centre line profile, about inside edge profile and, about outside edge profile, the first one is the most commonly used.

The usual calculated centre line profile is the base line and one-half of the required elevation change is made at each end.

In Fig. 4 at section A, the pavement is normal to the crown slope. From A to B the inner half is kept at normal crown slope and the outer is gradually raised till at B it is in level. The distance from A to B is termed as "Tangent Run-out". From B to C again the inner half is kept at N.C.S. and the outer edge is gradually lifted up till at C it reaches the slope of the inner half of the pavements. From C to D the outer edge is lifted up as much as the inner edge is depressed till D, where full Superelevation is achieved.

Methods of Providing Superelevation

1. *When the Curve is Transitional Throughout or the Curve is Circular with Transitional Curves on both ends of Circular Curve.*

The length of transition curve should not be less than superelevation run off length, determined by speed of the vehicle and the lane width. In no case the length of transition curve be less than run off length.

The superelevation should be provided proportional to the length of the point from the origin of the transition curve. Full superelevation is developed where transition curve ends or joins a circular curve.

2. *The Curve is Circular with Superelevation Run off Along Both tangents to and on Parts of the Circular Curve.*

In this 75% of run off length is provided along tangent and 25% along the circular curve; the maximum superelevation does not occur at beginning of circular curve but at a distance 25% of run off length, beyond the beginning of circular curve. (See Fig. 5.)

On Karachi-Hyderabad, Lahore-Multan Lahore-Lyallpur and Sheikhupura-Sargodha Super Highways, Superelevation on horizontal curves is provided by this method.

A practical example follows:

A road is 24 feet wide. It has a cross slope of 2%, deflects at 90°. Design superelevation transition with a circular curve for e max. = 0.08 and V = 50 M.P.H.

Solution:

For e max. = 0.08 and V = 50 M.P.H.,

The maximum degree of curve should be 7.5°. It should be designed as flat as possible but for curves of 2 degrees and below no superelevation transition should be provided.

