IRRIGATION 4"

EC × 10⁶ (I.W)	Depth of Soil	R_1 EC × 10³ B/A	R_1 SAR B/A	R_2 EC × 10³ B/A	R_2 SAR B/A	EC (I.
						8
850	1	1.3/1:5	6.4/9.43	1.9/2.5	6.1/6.6	
	2	1.1/1.9	5.0/6.6	0.8/2.0	2.84/3.7	
	3	1.2/2.5	3.9/8.84	1.2/3.2	5.68/7.0	
	4	1.9/2.4	7.25/12.0	2.45/1.3	7.28/7.5	
	5	1.5/1.9	8.74/8.9	3.0/1.2	7.5/7.0	
						2
2000	1	6.5/4.5	11.65/38.0	6.5/2.1	7.42/55.0	
	2	6.5/2.1	10.08/38.0	3.9/5.5	10.92/59.0	
	3	1.1/4.2	4.35/31.7	3.8/4.5	4.89/31.4	
	4	0.9/2.6	4.18/10.81	3.25/4.0	2.92/20.0	
	5	1.0/2.0	3.94/5.0	2.2/2.8	12.0/17.0	
						2
2500	1	2.8/1.15	4.09/11.93	1.5/6.5	9.84/27.4	
	2	3.2/1.55	4.57/12.0	1.05/3.2	5.32/19.9	
	3	1.9/3.12	5.5/21.6	1.6/4.25	10.66/29.5	
	4	1.3/5.5	5.39/23.5	2.2/4.75	10.71/36.1	
	5	1.4/2.5	9.02/13.59	2.7/4.75	8.46/36.1	
						3
3000	1	1.2/2.6	5.68/13.3	2.8/3.0	13.02/15.28	
	2	1.4/2.4	7.95/11.1	3.4/3.0	14.1/20.4	
	3	1.1/2.4	4.97/86.2	3.5/5.0	15.2/28.4	
	4	1.8/4.0	5.0/44.75	2.4/4.5	7.44/9.9	
	5	1.2/5.5	5.68/46.49	2.1/4.2	10.08/15.0	

IRRIGATION 3'

EC×10⁶ (I.W.)	Depth of Soil	R_1 EC×10³ B/A	R_1 SAR B/A	R_2 EC×10³ B/A	R_2 SAR B/A
850	1	1.7/1.5	6.9/11.1	1.6/2.2	10.66/8.0
6	2	2.0/1.2	7.42/4.4	1.6/1.4	10.66/4.16
3.7	3	1.65/3.2	9.88/9.83	1.35/2.4	7.6/5.21
7.0	4	1.45/4.5	7.46/8.1	1.4/4.5	7.98/14.48
7.5	5	1.3/4.2	7.22/17.2	1.9/6.0	6.87/20.87
0					
2000	1	3.2/2.6	16.08/9.0	2.1/2.3	7-42/10.5
55.0	2	3.8/2.2	16.43/14.0	2.8/2.0	10.5/13.8
59.0	3	4.0/4.5	14.53/15.0	1.5/3.2	11.12/20.0
31.4	4	2.3/2.8	9.07/20.3	1.7/2·8	15.0/26.0
20.0	5	2.7/4.8	10.6/31.2	2.2/4.5	8.9 37.9
7.0					
2500	1	1.8/2.8	6.32/9.5	3.4/2.9	16.4/9.42
27.4	2	2.6/1.9	12.3/10.5	3.5/2.4	18.4/9.52
19.9	3	1.95/2.6	13.57/18.5	4.2/2.2	19.0/17.4
29.5	4	1.75/2.9	8.71/13.8	2.7/3.0	11.27/24.5
36.1	5	2.0/3.4	8.04/28.1	1.9/3.4	9.71/25.2
36.1					
3000	1	3.8/3.2	15.75/13.4	-/2.8	-/11.2
15.28	2	3.8/4.6	19.5/18.5	-/2.4	-/22.0
0.4	3	4.2/5.0	20.79/28.0	4.7/3.0	14.35/24.6
3.4	4	4.25/5.1	13.02/29.0	-/3,4	-,25.2
9.9	5	4.5/6.6	-/49.3	4,2/4,0	5,92/38.8
15.0					

trate into the soil to depths below the root-zone. The sodium adsorption ratio showed increase in all the cases for which the periodical application of gypsum in advisable. Similar results have been reported by other workers also.

Effect On Crop Yield

Table No. IV shows the yields of different crops in various crop rotations. In crop rotation No. I the yield of the maize crop did not show much decrease in any treatment. The crop remained in the field for three months and almost the whole of this period was covered by the rainy season. The heavy rainfalls were often received when the crop had already been irrigated and the moisture in the soil profile was almost at the field capacity level. Thus nearly the whole of the rain water would have passed below the root-zone and took away the salts left there with saline irrigation applications. So the chances of accumulation of salts in the soil profile in all the treatments were eliminated and the crop remained in normal condition. Berseem is a rabi crop. It showed decrease in yield in all the treatments with saline water application. It was because of the reason that the rainfalls received during the growth period of the crop were almost negligible due to which the accumulation of salts in the root-zone could not be avoided. The fall in yield was more when the electrical conductivity of the irrigation water used was high and the depths of irrigations were shallow. However, to some extent the adverse effect was reduced with the increase in depth of the same irrigation water.

Before sowing the cotton crop two heavy irrigations were applied to the soil to leach down the salts to ensure proper germination of the crop seed. After this, much of the growth period was covered by the rainy season. At times the rainfalls were had when the crop had been irrigated which eliminated the chances of accumulation of salts in the root-zone of the crop. Thus the crop yield was not adversely affected.

The chari crop also grew mostly in the rainy season. About 24'' rainfall was received during its growth period. Thus the possibilities of any adverse effect due to the accumulation of salts in the soil were removed and the crop gave the normal yield in all the cases.

The toria crop followed the chari crop, when it was sown, the soil would be almost free of salts. Only three irrigations were supplied to the crop with which the salts retained in the soil even with 3'' deep irrigation applications and with electrical conductivity of the water 3000 micromohs/cm were not enough to raise their level to the extent that they could have any adverse effect on the growth

R = Replication

TABLE NO. IV SHOWING THE CROP YIELD IN LBS./PLOT IN ROTATION NO. I

EC × 10^6 of I.W.	Depth of Irri.	17-7-71—20-10-71 Maize		1-11-71—6-4-72 Berseem		27-5-72—25-11-72 Cotton		4-6-73—22-8-73 Chari		2-10-73—28-3-74 Toria	
		R I	R 2	R I	R 2	R I	R 2	R I	R 2	R I	R 2
850	6"	1.69	3.12	11.14	13.31	0.25	0.31	16.63	18.00	0.30	0.54
	4"	3.12	2.50	9.88	10.50	0.38	0.12	34.38	31.00	0.80	0.80
	3"	3.25	1.75	10.88	10.50	0.38	0.56	32.00	33.00	1.00	1.50
2000	6"	3.00	2.88	13.06	12.56	0.63	0.63	28.00	27.75	0.50	0.61
	4"	3.12	3.00	9.12	9.81	0.38	0.38	32.00	32.25	1.00	0.67
	3"	2.00	2.25	8.50	9.06	0.50	0.63	29.38	32.50	0.85	0.65
2500	6"	3.75	3.75	12.75	12.75	0 56	0.25	25.60	35.00	1.00	0.82
	4"	2 12	1.75	10.12	7.25	0.56	0.25	33.12	33.00	0.73	0.70
	3"	2.12	2.75	9.31	10.06	0.63	0.63	27.00	23.00	0.34	0.34
3000	6"	3.63	1.88	12.94	13.75	0.25	0.31	25.00	28.25	0.70	0.94
	4"	2.00	1.50	7.75	7.56	0.50	0.50	35.25	32:00	0.73	0.72
	3"	1.50	3.38	7.88	6.69	0.50	0.25	21.00	27.00	1.25	1.46