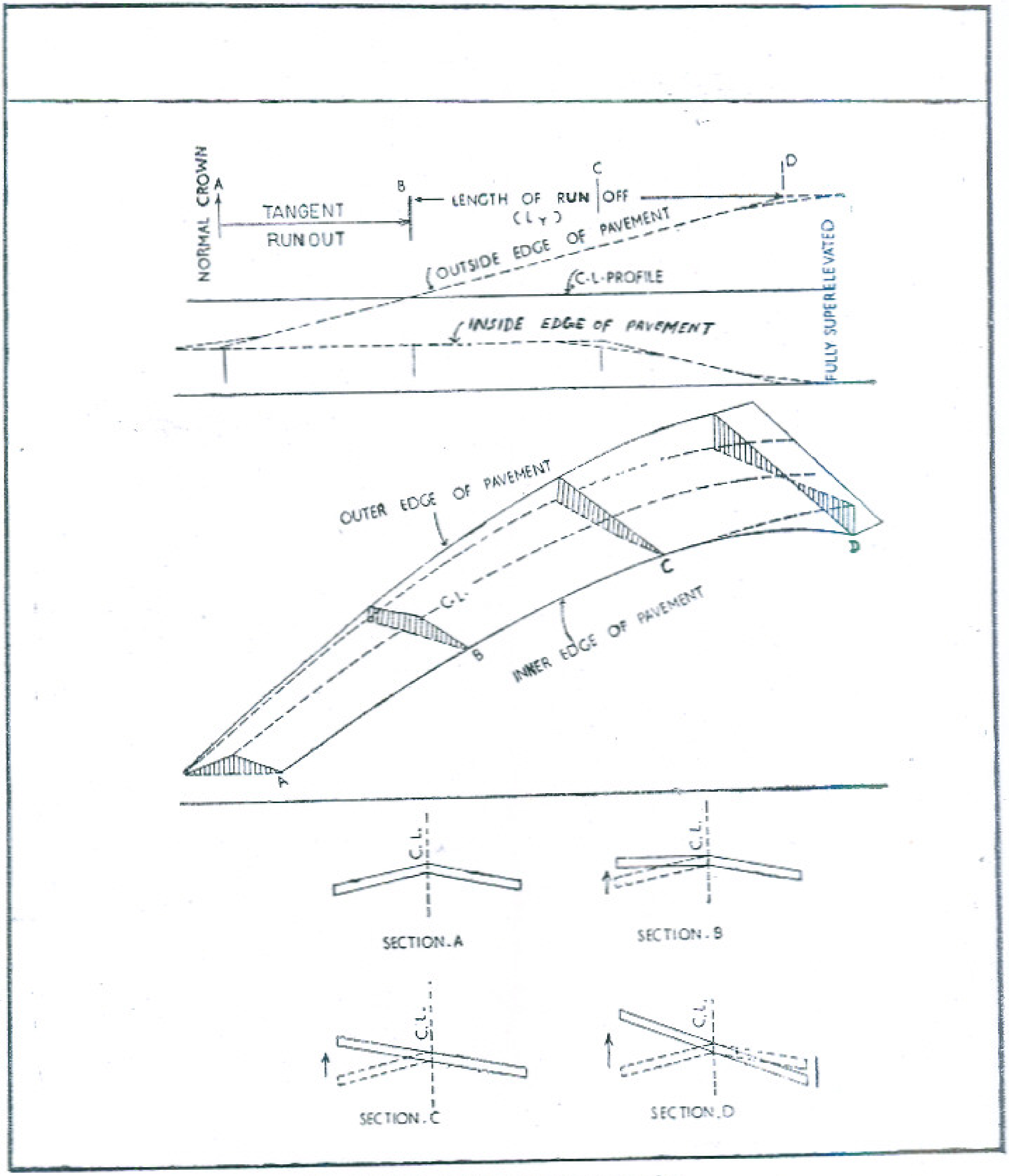


Fig. 4 : Method of attaining Superelevation

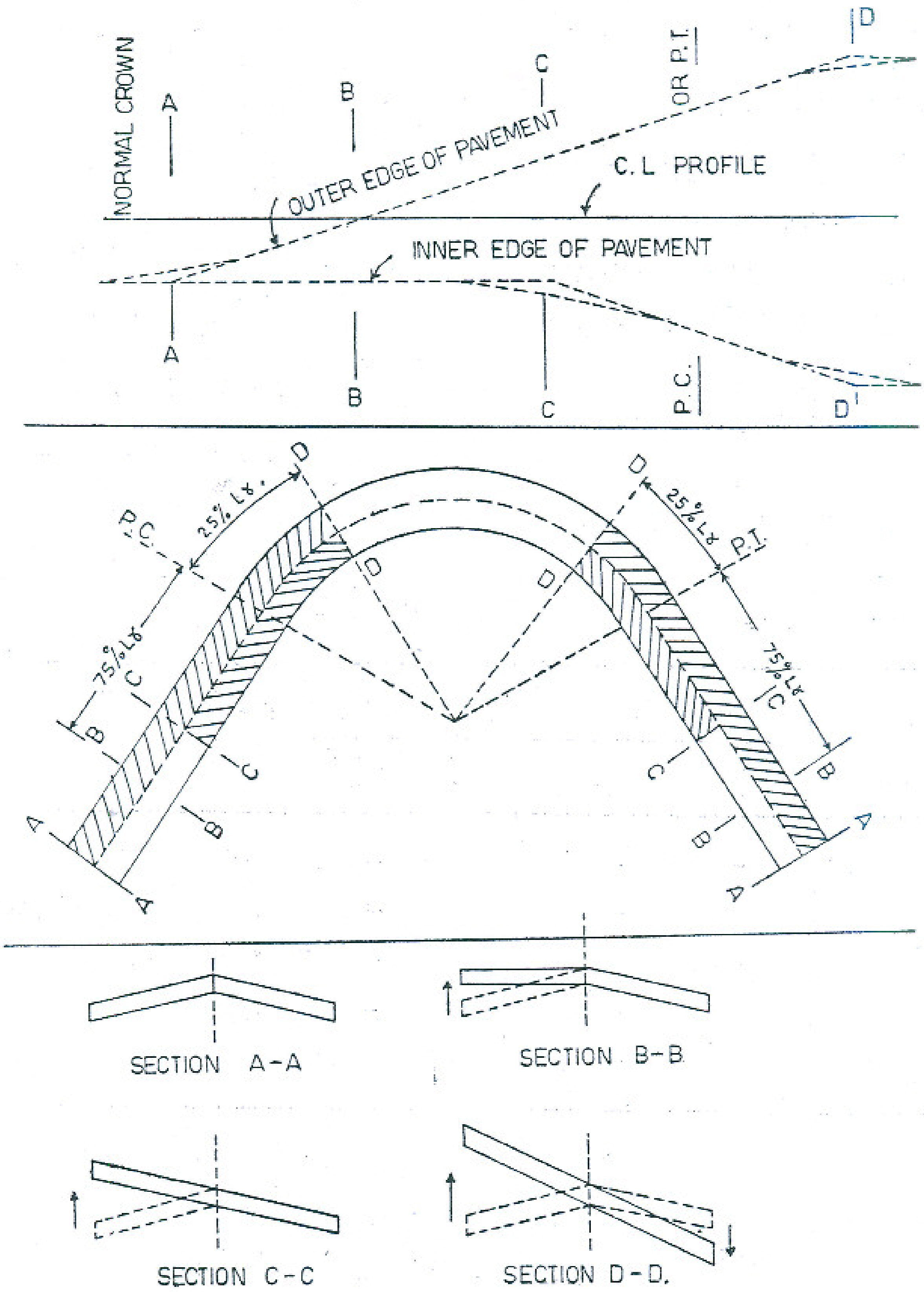


Fig. 5 : Superelevation Run off on Circular Curves

Let us take the degree of curve as 5. This is O.K. because the maximum limit is not exceeded.

$$R = \frac{5730}{D} = \frac{5730}{5} = 1146 \text{ ft.}$$

$$L = \frac{\text{Deflection Angle}}{D} \times 100 = \frac{0 \times 100}{5}$$
$$= 1800 \text{ ft.}$$

$$T = R \text{ Tan } \frac{\triangle}{2} = 1146 \times \text{Tan } 45° = 1146 \text{ ft.}$$

From Table 2 for D=5° and V = 50 M.P.H.

C=0.071 and relative slope of profile to centre line profile for a speed of 50 M.P.H. is $\frac{1}{200}$

Thus Lr (for outer edge of pavement) = .071 × 12 × 200 = 170 ft. and

Lr (for inner edge of pavement) = (.071 — .02) × 12 × 200 = 122 ft.

Tangent run out = .02 × 12 × 200 = 48 ft.

Also distance B B to C C in Fig. 5= .02 × 12 × 200=48 ft.

Suppose R.D. of P.C. is 100 + 00. As 25% of Lr is to be provided on curve, 25% Lr = $\frac{170}{4}$ = 42 ft. and 75% Lr=170 — 42 = 128 ft.

Thus R.D. of D.D. (Fig 5) is (100 + 00) + (00 + 42) = 100 + 42 and

R.D. of B.B. (Fig. 5) = (100 + 42) — — (01 + 70) = 98 + 72

R.D. of AA = (98 + 72) — (00+48) = 98 + 24

R.D. of C.C. = (100 + 42) — (01+22) = 99 + 20

Suppose the elevation of centre line at section AA is 200 ft.

and the centre line profile is at a longitudinal slope of + 1%.

Section	R. D.	Superelevation rate		Total Superelevation		Centre line Elevation	Outer edge Elevation	Inner edge Elevation
		Outer edge	Inner edge	Outer edge	Inner edge			
AA	98+24	—2%	—2%	—0.24′	—0.24′	200	199.76	199.76
BB	98+72	0%	—2%	0	—0.24′	200.48	200.48	200.24
CC	99+20	+2%	—2%	+0.24′	—0.24′	200.96	201.20	200.72
P.C.	100+00	+6%	—6%	+0.72′	—0.72′	201.76	202.48	201.04
D.D.	100+42	+7.1%	—7.1%	+0.85′	—0.85'	202.18	203.03	201.33

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Some Thoughts on Engineering Profession in Pakistan

R. K. ANVER P.S.E.I.
Director Review Cell

Mr. Anwer in his short article has voiced the feeling of all members of the Engineering profession. The common man only derives the fruits of perseverances and toils of the master builders without appreciating the difficulties and hardships which these pioneers had to surmount.

Naturally builders of the nation expect at least respect in the soci ty if no other rewards.

Mr. Anwar has not only voiced the social prestige, economic conditions, uneasiness and the inequality of the profession but has also put forth several suggestions for the improvement of the present conditions.

SOME THOUGHTS ON ENGINEERING PROFESSION IN PAKISTAN

The vital role that engineers are called upon to play in building a socio-economic structure of the country needs no emphasis. In the context of Pakistan, this role has special significance in the background of the traumatic conditions attending the emergence of Pakistan in 1947 and the trail of difficult problems it presented to the body-politic of this new-born State. We inherited a primitive agricultural system. Out of the modest area thus far developed and brought under plough, a considerable percentage was bedevilled by the twin plight of water-logging and salinity at an ever-increasing rate. According to a conservative estimate, one acre per minute of cultivated area was being rendered unfit and laid waste. On the other hand, a large portion of arable land was still lying virgin and awaiting exploitation. Simultaneously we found ourselves scores of decades behind the advanced nations in other spheres of development. In the industrial sector we had no manufacturing cap city and technical know-how. Similar was the condition in all other sectors. The entire Government machinery was reeling under impact of partition and rendered effete. Obviously the general living standard of the people was one of the lowest in the world and presented a morbid picture.

These conditions were the natural legacy of alien rule which exploited our country to the hilt, for more than a century and had little interest whatsoever beyond making this region serve as a hinterland for feeding their industries and to collect land revenues. The idle manpower was forced to join the army of mercenaries. Vast stores of minerals were left unexplored and the natural resources of the country remained buried unassayed. These problems were aggravated by the birth-day gifts of the influx of refugees in vast and unprecedented numbers, and the water dispute with India.

Beset, as Pakistan was with such intractable issues, it was only the abiding faith of our people and their unfaltering devotion to the id ology which sustained us all through. The independence of the nation ushered in an era of hope, which had to be realised by Unity, Faith and Discipline.

The onus of crashing through the poverty barrier by developing the State resources in all sectors also as to bring this nascent State abreast with the developed Nations, clearly devolved on the shoulders of Engineers. The Engineers accepted the challenge and put their shoulders to the wheel in ceaseless toil, to achieve these objectives with a spirit of complete dedication and devotion to duty. It is only their day and night work which has checked the menace of water-logging and salinity. It is the result of their unflinching and tireless efforts that the problem of replacement of supplies from India has been solved to-day and the Indus Basin Project Works stand out as glorious monument to the Engineers' imagination and unrelenting endeavours. Likewise in all other sectors such as communications and works, railways, telephone, telegraph, etc., a spectacular progress has been achieved. It is only due to their vision, sweat and perspiration that to--day we have constructed a sound infrastructure for our developing economy. The stupendous technological achievements in the country speak for themselves, and are a tribute to the indomitable determination and the back-breaking work that engineers have put in, under trying circumstances and hostile conditions, although a lot of work has still to be done, with continued devotion and single-mindedness.

This, in brief, may indicate the vitally important role of the engineers in our developing country. Paradoxically, however, the community of technocrats who are entrusted with this vital task, are not given the social status, the emoluments, or prospects, commensurate with their service to the community. On the contrary, we see today a lot of calumny being heaped on engineers as a class. They are being embroiled in all sorts of scand lous affairs and made convenient scapegoats of ills responsibility for which lies elsewhere. The impact of these adverse conditions on the engineers can be well imagined when smarting under an organised social structure denying them their due place in society, they are obliged to work in calculatedly inimical climate, in which they are generally castigated and looked down upon. This generates a feeling of frustration and discontentment which corrodes self-confidence and breeds inefficiency. The engineer is thus caught in the upper and nether mill-stones of lack of recognition on the one hand and a deliberately bolstered up hostility of public opinion on the other.

It would be beyond the scope of this article to cover the entire field. Nevertheless, an attempt is made in the succeeding paragraphs to identify some of the endemic problems with special reference to the engineers in Government service.