R = Replication

TABLE NO. IV SHOWING THE CROP YIELD IN LBS./PLOT IN ROTATION NO. 2

EC—10⁶ of I.W	Depth of irri.	23-7-71—20-10-71 Maize		2-11-71—20-2-72 Senji		14-3-72—27-2-73 Sugarcane		25-5-73—14-9-73 Guara		31-10-73—11-4-74 Wheat	
		R I	R 2	R I	R 2	R I	R 2	R I	R 2	R I	R 2
850	6"	5.38	6.06	9.26	10.00	49.00	59.00	1.63	1.81	4.50	5.50
	4"	3.12	2.25	8.50	6.88	34.00	28.25	1.63	3.00	6.00	5.63
	3"	4.12	4.19	9.56	8.19	49.00	34.38	3.12	1.63	4.25	4.75
2000	6"	4.50	5.50	9·12	8.56	35.00	40.00	1.50	1.38	6.75	5.75
	4"	3.50	3.12	8.25	7.25	31.75	24.12	1.56	1.31	6.25	5.50
	3"	4.00	3.12	8.63	7.75	32.56	35.88	1.12	1.69	5.88	6.00
2500	6"	4.00	4.75	7.00	8.63	37.88	32.50	1.00	1.38	5.38	5.75
	4"	2.23	2.12	8.38	8.75	20.75	25.50	1.50	0.69	5.88	6.00
	3"	4.25	3.50	7.25	6.00	27.50	28.38	2.12	2.75	6.00	6.38
3000	6"	5.00	4.25	8.50	9.75	21.50	25.00	1.00	1.12	6.00	6.12
	4"	2.25	1.38	9.19	8.19	21.88	20.63	0.63	0.50	6.25	6.12
	3"	2.38	2.00	6.00	6.75	22.25	18.88	1.44	0.50	6.00	6.00

R = Replication

TABLE NO. IV SHOWING THE CROP YIELD IN LBS./PLOT IN ROTATION NO. 3

EC—10^6 of I.W.	Depth of irri.	17-7-71—20-10-71 Maize		6-11-71—4-5-72 Lucern		31-10-72—10-4-73 Wheat		26-5-73—22-8-73 Chari		4-10-73—31-3-74 Gram	
		R I	R 2	R I	R 2	R I	R 2	R I	R 2	R I	R 2
850	6"	4.50	4.12	7.50	9.12	1.56	1.88	28.50	33.00		
	4"	3.75	3.50	5.12	4.88	1.12	1.81	26.00	19.00		
	3"	3.00	3.00	6.88	7.31	1.63	1.50	26.25	24.25		
2000	6"	4.38	4.50	8.44	8.19	1.75	1.81	19.00	31.00		
	4"	3.12	3.50	8.50	7.00	1.88	1.75	22.50	20.00	Failed	
	3"	2.12	1.88	6.44	6.56	1.63	1.50	20.00	24.00		
2500	6"	4.25	3.00	8.00	7.63	1.75	1.75	27.00	21.00		
	4"	2.88	2.88	7.94	6.81	1.38	1.50	28.25	26.25		
	3"	3.12	2.63	6.44	5.19	1.50	1.56	22.25	26.25		
3000	6"	4.00	4.54	7.88	6.44	2.00	2.00	25.00	23.00		
	4"	2.88	3.12	9.25	6.56	1.63	1.69	24.00	26.50		
	3"	2.63	2.06	5.38	6.12	1.56	1.69	24.50	28.50		

R = Replication

of the crop. So the crop did not show any decrease in yield in any treatment.

In crop rotation No. II the Maize crop gave the similar results as have been reported in crop rotation No. I. The yields of the Senji and Guara crops resembled with those of the berseem and Chari crops given in the same crop rotation.

The Sugarcane crop gave low yield in all the cases with saline water application. With shallow irrigation applications the crop was worst affected whereas in case of deep irrigations the yields were comparatively better, but it too were low than the normal one. The crop was sown in the month of March. The accumulation of salts in the root-zone with the application of saline water to the crop in the hot and dry Summer season could not be avoided. By the time the moon-soon season set-in, the crop had already suffered to the extent that the heavy rainfalls received later on, were not helpful to recover this loss. From this discussion it is concluded that the use of saline water to grow the sugarcane crop should be avoided. The wheat crop followed the Guara crop during the growth period of which 23. 94'' rainfall was received. Thus when the crop was sown, the soil was almost in normal condition. Moreover the wheat is a medium salt tolerant and low delta crop. The addition of salts in the root-zone even with water of EC 3000 micromohs/cm and 3" deep irrigation applications could not raise the level of salts in the soil to reduce its yield. In crop rotation No. III the yield of the Maize crop in all the treatments was similar to those given in the crop rotation No. I and II and the results of the lucern crop resembled with those of the Berseem and the Senji crops shown in rotation No. II respectively. The yield of the chari and the Wheat crops were also compareable with those of the same given in rotation No. I and II respectively. The gram crop failed in all the cases which shows that the crop is susceptable to high delta application and high salinity level of the irrigation water tried here.

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Buildings Bridges and Highways Section

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Construction of Some Heavy Foundations at Pak-Arab Fertilizers Factory, Multan

By
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M. Sc. (Struct : Engg)

The former West Pakistan Industrial Development Corporation established a fertilizer factory at Multan in 1960 with a 200 tons capacity Ammonia Plant. The production of Ammonia Plant was further improved by supplementing it with another small unit called "AMMOPAC". This small unit was capable of producing of additional 50 tons of ammonia daily. With the existing facilities the following two kinds of fertilizers are being daily produced at Multan :

1. Urea 200 tons
2. Calcium Ammonium Nitrate 300 tons

The factory known as Natural Gas Fertilizer Factory started the production of fertilizer in 1962/63. With the passage of time when the farmers realized the usefulness of the fertillizers and became alive to their necessity, the demand on the fertilizers improved to an extent that the production of the fertilizers both in the private and in the public sectors became inadequate to meet the total demand. This has resulted in the import of the fertilizer to the extent of 0.2 million neutrient tons per year which is a big drain on the foreign exchange resources of the country.

During 1972 a great necessity was felt to improve the capacity of the existing Natural Gas Fertilizer Factory and a scheme was therefore, prepared for the expansion of the existing facilities so as to produce the following daily quantities of fertilizers :

1. Calcium Ammonium Nitrate 1275 tons
2. Nitro-Phosphate 1050 tons

Generally Pakistani soils are alkaline and very low in organic matter.

1. Chief Engineer (Civil), Pak-Arab Fertilizers Ltd., Multan.

In areas where canal irrigation has been practiced since long, water logging and salinity pose a growing threat to land productivity. Large scale soil tests have shown a universal need for Nitrogen and Phosphorus in a ratio of 2 : 1 for high yields. It was therefore, planned to introduce phosphatic fertilizer to a bigger scale. This fertilizer will now be produced in this country in this new complex.

To achieve the new targets, the expansion of the existing N.G.F.F. included the construction of the following new plants at the existing site :

1. Ammonia Plant.
2. Calcium Ammonium Nitrate Plant with Prilling Tower.
3. Nitric Acid Plant.
4. Nitro Phosphate Plant with Prilling Tower.

In addition, the construction of Power House, Cooling Towers, Sub stations, Control House, Storage Buildings was naturally necessitated. Also the new Project will have capacity for the storage of Ammonia as well as of the Nitric Acid to the extent of 5000 tons and 6000 tons respectively as against the existing storage facilities of 2000 tons of Ammonia and about 600 tons of Nitric Acid.

The new Ammonia Plant will produce 910 MT of ammonia per day and will replace the existing total ammonia production which has only rated capacity of 250 tons. The new CAN Plant will have capacity to produce 1500 tons of Calcium Ammonium Nitrate daily in the prilled form. The NP Plant will also be producing 1050 tons of prilled Nitro-phosphate daily.