Today engineers are obliged to suffer a host of difficulties. An officer of Executive

Engineer's rank is called upon to sit in a meeting presided over by a Tehsildar who is much junior to him in status as well as qualifications and is unable to appreciate the basic philosophy of development. This anomaly exists all over the working conditions of an engineer, and the extent of bad blood and contempt of the system which this engenders can be well imagined. Again, in the warrant of precedence, even the name of Superintending Engineer who used to be placed along with the Commissioner of a Division does not figure anywhere. An Executive Engineer, who in pre-independence days enjoyed almost equal status to that of Deputy Commissioner is now relegated to a lower stratum of existence and almost ostracized from the bureaucracy.

As for the key posts and higher executive assignments in the engineering fields, these have been entrusted to non-engineers who can perform these functions at best vicariously, nevertheless get credit for what is really the entire labour and the achievements of the engineers. This creates a sense of despondency and frustration, and does not augur well for the larger interests of the country.

In terms of social prestige .way of life, economic conditions, the engineer today stands in a position of diffidence, unease and marked inequality as compared to the generalist, not withstanding the fact that farmer constitutes the real backbone of the country development and has much more important role to play. This situation has created environments, inimical to a harmonious and efficient growth of society, and immediate remedial steps are necessary to correct them, so that the engineer along with the doctors and others, is given his due share in society and status, to enable him to make his vital contribution to welfare and prosperity, without jealousies and handicaps.

A bit of introspection and self-appraisal would reveal that the fault does not wholly lie with the stiff-collared Bureaucracy, but also with the engineering organisation themselves. Some of the drawbacks and their suggested solutions are as follows:—

(i) **Lop-sided Education of Engineers**

The Engineer may be very competent technically in his own branch but he does not possess adequate expression due to lack of general knowledge and languages. The result is that he is gravely handicaped while arguing and presenting his point of view clearly. The solution seems to lie in including general subjects such as languages, sociology, economics etc. in the curriculum of Engineering Universities.

(ii) **Lack of Broad Outlook and General Knowledge**

In the present age, the secret of a country's supremacy over others essentially lies in its advancement in the technological field, and this calls for the creation of a technocratic society. In order to achieve this, we have to produce skilled and talented men for handling such sophisticated organizations.

As a class, the engineers seriously lack training in public administration. Their inferiority complex born of unbalanced and eccentric education and lack of opportunities, results in poor social contacts. This in turn breeds misunderstanding in public mind and poor image outside the department, which requires to be refurnished. It is only through rigours of special training that intellectual and cultural level of engineers can be raised.

These requirements underline the need for establishing an engineering service academy, where a thorough training in discipline, professional technique and sense of order should form its bulwark. The ideal should be to encourage in the trainee-engineers a climate of intellectual and objective approach, and inculcate in them the habit of building of their respective spheres with relentless and unswerving devotion. Besides, liberal and broad-based in-service training in public administration at institutes like NIPA and Administrative Staff College should be provided. Without such training, the engineers are bound to shrivel up into a maze of underlings.

(iii) **Observance of Code of Ethics**

Professional jealousies and rivalries have caused incalculable harm to the engineers. Strict observance to the code of Ethics recently evolved by the Engineering Congress should therefore be imbibed. This would go a long way to ensure integrity, courtesy and professional skill among the members.

(iv) **Lack of Publicity**

Usually it is seen that various engineering projects do not receive publicity in keeping with their importance. It is imperative that the socio-economic impact of such projects should be fully brought home and publicised for general education of the people so that a sense of participation is provided to the common man and the non-specialists in the bureaucracy and that engineers services don't go unrecognised and unappreciated. Exposure to healthy public criticism will also be helpful in further toning up the profession and professional ethics.

(v) **Refresher Courses**

In the present age, scientific and technical development has advanced to a stage that the sum-total of human knowledge is doubling over every 10 years. This fact alone underlines the necessity for organizing compulsory short-term refresher courses for all members. This *in-service* training facility is the best investment in human resources. It would improve breadth of vision, perspicacity and imaginations.

(vi) **Training at Important Projects**

Extending liberal training facilities for young engineers to learn techniques of planning and execution of various important engineering projects being executed within the country is also of immense significance and merits special attention.

(vii) **Proper Utilization of Specialised Knowledge**

A regular programme for training abroad should be chalked out and it should be ensured that people trained in specialised branches are posted in their respective fields on return to get optimum efficiency. At the moment, much of the talent is being wasted due to unimaginative approach in this respect.

(viii) **Creation of Technical Services Pool**

Promotional chances of engineers in general are limited. To do away with the state of inertia and restricted scope, which technical organization suffer from horizontal and vertical mobility amongst various engineering services has to be adequately increased by setting up a service pool on the basis of the economic pool in the centre. Only officers of recognised merit should be catapulted in the pool which should serve as a respository of administrative technocrats to man sensitive posts in the country. This would provide immense fillip to the technical services and liberate their talent in full measures.

The dictates of the present age a'so require complete change in the existing structure of the service. With the advent of Independence and upsurge of freedom there is a revolutionary change in ideas and values. With national Government in the saddle, the law and order problem is now fundamentally of a different kind, and of a different purpose as compared to that in pre-Independence days. The main emphasis is now placed on Development to serve the Commonwealth. Fierce dynamism is the call of day to replace the old static conditions.

In a country where about 80% budget (mainly produced by Engineering Services) is to be utilised for technical development in various fields, the necessity of setting up a technocratic society and producing administrative technocrats is very obvious against the existing out-moded service structure.

Now when the technical services have gained maturity, the time has come when the engineers should be allowed opportunity to exercise their talent in a free and unbiased atmosphere for attaining the objectives of development with real efficiency. A low ceiling placed over the career of engineers, should be done away with, if the nation is to flourish. Free atmosphere be let open to engineers by removal of overlordship of a particular service. If done, this would prove a great incentive for technological advancement of the country.

If the nation is to forge ahead in the field of technological advancement, and if the nation is to remain viable, a true balance in the public service with due consideration of the relative importance and utility of each service must be created. The monopoly of the elite service should be replaced by the dispersion of authority among those who, on account of their education and aptitude are better equipped to carry them.

If genuine demands for equity and justice are scornfully thwarted and hectored down and engineers intimidated, the result will be catasrophe. It unleashes a chain reaction of frustration which engulfs the better part of bureaucracy marring its efficiency and permeating its degenerating effect in the entire public life. It provides a fertile breeding ground for growth of all social evils and subsequent degradation.

As events of past few months have shown, majority of the officials in the hierarchy of officialdom are smarting and feel disillusioned on account of the uncalled for disparity in their service prospects. A great sense of frustration rankles their souls and resentment brews with ever-increasing intensity on this account.

Instances in other countries are not lacking to show that many engineers reached the very top in the administrative hierarchy, and acquitted themselves meritoriously. Engineers have given three eminent Presidents to U.S.A., Mr. Kosygen, the present Chairman Council of Ministers of U.S.S.R., belongs to the engineer fraternity. Mr. Soekarno, previous President of Indonesia was also an engineer, Mr. Khosla, another engineer, proved to be a dynamic Governor in India.

It only requires reorientation of thinking and dispassionate analysis of the problems with the object of identifying basic components of discontentment and unrest among technical service in the larger interests of the country. It may well be realised that in any developed state, bureaucracy serves as a nervous system and is indispensable. Its framework has therefore to be fabricated and operated in such a manner that it generates enthusiasm and vigour. It has also to be so fashioned as to liberate those intellectual and moral forces which are essential for development of a dynamic leadership.

Failure to grasp contemporary realities is bound to retard our national progress and corrode its efficiency to an alarming extent. So far only a half-hearted approach has been made to size up the situation. Superficial analysis heretofore have only masked the root of the problem rather than unravelled it.

Unfortunately, the present set-up is deprived of the chastening effects of vigorous competition. Socio-cultural framework has to be restructured so as to make it development, oriented and create a conducive atmosphere for the healthy growth of a technocratic society. Equal opportunities of career have to be provided to creat esprit d' ecore among all services.

The significant country-wide unrest among the various Government services in the recent past has brought to the fore the basic causes of all evils including the invidious rivalries existing within.