The new Nitric Acid Plant will produce 1200 tons in two lines as against 180 tons of Nitric Acid being produced by the existing plant.

For the construction of these buildings about 40 acres of land have been acquired on the eastern side of the existing factory and about 13 acres have been taken on the western end.

Heavy Foundations

The applied loading in a number of buildings have been very heavy but this paper describes the following foundations which are all supported on the piles

1. *Ammonia Plant.*
   - (*a*) Foundation for CO_2 Absorber (101-E)
   - (*b*) Foundation for CO_2 Stripper (102-E)
   - (*c*) Foundation for Condensate Stripper (103-E)
   - (*d*) Foundation fo Secondary Reformer (103-D)
   - (*e*) Foundation for Ammonia Convertors (105-DA & 105-DB)
2. Foundations for Absorption Tower in Nitric Acid Plant.

3. Foundations for NP Prilling Tower.
4. Foundations for CAN Prilling Tower.

Soil Investigation

The first step in the construction of this huge complex was naturally the determination of the soil characteristics of the site so as to determine the design parameters for the foundations.

Scope of Soil Testing

The scope of soil investigation consisted of the evaluation of the soil type, field density, moisture content and load carrying capacity of the sub soil strata. The soil investigation consisted of ;

1. Field Testing
2. Laboratory Testing

1. Field Testing

Field Testing comprised of ;

(*i*) Auger Boring

(*ii*) Sampling

(*a*) Collection of disturbed samples

(*b*) Collection of undisturbed samples

(*iii*) In-situ-Testing.

2. Laboratory Testing.

Laboratory Testing consisted of carrying out the following tests :

(*i*) Determination of moisture content.

(*ii*) Determination of Bulk and dry density

(*iii*) Grain size Analysis by

(*a*) Sieve Analysis

(*b*) Hydrometer

(*iv*) Consistency Limits (Liquid and Plastic Limits)

(*v*) Shear Strength Tests.

1. Informatory Bores

The informatory bore holes of 4" dia were taken upto a depth of 100 ft. below natural surface level and disturbed samples were collected at 5' intervals. For these bore holes, the hole was advanced upto water table by means of hand augers and then by percussion boring.

2. Sampling :

(*i*) Disturbed Samples

Disturbed samples were collected from the informatory bore holes upto a depth of 100 ft. at every 5' intervals or at change of strata whichever was earlier sent in polythene bags for laboratory testing.

The natural moisture content of these samples was also determined at the site with the help of the speedy moisture meter.

(*ii*) Un-Disturbed Samples

Un-disturbed samples were collected by thin wall Shelby tubes of $1\frac{1}{2}$" dia and 9" long from top sandy silt upto a depth of about 10-12 ft. These samples were used for the determination of field density of the soil strata.

3. **In-Situ Testing**

(*i*) **Standard Penetration Test**

Because of the extreme difficulty in obtaining undisturbed samples from granular soil and in securing the undisturbed specimen from the sample, the engineering properties of such a soil are determined by taking disturbed samples and by measuring the relative density by penetration test. Standard Penetration Test was performed at an interval of 3 ft. upto a depth 28 ft, which is the depth at which water table is generally encountered at site. Standard penetration resistance (N) was recorded for a total penetration of 12" of the standard split-spoon sampler caused by a weight of 140 lbs. falling through a height of 30"

(*ii*) **Dutch Cone Penetration Test**

Of the various penetrometers designed for use in soils, the Dutch Cone Penetrometer which was developed by the Soil Mechanic Laboratory at Delft, the Netherlands is widely used. penetrometer is a cone which is pushed into the soil by hand or by mechanical means. The pressure required to advance the cone at a slow constant rate is observed and is known as the penetration resistance.

The cone has a base of 10 cm^2 and is fixed to a steel push rod. Penetration resistance of only the cone and sleeve and the cone are measured. Thus the soil friction along the push rod was eliminated by surrounding the push rod by the steel tube. Table I gives the type of soil testing carried out in the field in each of the following plants :

Table I

TYPE OF SOIL TESTING CARRIED OUT

S. No.	DESCRIPTION	Number of informatory bores	Number of S.P.T. carried out	Number of Dutch Cone Penetration Tests carried out	Number of Open pits Tested
1.	Ammonia Plant	2	8	5	x
2.	Nitric Acid Plant	2	x	1	1
3.	CAN Prilling Tower	1	1	1	x
4.	NP Prilling Tower	x	1	1	x

Laboratory Testing :

Laboratory Testing was carried out to supplement the results of the field testing and was achieved as per programme mentioned earlier.

Interpretation of Soil Investigation Results

1. Ammonia Plant.

This is the basic plant in the whole project and carries very heavy loads at 5 different locations in its battery limits shown in Fig. No. 1. The plot measures 127mX70m. The site of the Ammonia Plant is relatively flat. The top soil is dry and fairly loose in the upper two feet strata. Water table in this area was observed to be at a depth of 28 ft. during November, 1974.

The sub soil consists of fairly uniform deposit of sandy silts upto a depth of 10-12 ft. in a fairly dense state. This layer is supported by a layer of fine to medium sand nearly 50 ft. thick. The percentage of medium sand generally increases with depth within this layer. Below 60 ft. from the natural surface level, traces of pea size gravel and "Kankar" have been detected. The content of this gravel generally varies from 1% to 20% and it was found to exist between 60 ft. to 75 ft. below natural surface level. At a depth of 92 ft. some traces of gravel were observed again.

The moisture content in the top sandy silt is generally low ranging from 2 to 10%. It increases near the water table. The average dry density at the site upto water table varies from 80 lbs/cft. to about 100/lbs cft.

The upper sandy silt is of low plasticity. The rest of the soil strata is almost entirely non-plastic with the exception of few pockets of soils of low plasticity.

The N values obtained from Standard Penetration Test vary from 10 to 55 with an average value of 20 beyond a depth of 10 ft. From Dutch Cone Resistance Vs depth curves, it was observed that the maximum cone penetration resistance values lie at a depth, of 60 to 70 below natural surface level. At this depth, traces of gravel were also found. The cone resistance values vary from 132 Kg/cm^2 to 168 Kg/cm^2 within a depth of 60 ft. to 70 ft.

The bearing capacity of the soil was determined from the relation $Es = 1.5\, q_c$. where Es = young's Modulus for granular soils in compression and q_c = Dutch Cone Bearing capacity.

2. Nitric Acid Plant.

Fig. 2 shows the layout of the Nitric Acid Plant indicating the L-shaped and T-shaped areas for the Absorption towers. In case of Nitric Acid Plant, 2 bore holes were carried out upto a depth of 100 ft.

One open pit was also investigated from which disturbed and undisturbed samples were collected at 5, 6 and 7 ft depth.

The top two feet strata consist of a loose fill material. Below this soil there is a layer of sandy silt of low plasticity. This layer lies over a deposit of silty sand in which the percentage of medium sand increases with depth. Ground water table was found to be at a depth of 28 ft. below natural surface level during the month of Feb. 1975.

The natural moisture content in top soil varied from 12 to 7% alongwith depth of the soil. The average dry density of the soil varies from 92 to 95 lbs/ft^3, showing that the sub soil is in a medium dense state. The load carrying capacity of the sub soil has been worked out on the basis of the Triaxial Compression Tests carried on samples collected at 5, 6 & 7 ft depths from the one open pit.

The average value of the allowable bearing capacity for shallow founation at 5 ft. depth was recommended to be 0.9tons/sq. ft.

The results of Dutch Cone Penetration Test showed the maximum penetration resistance of 180 Kg/cm^2 at depth of about 60 ft. below natural surface level.

3. Can Prilling Tower

The top 2 ft. soil at the CAN Prilling Tower consists of a loose, fairly dry, fill material. Below this lies ten feet layer of sandy silt followed by silty sand. Fine to medium sand is encountered at 23 ft depth and continues upto 50 ft. depth. Ground water table was observed at 29 ft. below natural surface level during the the month of March, 1975. Traces of gravel were found at 50′ depth and remain present upto 78 ft. below natural surface level.

The results of the Standard Penetration resistance of the sub soil at the site was determined upto the water table. The top 10 ft. of the sandy silt lies in a loose state whereas the soil below 10′ is in medium dense state with the maximum value of N recorded as 20.

The Dutch Cone Penetration resistance in case of CAN Prilling Tower was low upto water table. It then increased with the depth reaching a maximum value around 70 ft. depth This value was found to be 190 Kg/cm^2.

4. NP Prilling Tower.

In case of NP Prilling Tower also the 2 ft. top layer is in a loose state. The top soil is followed by sandy silt 10 ft. thick laying over silty sand 5 to 6 ft. in thickness. The rest of the strata consists of fine to medium sand with traces of gravel found after 45′ depth. The depth of the ground water table was found to be 30′ below natural surface level during the month

of March, 1975.

The results of the Dutch Cone Penetrometer showed that the penetration resistance is generally low at point upto the ground water table beyond which the resistance tends to increase and a maximum value is obtained at 68′. below natural surface level where the sub soil oppears to lie in a fairly dense state. Penetration resistance was only tested upto a depth of about 68′ below natural surface level, and the value of the penetration resistance continued improving all the time. The value of the penetration resistance was observed to be 180 Kg/cm² at depth of 68′.

In general the soil at the site of Pakarab Fertilizers Factory is in a loose state in the upper 2′ ft. to 5 ft. below which the soil changes to silt in a medium dense state. The soil below 5 ft. can be classified as SM and changes to SP beyond 15 ft. The group symbols are based on Cassagrande's classifications.

The soil is predominenly sandy from a depth of 15 to 100 ft. with medium sand varying from 11 to 74%. The coarse sand constituent is only from 1 to 12 percent, the remaining being fine sand which also varies with depth from 11 to 55 percent. The fraction of clay is only minor with 1 to 2 percent and is generally missing at depths beyond 20′. Fig : 3 represents the type and characteristics of soil at the Pakarab Site in general.

LOADING DATA

(a) Ammonia Plant

Tabie 2 below gives the loading data for the Ammonia Plant.

Table 2

LOADING DATA FOR HEAVY FOUNDATIONS IN AMMONIA PLANT

S. No.	Foundation for	CASE	Vertical Load KN	Horizontal Load KN	Moment KNm	Permissible Max. Dimensions MM
1.	101-E	Erection	$P_e = 1840$	$H_e = 0.8\ H_o$	$M_e = 0.8\ M_o$	
		Operating	$P_o = 4800$	$H_o = 228$ $F_x = 395$	$M_o = 6454$	6500x6500
		Tests	$P_w = 5921$	$H_w = 0.5\ H_o$	$M_w = 0.5\ M$	

2.	102-E	Erection	$P_e = 1444$	$H_e = 0.8\ H_o$	$M_e = 0.8\ M$	
		Operating	$P_o = 3540$	$H_o = 352$	$M_o = 12422$	7400x7400
				$F_x = 385$	$M_x = 2383$	
		Tests	$P_w = 7812$	$H_w = 0.5\ H$	$M_w = 0.5 \times M$	
3.	103-E	Erection	$P_e = 147$	$H_e = 0.8\ H_o$	$M_e = 0.8\ M_o$	
		Operating	$P_o = 264$	$H_o = 11.5$	$M_o = 1340$	3700x3700
				$F_x = 133.00$	$M_x = 1226$	
		Tests	$P_w = 320$	$H_w = 0.5\ H$	$M_w = 0.5\ M$	
4.	103-D	Erection (Max. Col. Load)	$P_e = 3260$	$H_e = 296$		
		Operating (Max. Col. Load)	$P_o = 4403$	$H_o = 218$		14050x13600
		Tests (Max. Col. Load)	$P_w = 4429$	$H_w = 62$		
5.	110-H	Erection (Max. Col. Load)	$P_e = 1320$	$H_e = 45$		
		Operating (Max. Col. Load)	$P_o = 2217$	$H_o = 66$		13000x7000
		Tests (Max. Col. Load)	$P_w = 1889$	$H_w = 28$		

where ;

KN = Killo—newton force (1 KN = 100 Kg)

KNm = Killo—newton meter moment

e = Loading under erection condition

o = Loading under operating condition

w = Loading under hydrostatic test condition

x = Earthquake force

There are five different locations in Ammonia Plant where the applied load is of very heavy intensity and required special design consideration. Generally from the table above it can be observed that the loading on the foundation is maximum when the test loads are applied.

(*b*) Nitric acid Plant

There are four Absorption Towers each having a height of about 62 metres. Over the 2 (two) Absorption towers, additional structure of about 18 metres high will also be erected. Maximum loading for each absorption tower is given below :

(i) Maximum Vertical Load = 1550 metric tons

(ii) Maximum Horizontal Load = 65 M tons

(iii) Maximum Moment = 2420 tons meter

(*c*) Prilling Towers

The maximum applied loading on the two prilling towers is given below :

	CAN PRILL: TOWER	NP PRIL: TOWER
(i) Maximum Vertical Load	9048.5 tons	6374.4 tons
(ii) Maximum Horizontal Load	152 tons	120 tons
(iii) Maximum Moment	6246 tons m	5217 tons m

Type of Foundations

From the above loading and the permissible dimensions which have been fixed according to the process requirements, it is evident that the applied load is much more then the safe load carrying capacity of the soil. It was naturally concluded to transmit the load to the sub soil with the help of piles. Piles are normally used to transfer load to the soil upto suitable bearing stratum. Generally the piles are of 2 types :

(*i*) End Bearing Piles

(*ii*) Friction Piles

The end bearing piles can be located at places where there is a suitable bearing stratum at a reasonable depth. In case of friction piles, the load is transferred by means of skin friction along the length of the

piles. In the present case the piles are mainly friction piles but their ends are resting on a comparatively harder stratum. From the results of the soil investigation it was observed that at a depth between 60 to 70 ft. below natural surface level the Dutch Cone penetrometer showed high penetration resistance of about 180 Kg/cm². There are also traces of gravel at this level which makes this portion of the soil very suitable for resting the ends of the piles.

Selection of Piles

Depending upon the type of equipment and resources available in the country, it was decided that cast-in-situ piles will be easy to construct. The typical pile used in the whole Project consists of 457 mm in diameter and is 18300 mm long as shown in Fig. 2.

All the piles were put in position with the help of reverse rotary rig except some piles in Nitric Acid Plant area which were also done with direct rotary. The process of boring the piles consisted in pushing the cutting tool when the water is being simultaneously drawn out which brings the cut out material which is dumped in an open water pit. After boring the hole for pile, steel cage is lowered to full depth in the pile hole. Since in the present case the length of pile required jointing of 2 cages of reinforcement, the process consisted of lowering one cage and welding the second cage over it with 40 times the dia lap between bars. When the full length of reinforcement was lowered in the bored hole tremi pipe of 8" diameter with a bucket on top was lowered. Tremi pipe is used to pour concrete and it was progressively withdrawn till the concreting was done upto about 1 to 1.5 meters above the required cut-off level. Table 3 gives the number of piles in each area of the four different sites where piling has been done.