Fortunately, the present Government fully conscious of the situation is already seized with the problem and, before long, structure change of significant import in the bureaucratic edifice may be forthcoming in deference to the popular demand.

This would open new vistas of opportunity for the engineers in particular and as such they should be well prepared to accept new challenge and new responsibilities.

On their preparedness and professional morality will depend the future drift of the events.

Bricks—Their Contribution to Development

S. M. RAFI AHMAD

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Development and adoption of new size of bricks has always been advocated by Mr. Ashfaq Hasan, Director, Building Research Centre, Lahore. He has been advocating the standardisation of the new size of the bricks.

This article by Mr. Rafi Ahmad is in the same line. He has enumerated the advantages of adopting the new dimensions of the bricks. He has also put forth several suggestions to improve the manufacture of quality bricks which forms the most important items of building materials.

Bricks—a Record of Civilization

The burnt clay brick was born when the potter learnt to convert mud into solid rigid bodies. Since times immemorial man has used burnt clay bricks for construction of houses, forts, places of worships and structures for crossing water-courses. In this subcontinent the shape and size of bricks used in an old structure determines its archaeological age. It is very interesting to see that while ancients of Mohenjo Daro used large bricks of nearly the size that we use today, the later-day people of the Mughal era used small tiles. Extent of use of burnt brick in any era is perhaps a direct measure of development in that era.

One comes across various types and sizes of bricks in different parts of the world and in different times of the history in the same part of the world—man has never been satisfied with the sizes and shapes of bricks. When the large irrigation works were being constructed in the Sutlej Valley Project, bricks 12″×6″×3″ were developed for walls of 12″ and 18″ size. In ordinary building work, the 9″ brick has been continued to be used for quite a long time. This size was perhaps adopted because 9″ thick walls built in hydraulic lime mortar can stand load of a single storeyed building and further 9″ are three quarters of a foot and one-fourth of a yard. In the English practice, brick-work is paid at the rate of cubic yard and brick paving is paid at the rate of square yard. Perhaps this was another reason for adopting 9″ size which is 1/4th of a yard. Whatever be the reason for adoption of this size, the 9″×4½″ brick became standard brick for universal use.

Development of Modern 8″×4″ Bricks

Its advantages:—The inquisitive nature of man, however, continued to look for a better size of brick and this resulted into development of the 8"×4" brick at West Pakistan Building Research Station. The 8" brick developed by the West Pakistan Research Directorate has many commendable uses. It is not only handy but gets very well burnt due to deep frog and at the same time results into lighter structure. The 8" size gives a foot of width when a brick and a half are taken together. This saves labour of adding inches and fraction of inches while estimating quantity of masonry in a building. Hence the 8" brick is not only handy resulting into speedier brick laying, but is convenient for the sake of estimating, drafting and has better insulating quality because of the deep frog.

In our country all construction is paid at the rate of 100 or 1000 C. ft. A wall 1—1' thick (which is nearly equal to the usual size of 13½" for most of the walls) is very easily calculated for load bearing capacity as well as for estimation of brick-work, while an 8" brick wall in cement is more strong for an ordinary single storeyed structure. Hence it is to be seen that the new 8" brick can contribute a lot to development by facilitating brick laying and making estimation and quantity surveying a very much easier task than it has been hitherto.

Manufacture of Salt-Free Compressed Bricks

A brick to be good is not only to be of the right size but must have a specified density and a uniform pleasing colour. In addition to these physical qualities it must have a long life and be immune to weathering action. Unless a brick is of the right chemical composition it cannot be a lasting piece. The clay going into the making of a good brick should neither be too sandy or too fat. It should not contain any harmful hygroscopic salts and should not get distorted in burning and must not develop a disagreeeable texture and colour. In this Province, the rise of subsoil water level due to extensive irrigation has resulted into upward travel of soil salts which appear on the surface of ground as the subsoil water coming up to the surface due to capillary, gets evaporated. This has caused a universal and wide-spread increase of the salt contents of all the brick-making clays. Most of these harmful salts do not change on burning and continue to cause deterioration of the brick after it is put in the structure. A large number of beautiful buildings are suffering from such decayed bricks and every day more and more areas are being affected and it has become almost impossible to find any salt-free brick anywhere. In order to enable bricks of today to contribute effectively and permanently to the development of the country, it is very necessary to arrange salt-free clays for manufacture of bricks which operation is so far an art and needs to be developed into a science using modern methods. The present era will perhaps not be remembered with a good name if we continue to use present-day brick of all sizes made out of salt-laden clay—already buildings constructed a decade ago have been showing signs of deterioration. A halt must be put to this.

It is not impossible to get rid of the salts in bricks and also to get rid of salts in the soil for good construction. Modern technology has made it possible to prepare slury of brick clay, dissolve the salts out of it into water and separate it from clay by sedimentation. If we can reclaim a percentage of clay like this, the salt-free clay can be mixed with the ordinary silty clay to bring contents of salt down to an extent which is not so harmful. Bricks are made by modern methods in this fashion.

Lack of Quality Bricks

To attain proper density, to ensure minimum porosity the brick-clay should not only be free from salt; buts should also be compressed with the least possible moisture. In modern brick-making plants clay of the correct chemical composition is mixed with requisite quantity of sand and mortar and burnt into hard well pressed unburnt bricks. The unburnt bricks in their turn are burnt at controlled temperature in modern kilns to be converted into burnt clay bricks of high quality. While Pakistan has gone ahead in some of the industries, no attention whatever seems to have been paid to the manufacture of bricks though there is a bad scarcity of bricks everywhere and good bricks are not to be seen anywhere. No two bricks from one and the same batch from the same kiln are of the same size, with the result that the engineers and the masons find it hard to build walls of regular shapes. Most of the bricks available today in West Pakistan contain a high amount of salt which entails deterioration of structure. Bricks are going into construction of almost every structure of importance, but absolutely no attention is focussed on their quality. The brick manufacturers have decided to make as much money as possible in minimum possible time. While they may not be able to help salts in the clay, nothing prevents them from maintaining a standard size and from proper kneading and in tempering of clay. Also there can be no excuse for over-burning or under-burning. But since their products sell, they do not bother. Manufacture and supply of bricks of proper size and quality is perhaps number ONE problems of all Civil Engineers of all sorts. They must accept newly developed 8″ brick and ensure its manufacture to standard size and specifications. The brick making industries are controlled by two factors. The first is, of course, the law of supply and demand and the second is availability of sites for establishing kilns. While the former is an economical factor the latter is controlled by the Revenue Department in our country, the poor engineers having no say and they are forced to accept whatever bricks are offered. It is, therefore, very necessary to take the matter of manufacture and supply of bricks of correct size and specification at the national level and to devise ways and means for the proper supply of this most vital basic need of development. Modern technology has made it quite possible to make really good bricks out of clays presently available and the availability of natural gas has facilitated establishment of mechanical gas-fired kilns and it is therefore believed that bricks of the right size, shape, colour, weight and bearing capacity can be manufactured in this country provided there is a will to do so and a uniform specification is adopted throughout the country with no mental reservation whatsoever.

Suggestions to Improve Quality of Bricks

Some concrete suggestions for improving quality of bricks in view of what has been stated in the foregoing paragraphs, are now given.

Licensed Kilns

The foremost problem is that of regulating the manufacture of bricks. Unfortunately this is presently not in the hands of engineers, but in the hands of the Revenue Department which department is the least qualified to look into that problem. All brick kilns must be licensed and the local Superintending Engineers of the Buildings Department should be the authority for issue and renewal of such licences. Any brick-kiln found manufacturing bricks of low standard will lose its licence and no renewal will be granted to those who fail to improve their quality after due warning.

Automatic Gas-Fired Kilns

Larger cities like Hyderabad, Multan, Lahore and Lyallpur where the demand for brick is very large should start automatic gas-fired kilns. If the private sector is shy, the W.P.I.D.C. should come forward to establish brick-making plants at some or all these places and later on hand over to the private sector according to their usual policy of disinvestment, once private sector is willing to take up a new venture. Unless this is done the cost of brick-making will go on rising with rising cost of labour and fuel and the quality of brick will suffer because of lack of competition among the brick makers and lack of fully trained labour for moulding.