Table 3

NUMBER OF PILES UNDER HEAVY FOUNDATIONS

S, No.	PLANT	AREA	Number of Piles
1.	Ammonia	101-E	25
		102-E	39
		103-E	09
		103-D	57
		110-H	35
2.	Nitric Acid	L-Area	114
		T-Area	132
3.	CAN Prilling Tower	—	181
4.	NP Prilling Tower	—	132
		Total :	724

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	181
	132
:	724

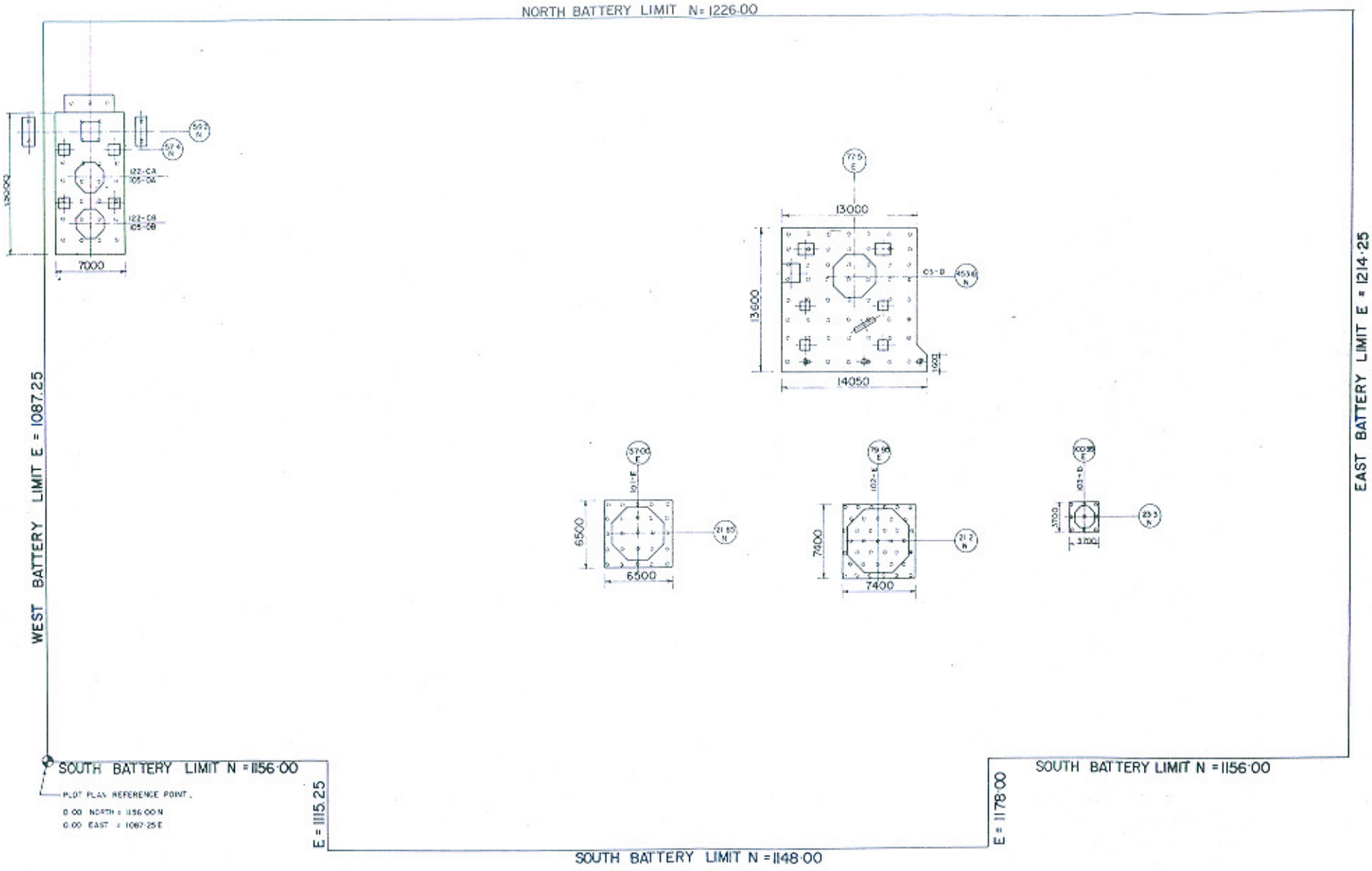
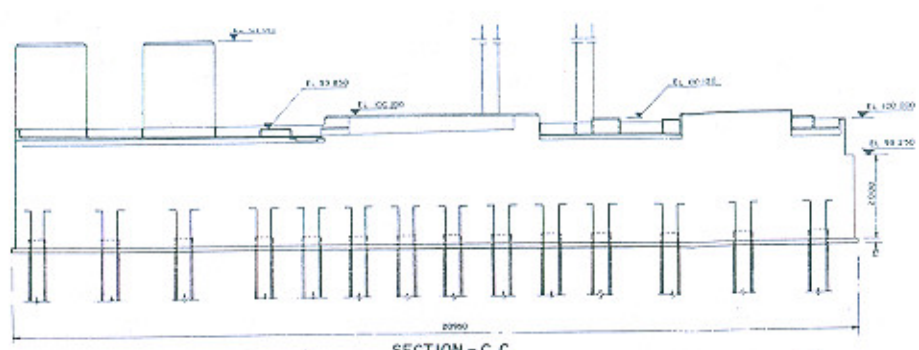


FIG. I

LAY OUT OF AMMONIA PLANT
SHOWING LOCATION OF HEAVY FOUNDATIONS AT
PAKARAB FERTILIZERS LIMITED MULTAN



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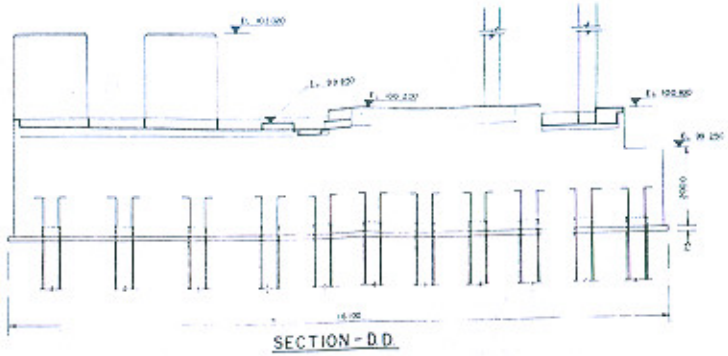