Remove Salts from Brick-making Clay

Manufacture of salt-free bricks for use in reinforced brick-work and walls of very important structures must be arranged. Since all sorts of salts in the clay soil are water soluble, it is possible to mix large quantity of water with clay turning it into a slury and allow the clay particles to settle down as is done in case of waterworks for removal of clay and silt from water by the process of sedimentation. While in the waterworks sediment is the waste, in clay-purifying plant supernatant water will be a waste and bottom deposit will be a useful product. Intermediate quality of bricks can be made by mixing certain quantity of salt-free clay with ordinary clay. Such bricks can be used in better class buildings.

If glazed bricks and glazed tiles were to be manufactured simultaneously, the brick making plants could reduce their overhead cost by apportioning a good chunk of the cost on these sophisticated products.

Change of P.W.D. Specifications

The specifications of the Public Works Department must all be altered to be in line with the 8″ modular brick. Design tables, standard drawings and such other documents need to be rewritten because 8″ is optimum size brick for our needs. The Buildings Research Laboratory must take upon its task of surveying the quality of clay available in different places and indicate the different mixtures for a good brick. Detailed surveys of course will have to be carried on for establishment of kilns in new areas but it is very necessary to carry on surveys of existing areas for improvement of bricks and for the purpose of general classification.

The production, quality and cost of bricks must be controlled properly so that building costs and the quality of building work are regulated.

Use of pyrometers for determination of temperature should be encouraged so that simple eye estimations are avoided.

Develop Bloated Clay Aggregates

Crushed brick aggregate and bloated clay aggregate must be manufactured so as to save the cost of transport of stone aggregate from very long distance thereby resulting in cheapening of the cost of buildings.

It is believed that the contribution of present day bricks to development will not be a happy one unless we do something about improving their quality and size. Let posterity not judge us by kallar-eaten walls, falling plasters, most non-uniform masonry and crumbling edifices!

Irrigation and Power Projects of East Pakistan (The Ganges Barrage)

By **EDITORAL STAFF**

The article is based upon data collected by the editorial staff from various sources. Some of the recent information even appearing in Pakistan dailies has been utilized.

The authentic:y of the data and the conclusions thereof are essentially of the editorial staff and do not represent the views of the Government or any official organization.

In West Pakistan little is known about the Irrigation and Power Projects of East Pakistan. The Irrigation and Power problems of East Pakistan are beyond the imagination of those who have all along lived in West Pakistan. Everybody is given to understand that East Pakistan receives heavy rainfalls and regular intense floods and thus does not stand in need of Irrigation waters. The area is often classed among the humid zones of the world. But the facts are otherwise. In four months of a year it receives too heavy floods and intense rains particularly during the three summer months. Eight to nine months of a year are dry with scanty rainfall insufficient to grow crops. An area receiving the highest order of rainfall in Indo-Pakistan subcontinent thus urgently needs irrigation waters. This is known to only a few engineers of West Pakistan.

More than half of East Pakistan is hardly 30 ft. above sea level. The elevation of Dacca is 20 to 25 feet above sea. Khulna, Barisal, Noakhali are only 5 to 10 feet above mean sea level so that large areas are exposed to the incessant intrusion of sea, tidal rise of which constantly submerges vast areas under sea water. Heavy rainfall, enormous floods, countless depressions and innumerable rivers and streams would make every one feel excessive existence of ground water potential but surprisingly enough the facts are otherwise.

It is the intention of the journal to start a series of articles to introduce the engineering aspects of Irrigation projects of East Pakistan. Presently during the last few years much has been said about the Ganges Barrage in East Pakistan. We are thus starting this series with this project of East Pakistan.

Basic Data of East Pakistan

East Pakistan came into being on the 14th August, 1947 with the creation of Pakistan. Before independence, it was a part of the provinces of Bengal and Assam.

It is bounded on the north, east and west sides by India except for the south eastern tip which adjoins Burma. On the south lies the Bay of Bengal.

East Pakistan has an area of 55126 square miles and its population is presently estimated to be about 1270 persons per square mile. In the central part of the province, the density in some places is as high as 3,000 persons per square mile.

Except for the Chittagong and the Chittagong Hill Tracts, East Pakistan comprises a flat delta, formed by the activity of the Ganges, the Brahmaputra and the Meghna rivers and their tributaries. The land slopes from north to south starting at an elevation of about 200 feet above mean sea level. In the first 100 miles, the land slope is somewhat steeper and the elevation gradually reduces to about 60 feet. Thereafter the slope is much flatter and the elevation drops to about 15 feet in the vicinity of Dacca. Beyond Dacca, the slope is very flat, being only 3 to 6 inches per mile. The elevation near the coast is only a few feet above mean sea level. Most of the area of the province lies below 80 feet and almost half of the province has an elevation of less than 15 feet above mean sea level. The land to the west of the Brahmaputra is relatively higher than the land to the east of this river. Fig. 1 shows the western portion of East Pakistan. The elevation contours lie between 40 feet in Rajshahi and Pabna to 5 feet in Khulna.

The deltaic soil is generally fertile so that the predominant economic activity of the province is agriculture. It employs 80 per cent of the labour forces and accounts for about 66 per cent of the gross national product.

Most of the arable land of the province has been cultivated for decades by primitive methods using manual power and indigenous tools. Rice is the staple food of the people and in terms of acreage and crop value, it is the most important crop. Other major crops are jute, pulses, oil seeds, fruits, vegetables, sugarcane and tea etc. Also important are many minor crops like wheat, cotton, tobacco, chillies, betel-nut, betel leaf, fodder etc.

Rainfall in East Pakistan

East Pakistan receives on the average an annual rainfall of 50 to 150 inches. Eighty per cent of this occurs during the monsoon season, that is from June to September. In Table 1 we have put forth mean monthly rainfall for eleven districts. The obvious inferences from this table are that from October to April *i.e.*, for about seven months in a year, rainfall is of a very low order. The heavy rainfall months are June to September; very heavy precipitations are received during the three months of July, August and September.

The Western area comprising the districts of Rangpur, Bogra, Pabna, Jessore and Khulna receive generally low order of rainfall.

The Crops

Out of 35 million acres of East Pakistan about 25 million acres are cultivated but produce very low yields.

The temperatures and seasons are such which can produce crops all the year round provided water is available. The main staple crop of the area is rice so that two or three crops can be produced in a year.

FIG.-1

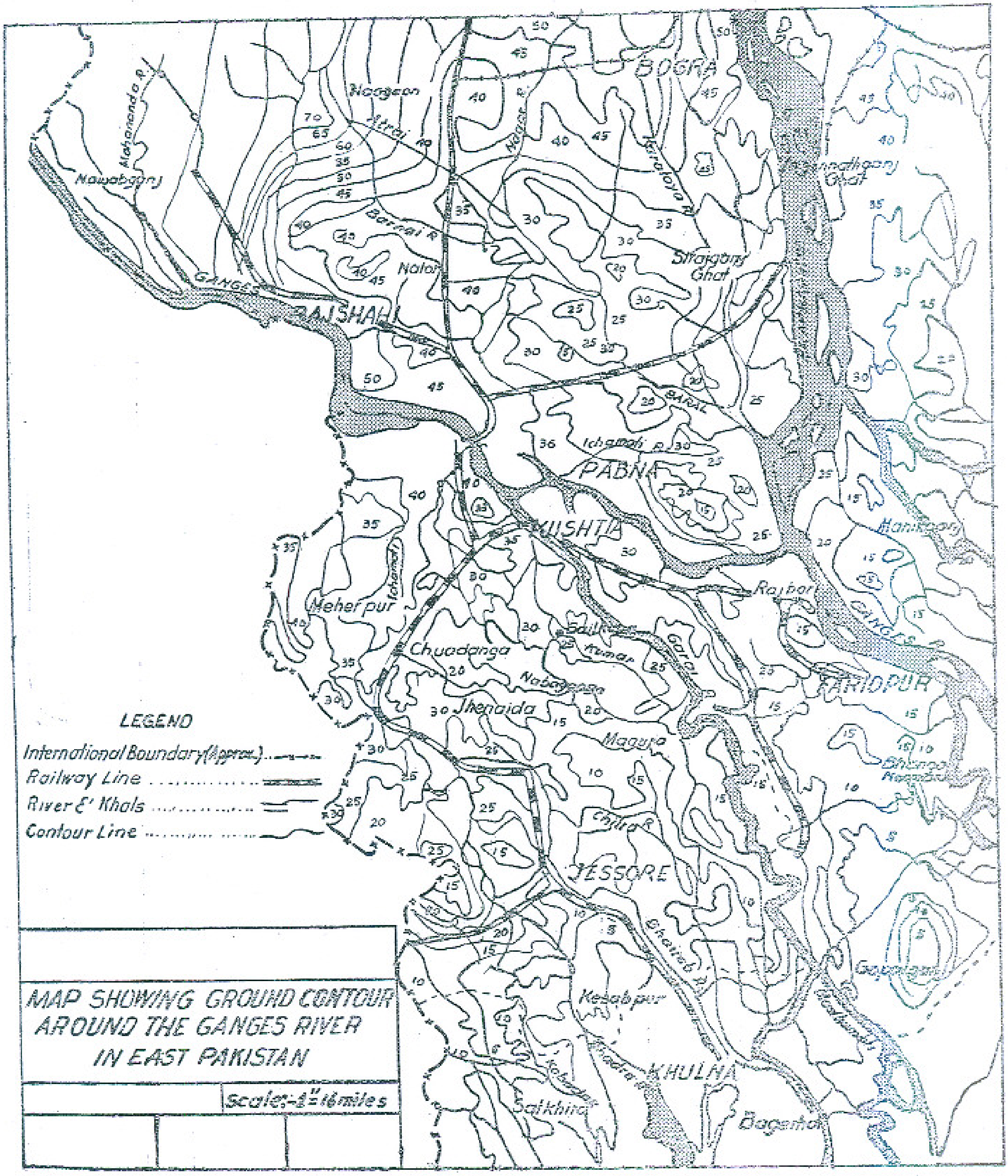

MAP SHOWING GROUND CONTOUR
AROUND THE GANGES RIVER
IN EAST PAKISTAN
Scale:-1" = 16 miles
LEGEND
International Boundary (Approx.)
Railway Line
River & Khals
Contour Line
BOGRA
RAJSHAHI
PABNA
KUSHTIA
FARIDPUR
JESSORE
KHULNA
Naogaon
Nawabganj
Natore
Sirajganj Ghat
Meherpur
Chuadanga
Jhenaida
Magura
Rajbari
Kesabpur
Satkhira
Bagerhat
Gopalganj
GANGES
Atrai R.
Baral
Garai
Nabaganga
Chitra R.
Ichamati R.

TABLE I

Mean monthly rainfall in inches in some districts of East Pakistan

Month	Rangpur	Bogra	Pabna	Jessore	Khulna	Mymen-sinh	Dacca	Barisal	Sylhet	Comilla	Chitta-gong
January	0.4	0.47	0.38	0.42	0.53	0.34	0.48	0.48	0.36	0.55	0.35
February	0.64	0.81	0.77	1.10	0.86	0.72	1.01	0.73	1.28	1.21	1.09
March	2.64	1.0	1.15	1.17	1.10	1.56	1.81	2.17	1.89	4.43	2.37
April	3.35	2.43	2.88	3.66	3.55	5.49	5.84	4.18	11.9	6.59	5.74
May	11.61	7.95	7.07	7.44	7.26	11.86	9.41	8.02	23.2	12.6	10.87
June	19.64	13.13	11.45	11.56	12.2	18.3	13.5	17.0	32.8	20.4	20.70
July	16.3	12.5	10.5	12.8	14.3	14.6	12.7	18.1	26.0	19.7	25.3
August	13.54	13.5	10.9	11.6	12.1	15.6	13.4	15.6	24.8	17.0	22.5
September ..	12.77	11.0	8.0	7.9	8.1	13.9	9.2	7.12	10.6	8.2	8.6
October	6.76	6.3	5.73	5.0	4.3	6.8	5.6	7.12	10.6	8.17	8.6
November ..	0.29	.62	0.61	0.70	1.1	0.6	0.72	1.5	1.4	1.5	2.4
December ..	0.6	0.9	0.12	0.12	0.1	0.11	0.17	0.3	0.14	0.19	0.53
Annual Total ..	85.89	69.85	60.40	64.1	66.92	90.4	74.2	84.8	141.1	100.6	113.0

Two type of rice crops sown in March-April are called broadcast Aus and Aman crops. Both are sown at the same time. Broadcast Aus is harvested in June-July whereas broadcast Aman is harvested in November-December.

The second rice crop is transplanted Aman, sown in July-August and harvested in November-December. Jute is also sown in March-April and harvested in June-August.

The Rabi crops again include rice called Boro, sown in December-January and harvested in April. Other important crops of this season are cereals, chillies, pulses, oil seeds, potato, tobacco and fodder. Sugarcane is grown both in Kharif and Rabi.

Poor spacing of rainfall brings in serious consequences. Aus and jute which are sown with the first pre-monsoon rains often suffer from drought before the monsoon sets in. Transplanted Aman rice is usually safe from moisture deficiencies but drought at the end of the monsoon often prevents full maturing of the grain. Early floods drown Aman seeding beds before they are established.

Flood causing a rapid rise in water level often drown Aman when the growing crop cannot keep ahead of the rising water. Late floods may catch the broadcast Aman rice in the germinating stage when it will grow no taller.

Thus both drought and floods are the main causes of low yield and of failure of the main rice and jute crops.

Rivers of East Pakistan

Three main rivers flow through East Pakistan. The biggest of the three is the Brahmaputra which rises near the Manasarowar lakes and travelling West to East through Tibet parallel to the Himalayan ranges turns almost ninety degrees into Assam. It flows along the foot of Assam Hills almost East to West making a downward turn near Golpara, it enters East Pakistan after traversing about another fifty miles. Now it flows north to south direction. It starts its deltaic nature after Bahadurabad when distributaries of rivers start taking off from the main stream.

The second river is the Ganges which is one of the great rivers of the Himalayas. It drains nearly 3,77,400 square miles and is about 1340 miles in length from its start in the Garhwal-Tibet border about 30 miles north of the famous Nanda Devi. It joins Brahmaputra in East Pakistan at Goalando.

Its deltaic characteristics starts nearly at Farakha when the streams Bhagirathi Hooghly on the right and Pagla on the left take off from the river. In East Pakistan several distributaries take off from the Ganges both from the right sides and the left. It forms a great delta criss crossed by many distributaries and branch distributaries joining the Bay of Bengal forming a series of swamps intersected by a network of channels, and the famous Sunderbans forests on the seaboard tracts.

On the left side of the Ganges there are not many distributaries, the important one being the Baral river.

The third major river of East Pakistan is the Meghna which rises in Assam and joins the combination of the Ganges-Brahmaputra now called Padma near Chandpur. The vast confluence below Chandpur forms a broad estuary known as the Meghna which enters the Bay of Bengal near Noakhali. Between Bhagirathi on the West in India and Meghna on the East in Pakistan, lies the great delta of the Ganges with its many distributaries and branches. Almost all distributaries in the delta flow southward towards the sea.

These rivers during summer bring in enormous volume of water. A few typical hydrographs of the Ganges for the year 1963 and 67, are shown in Fig. 2. The maximum flow during September rises to 20 lakh cusecs. The high river stage months are July, August, September and October. Very sharp

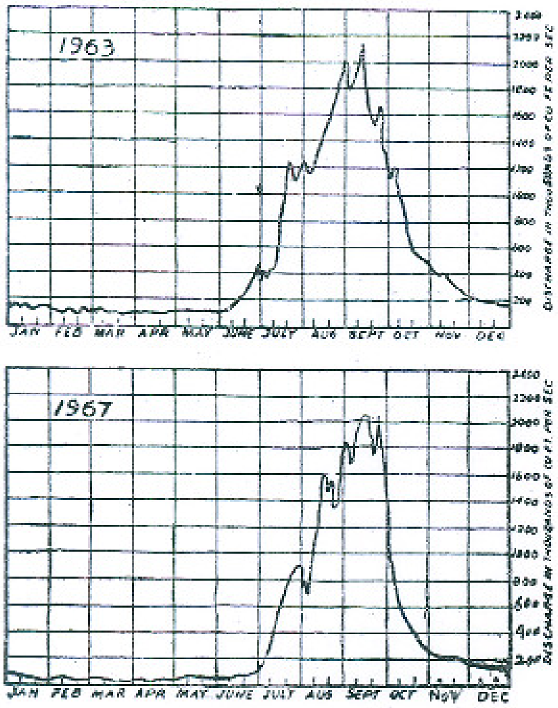


Fig. 2. River Ganges at Hardinge Bridge Hydrographs 1963 and 1967

rise occurs during July and similar quick fall takes place during October. The river for about nine months of a year attains a very low order of flow falling below 1.0 lakh cusecs. Some idea of the enormous volume of summer flow can be had from Table 2.