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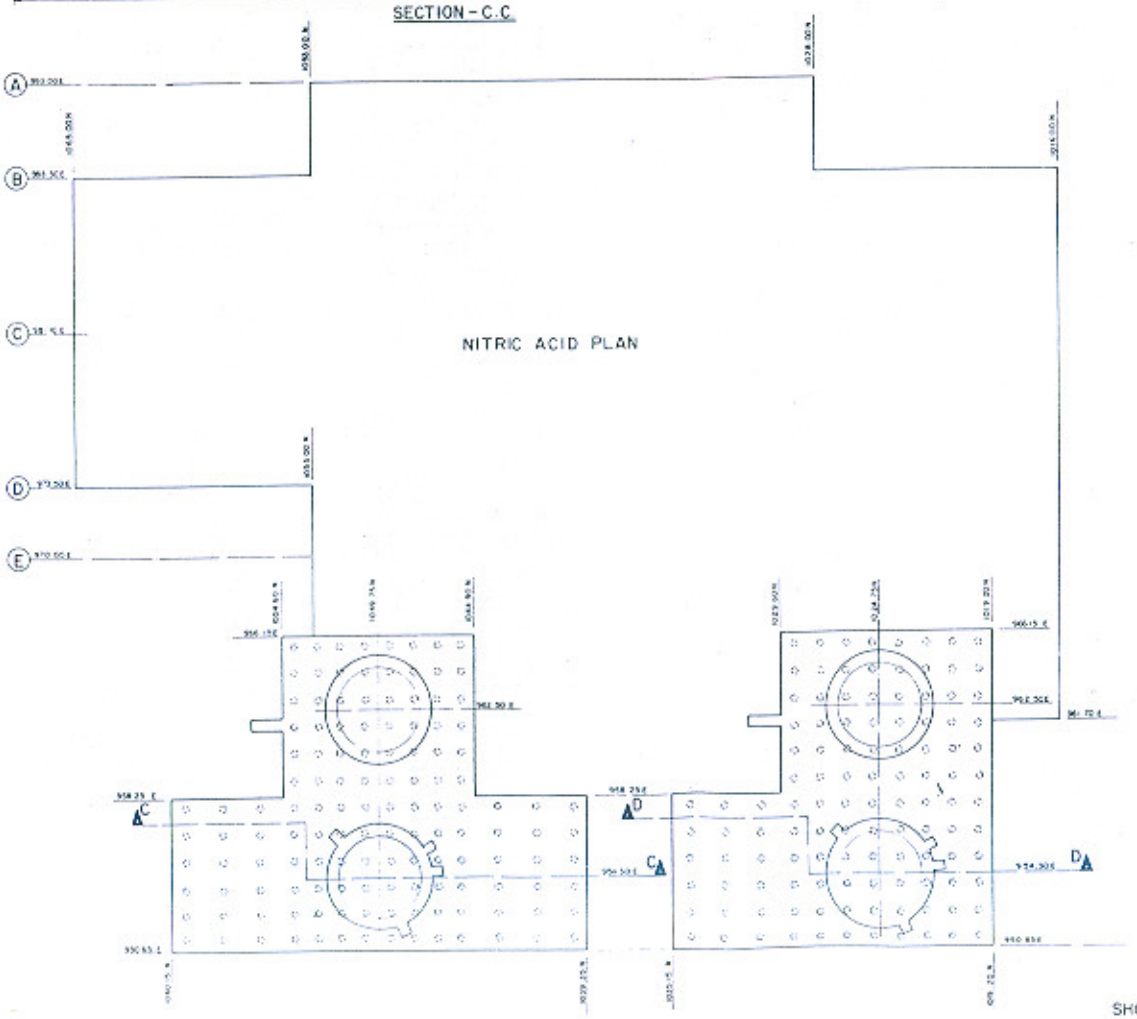
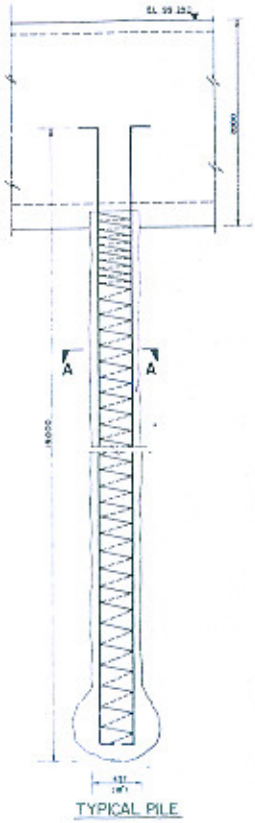


NITRIC ACID PLAN



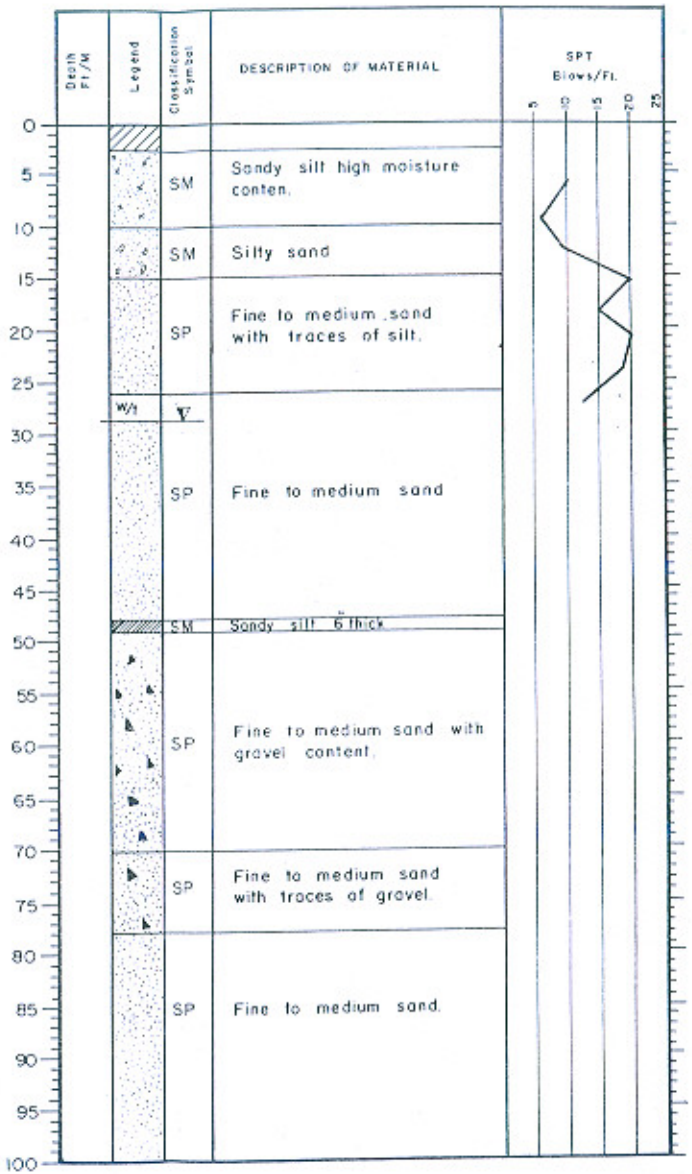
TYPICAL PILE

SEC A.A

FIG 2

LAY OUT OF NITRIC ACID PLANT
SHOWING L&T SHAPED AREAS FOR ABSORPTION TOWERS AT
PAKARAB FERTILIZERS LIMITED MULTAN

Depth in ft.	Gravel %	Sand %			Silt & Clay Fraction %	Soil Type
		Course	Medium	Fine		
5	–	0.00	3.00	11.00	86.00	SM
10	–	0.50	4.50	13.00	82.00	SM
15	1.50	1.00	50.50	37.00	10.00	SP
20	–	1.00	60.00	34.00	5.00	SP
25	–	1.00	64.00	31.00	4.00	SP
30	–	0.50	44.50	55.00	0.00	SP
35	–	1.00	39.00	60.00	0.00	SP
40	–	–	–	–	–	–
45	18.00	6.00	55.00	19.00	2.00	SP
50	–	1.00	5.00	12.00	82.00	SM
55	12.00	4.00	60.00	22.00	2.00	SP
60	4.00	4.00	57.00	35.00	0.00	SP
65	2.00	3.00	50.00	40.00	5.00	SP
70	–	–	–	–	–	–
75	6.00	4.00	45.00	44.00	1.00	SP
80	–	1.00	46.00	51.00	2.00	SP
85	–	–	–	–	–	–
90	–	4.00	60.00	36.00	0.00	SP
95	–	0.00	40.00	59.00	1.00	SP
100	–	1.00	45.00	54.00	0.00	SP