Floods in East Pakistan

Another enormous problem for East Pakistan is the protection from floods. Out of 55000 square miles of East Pakistan, nearly 26000 square miles are vulnerable to floods both from upland discharges of the rivers and local rainfall and by tidal inundation. An idea of areas vulnerable to floods can be had from Fig. 3.

As already mentioned, nearly half of East Pakistan lies below 30 feet contour so that these areas are worst to suffer.

The Ganges Basin

A study of Fig. 1 shows that enormous areas of the districts of Rajshahi, Pabna, Kushtia, Jessore, Faridpur, Khulna and Barisal are directly dependent upon the water of the Ganges.

Because of centuries of negligence, East Pakistan today is still in early stage of development. Before independence, no major work of any kind was undertaken in this region. There were only meagre hydrological data or information about the rivers, land contours, and soil strata. Gradually a network of Ganges, discharge and sediment observation stations have been built up and ground contour surveys and soil surveys have been carried out. Now considerable data

TABLE 2

Discharge of Major Rivers in East Pakistan

(in Thousand cusecs).

Month	Ganges at Hardinge Bridge		Brahmaputra at Bahadurabad		Meghna at Bhairah Bazar	
	Max	Min	Max	Min	Max	Min
May ..	111	75	849	629	88	68
June ..	342	154	1370	1140	190	148
July ..	1050	639	1600	1420	322	257
Aug. ..	1860	1390	1960	1550	323	274
Sept. ..	1980	1290	1710	1250	336	273
Oct. ..	1490	626	1140	759	286	236
Nov. ..	584	254	529	374	117	98

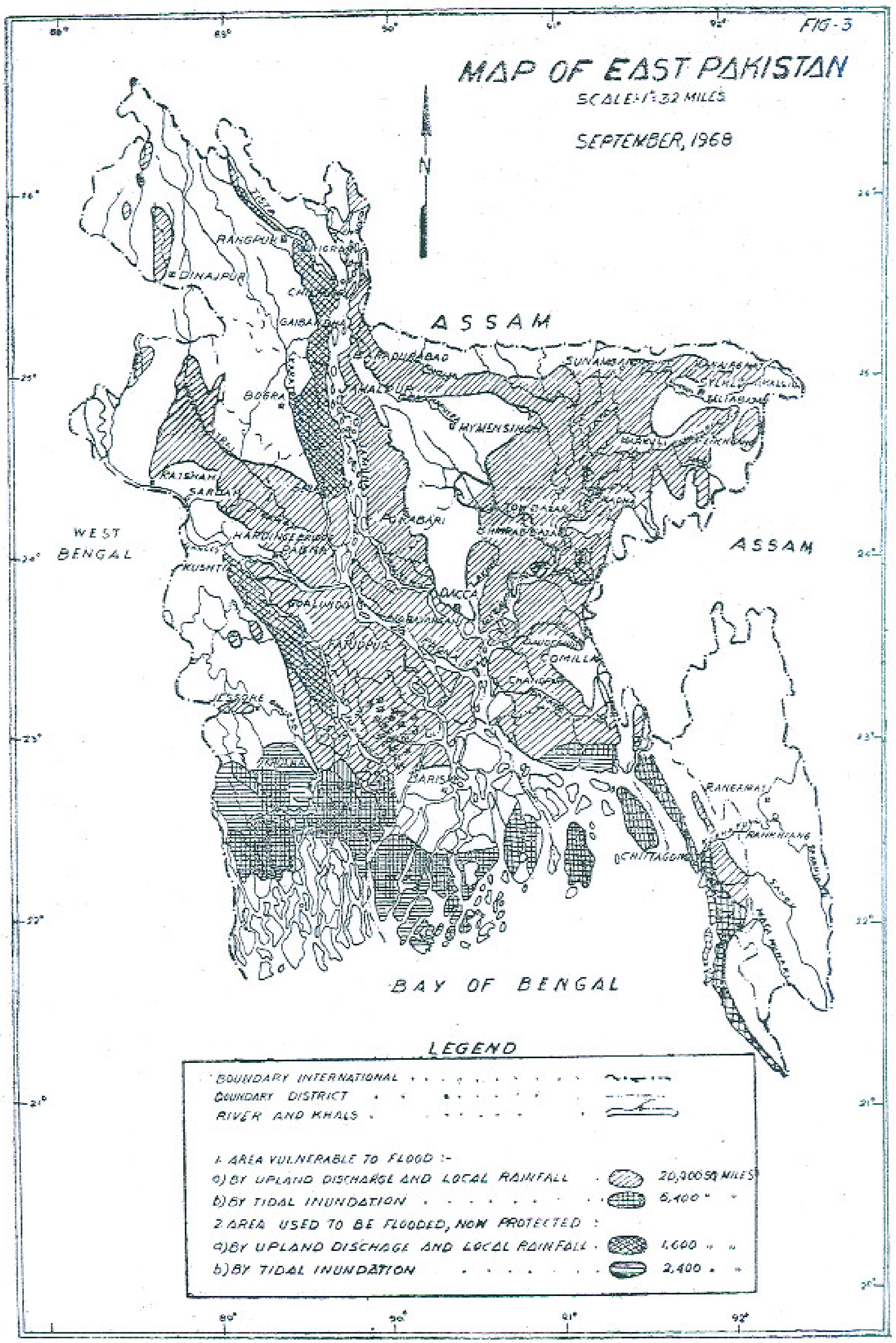


FIG-3
MAP OF EAST PAKISTAN
SCALE 1"=32 MILES
SEPTEMBER, 1968
N
ASSAM
WEST BENGAL
ASSAM
BAY OF BENGAL
RANGPUR
DINAJPUR
BAHADURABAD
BOGRA
MYMENSINGH
SUNAMGANJ
SYLHET
RAJSHAHI
PUNABARI
HARDINGE BRIDGE
KUSHTIA
DACCA
GOALUNDO
FARIDPUR
COMILLA
CHANDPUR
JESSORE
BARISAL
CHITTAGONG
RANGAMATI
LEGEND
BOUNDARY INTERNATIONAL
BOUNDARY DISTRICT
RIVER AND KHALS
1. AREA VULNERABLE TO FLOOD :-
a) BY UPLAND DISCHARGE AND LOCAL RAINFALL 20,300 SQ MILES
b) BY TIDAL INUNDATION 6,400 " "
2. AREA USED TO BE FLOODED, NOW PROTECTED :
a) BY UPLAND DISCHAGE AND LOCAL RAINFALL 1,600 " "
b) BY TIDAL INUNDATION 2,400 " "

have been collected for water development schemes. So far as irrigation is concerned no organised system existed in the provinces, before independence though farmers have practised irrigation by using indigenous methods to lift water from rivers and wells. Floods irrigation has also been done by blocking up streams with earthen bunds to store flood water temporarily for agricultural uses. After independence, a number of small masonary weirs and spilways were constructed introducing modern irrigation methods. Two large irrigation schemes have been taken up in the province. These are the Teesta Barrage Project and the Ganges Kobadak Project. This project named after two important rivers of East Pakistan was undertaken in 1954. It was intended to irrigate 1.98 million acres of land in the districts of Kushtia, Jessore and Khulna by lifting water from the Ganges just below the Hardinge Bridge and distributing it through canals.