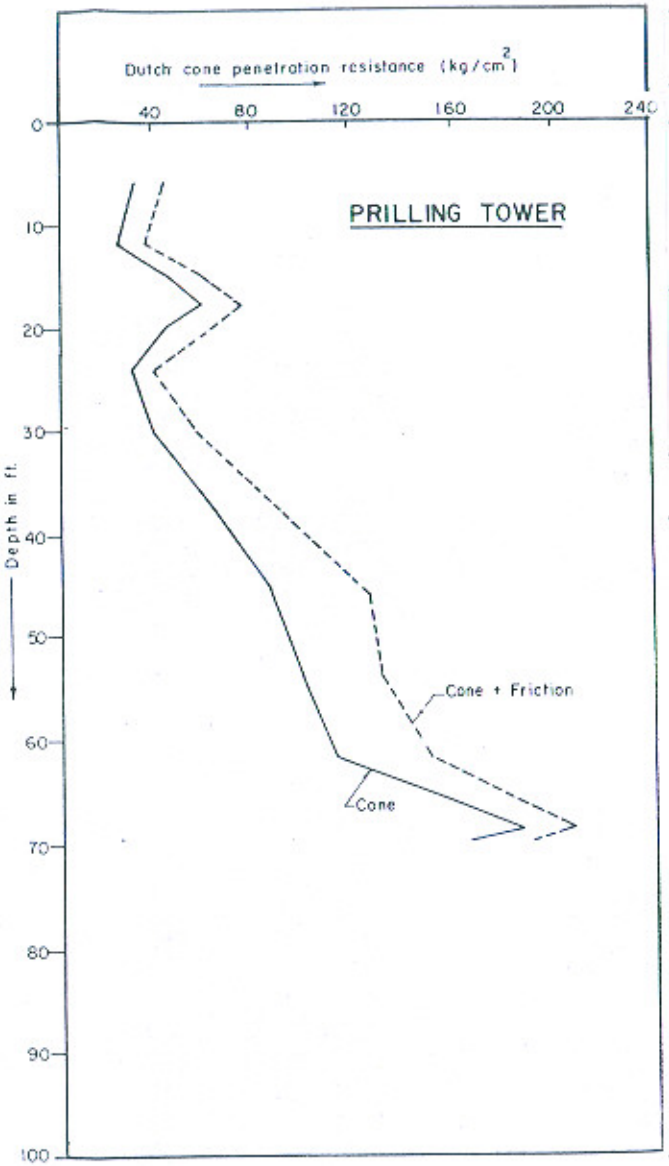


FIG. 3

ENGINEERING PROPERTIES OF SOIL AND ITS CLASSIFICATION AT PAKARAB FERTILIZERS LIMITED MULTAN

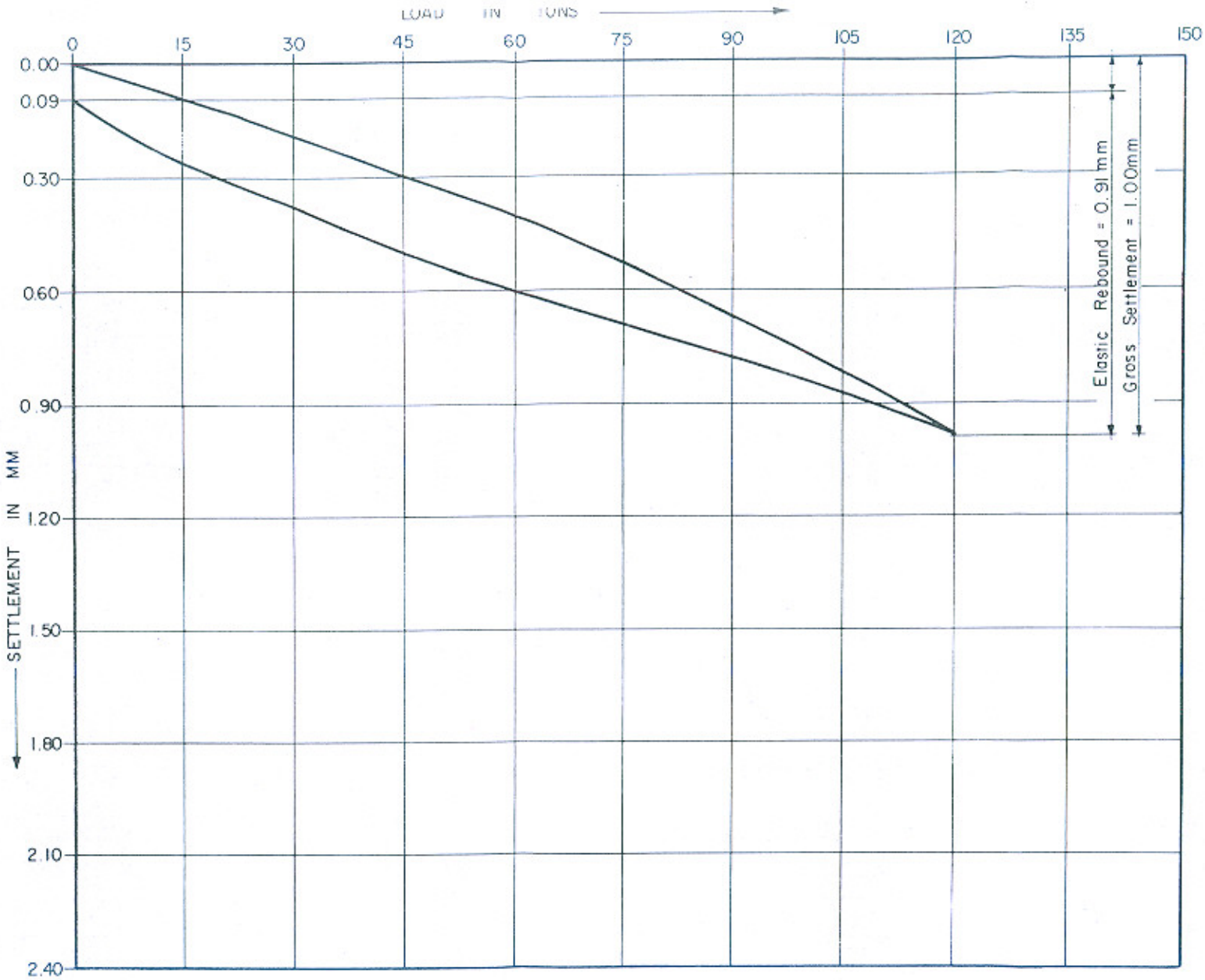


FIG. 4

LOAD/SETTLEMENT DIAGRAM
OF PILE No. 171 IN NITRIC ACID PLANT
PAKARAB FERTILIZERS LIMITED MULTAN

Pile Caps

The load exerted by a structure is transferred to a group of piles through pile footings or pile caps. Pile caps are almost invariably made of reinforced concrete and are designed as individual footings subjected to the applied loads including the weight of the pile cap itself. Under a concentric load, all piles in the same group are assumed to take equal axial support. Wherever the conditions permit, the piles are arranged in the most compact geometric form in order to keep stresses in the pile cap to a minimum. The geometric forms as laid out in Ammonia as well as in the Nitric Acid Plant are shown in figures No. 1 and 2. The form under the prilling towers was naturally concentric circles.

The pile cap is designed usually in accordance with the following assumptions when the loading is either ecentric or concentric plus a moment :

(*i*) Pile cap is perfectly rigid

(*ii*) Pile heads are hinged to the pile cap, therefore, no bending moment is transmitted from the pile cap on the piles.

(*iii*) Piles are short and elastic columns, therefore, the deformations and stress distribution are planar.

These assumptions permit the use of elastic theory for calculations of the pile loads and stresses in the pile loads and stresses in the pile cap.

Pile cap should be large enough to have a minimum edge distance of 100 to 150 mm of concrete beyond the outside face of the exterior piles. Ordinarily the piles are embedded atleast 6" in the caps and reinforcing bars are placed at a clear distance 75 mm above the pile head. In the present case the reinforcing bars in the piles are projecting into the caps by 300 to 400 mm and 120 to 150 mm top portion of the pile heads has been embedded in the pile cap. Table 4 gives the dimensions of each pile cap in four different sites.

Quality Control

The concrete in all the piles is of high quality as the minimum crushing strength specified varied from 3750 to 4500 psi using a mixture of local and Lawrencepur Sand. The crushed stone used for the piles was carted from Sargodha. Since the moulding of the test cubes at site, their curing and their ultimate testing is under better control conditions, it was therefore, thought necessary to keep the strength of the works cubes higher than it was actually required. Table 5 shows the strength of the works cubes which were tested at different sites.