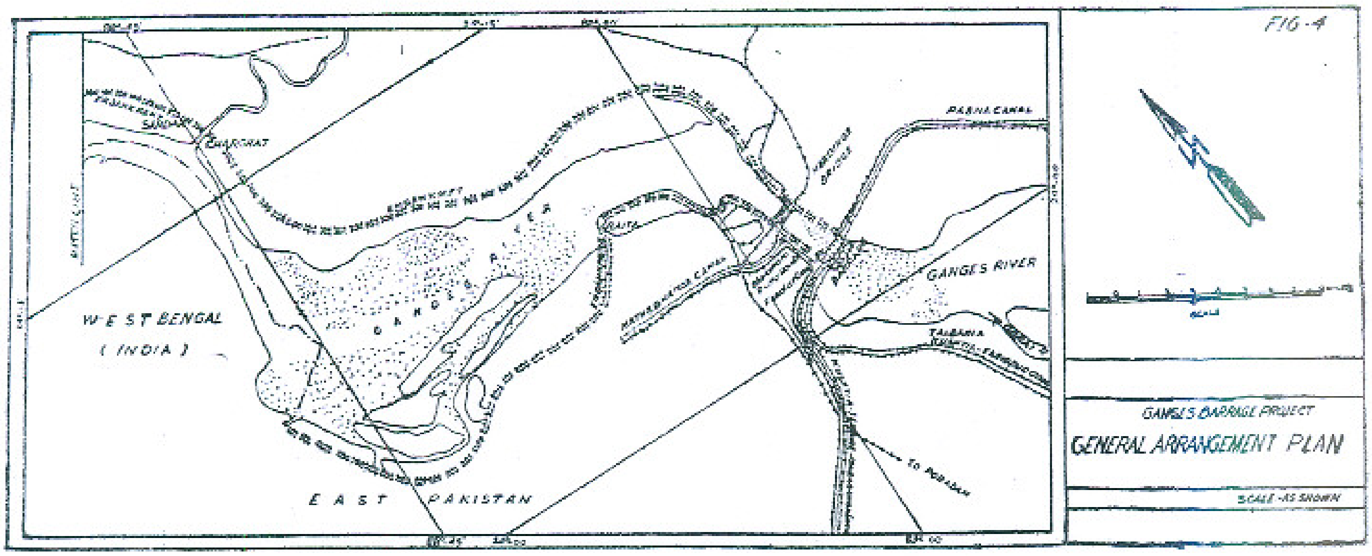
The first phase of the project called Kushtia unit meant to irrigate 1.2 lakh acres is nearing completion. The estimated cost for this unit was 51 crores. Up to June 1968, twenty-nine crores have been spent.

The second phase is to irrigate 2.3 lakh acres. This is in progress. It was soon obvious that pumped supplies were very costly and yet irrigation was very necessary for all the seven eastern districts.

In the master plan the construction of a Barrage on the Ganges, down-stream of the Hardinge Bridge, was found essential. The proposed barrage when constructed will command about 4.25 million acres of land lying on both banks of the Ganges. The commanded area will include the Ganges-Kobadak, Faridpur-Barisal, Western Rajshahi, Southern Rajshahi and Pabna areas. The present Ganges-Kobadak project will be incorporated in this project.

The feasibility of the barrage has been established and a preliminary design was prepared by Tippetts-Abbett-McCarthy Stratton of New York in 1963 and further details have been put forth recently by Associated Consulting Engineers of Pakistan.

The Ganges Barrage Project aims at irrigating 4.25 million acres of land in the districts of Kushtia, Jessore, Khulna, Faridpur and Barisal on the right and Pabna and Rajshahi on the left bank of the Ganges in East Pakistan. The project envisages construction of a barrage on the Ganges about 2½ miles below the Hardinge Bridge. The length of the Barrage would be 6990 ft. in between the abutments having 100 regulating gates. It will divert a maximum of 49,000 cusecs of dry months' discharge into various canals to be taken out from the head. On the right bank there would be three canals and on the left bank there will be four canals. Out of these there would be 3 pumping stations on the left and one on the right. The location of the barrage and offtakes of main canals is shown in Fig. 4. For the facility of implementation, the scheme has been divided into two phases—phase I to irrigate 2.94 million acres (excluding 0.35 million acres of Kushtia unit) in the districts of Kushtia, Jessore, Khulna, Faridpur, Barisal and Pabna and the phase II for 0.96 million acres by pumping in the districts of Rajshahi. The P.C.I. amounting to Rs. 348.93 crores is for Phase I. This is under consideration. P.C. 1 of the Phase II would be prepared in due course. On the right bank, the feasibility report of Jessore Unit, Phase I, Phase II and Phase III have been prepared. The feasibility report of Jessore Unit Phase IV is also under preparation. On



the right bank the feasibility report of Faridpur Unit of Faridpur-Barisal Project is in progress. On the left, Southern Rajshahi is an approved project. The feasibility report of other area are proposed to be taken up. The feasibility of the Pabna project is in progress.

In the planning of the irrigation of the areas under different units mentioned above, interlinking of the canal system of the pumping project with the gravity scheme would be kept in view when the Ganges Barrage materialises.

Quick drainage occurs in East Pakistan

The distribution of rainfall in East Pakistan is given in Table 1. Except for about three or four months, the rest of the year has insignificant effective rainfall.

There are a few other factors which are very characteristics of East Pakistan. The general topography of East Pakistan consists depressions, uneven lands, scars, deep cuts, beds of old river channels so that flat plane lands as we are accustomed to come across in the Indus alluvium, do not exist. Except near the sea coast under the action of tides which flattens the scars and eliminates the cuts and depressions etc., the lands in the rest of East Pakistan is uneven. This results in quick run off of the rain water into depressions. With the fall in levels of the big rivers, this water is drained out. Ganges, for instance, shows about 22 feet fall of water levels between the winter and the flood periods. After October the rivers start falling and the depressions also start draining out.

Soils in East Pakistan are of Lateritic Nature

The soils of East Pakistan have another characteristic. Being a deltaic area the soils are generally heavy and of low permeability. It is also well known that soils getting intense rains slowly become lateritic in nature which are rich in iron contents and low in fine grades of clay colloids which are either washed away or infiltrate to deeper depths.

When such soils are cultivated with rice crops, under a constant head of water possibility of washing down of the fine particles exist and which can get collected at some distance below the surface. This layer of low permeability thus helps to grow rice crops. This is an important point to note, in the case of East Pakistan soils.

TABLE 3

Monthly and Annual Evaporation in East Pakistan

Month	Evaporation, inches, at indicated station										
	Rang-pur	Bogra	Pabna	Jessore	Khulna	Mymen-singh	Dacca	Barisal	Sylhet	Comilla	Chitta-gong
January	3.04	2.71	2.14	2.50	3.58	2.11	1.92	2.69	2.64	2.81	3.70
February ..	3.26	3.39	3.11	3.12	3.96	2.62	2.68	2.38	3.14	3.41	3.93
March	5.80	5.90	5.32	5.39	5.70	4.15	4.82	5.38	4.86	5.96	5.60
April	6.21	7.07	6.54	5.83	6.15	5.24	5.56	5.45	4.76	6.13	5.82
May	4.98	5.32	5.45	5.49	6.55	4.41	5.14	5.93	4.39	5.20	5.88
June	3.84	3.56	3.72	3.84	4.12	3.55	4.14	3.92	3.95	3.85	4.24
July	3.86	3.50	3.64	3.86	4.11	3.47	3.97	3.64	3.75	4.08	4.49
August	3.90	3.24	4.01	3.66	3.93	3.18	3.62	3.80	3.81	3.80	4.34
September ..	3.93	3.95	3.74	3.47	4.44	3.78	3.51	3.99	3.71	3.99	4.52
October	4.04	3.27	3.65	3.47	4.96	4.27	3.17	4.08	3.20	3.71	4.06
November ..	3.00	2.55	2.55	2.93	3.61	2.90	2.15	3.99	2.69	3.02	3.60
December ..	2.60	2.34	2.17	2.39	3.14	2.10	2.11	3.01	2.42	2.49	3.12
Annual	48.46	46.80	46.04	45.95	54.24	41.76	42.79	49.26	43.32	48.45	53.30