Table 4

DIMENSIONS OF PILE CAPS

PLANT	AREA	SIZE OF PILE CAP LENGTH mm	BREADTH mm	DEPTH mm	AREA OF PILE CAP M^2
Ammonia	101-E	6500	6500	1200	42.25
	102-E	7400	7400	1200	54.76
	103-E	3700	3700	1200	13.69
	103-D	14050 (Approx)	13600	1000 to 1200	191.080
	110-H	—	—	1200	105.853
Nitric Acid	L-Area	—	—	2000	203.38
	T-Area	—	—	2000	234.21
		OUTER DATA	INER DATA		
CAN Prill: Tower		29000	14000	2000	2026.32
Np Prill: Tower		25500	13500	1700	1470.26

Test Piles

Generally load tests are made to determine the bearing capacity and to establish the load settlement characteristics under the compression load. Usually the pile foundations are designed on an estimated capacity which is arrived from a thorough soil study. The designed capacity of each pile is 60 tons in this case. It was desirable to have the load tests carried out before starting the piling so as to verify the adequacy of the design capacity. However keeping in view the tight time schedule, test piles were placed in position simultaneously alongwith the service piles.

Load tests give reliable results for piles in a grannular soil and frequently the bearing capacity of the piles cannot be established other than by the load tests.

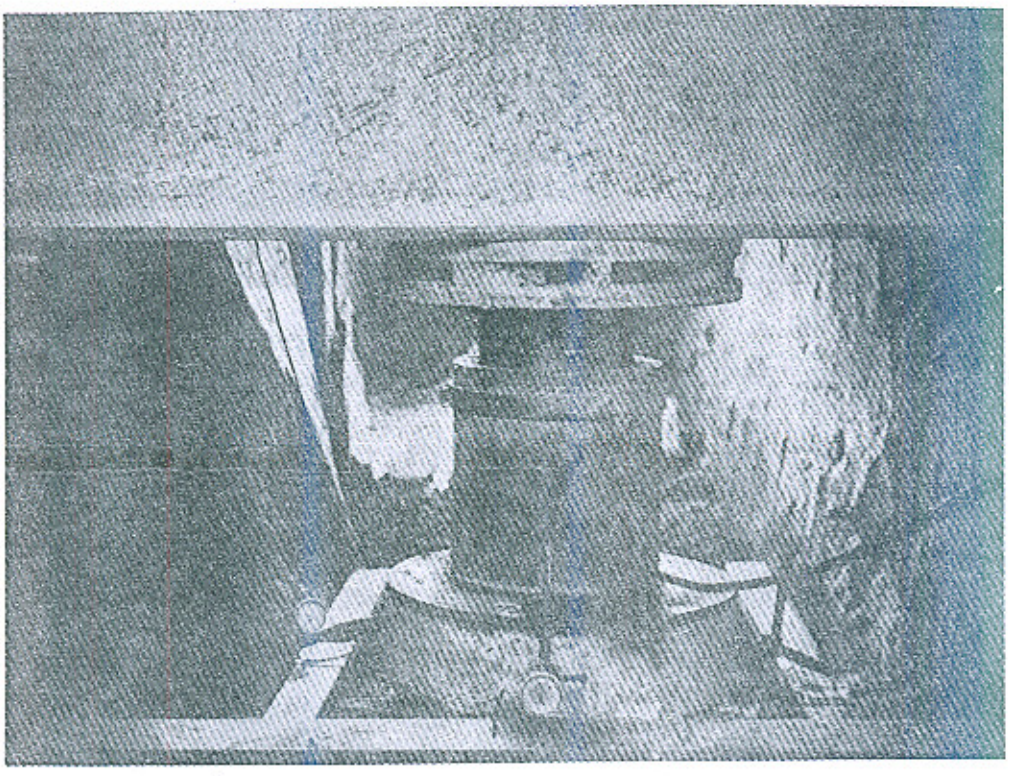
The test was conducted by shaving test piles at the top and applying pressure of twice the designed load of the service pile with the help of a jack. The settlement of the pile within a known period was observed. The load was than released and recovery of settlement of the pile was also noted. A typical graph is shown in Fig. 4. The residual settlement in this case was only .09 mm. Table No. 6 shows the piles tested in each area :

Table 5

STATEMENT SHOWING 6" WORK CUBES TESTED AT THE SITE OF HEAVY FOUNDATION

PAK-ARAB FERTILIZERS LTD MULTAN

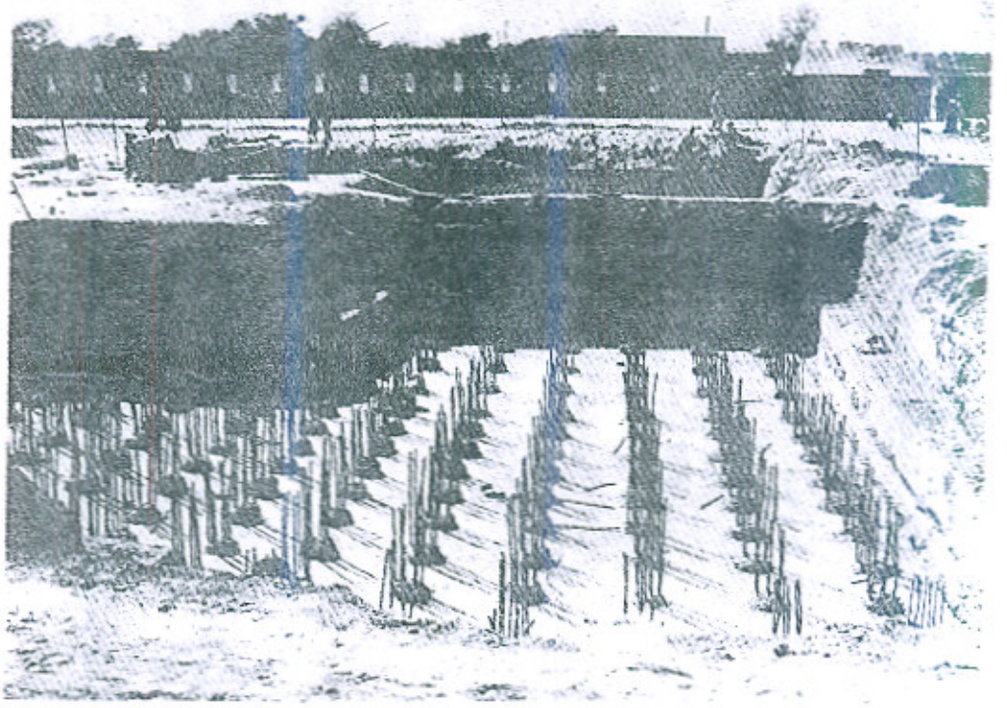
		PILES						PILE CAPS					
PLANT	AREA	Number of Piles	Quantity of conc m^3	Cubes tested for 7 days strength	Cubes tested for 28 days	Strength at 7 days (psi)	Specified strength at 28 days (psi)	Specified strength at 28 days (psi)	Quantity of conc m^3	Cubes tested for 7 days strength	Cubes tested for 28 days strength	Strength at 7 days (psi)	Strength 28 days (psi)	Specified strength at 28 days (psi)
Ammonia	101-B	25	72.02	24	—	Max : 4206	5211	4500	66.28	4	4	Max : 4801	4722	4000
						Min : 3128	4372					Min : 3611	4555	
	102-B	32	117.8	52	12	Max : 4337	5688	4500	90.624	4	3	Max : 4944	5694	4000
						Min : 2625	4693					Min : 3888	4722	
	103-B	9	27.02	24	12	Max : 4266	5688	4500	19.454	3	3	Max : 4372	4861	4000
						Min : 2844	3128					Min : 3361	4305	
	103-D	57	171.114	36	20	Max : 4834	5772	4500	210.418	4	3	Max : 4805	5123	4000
						Min : 2272	3839					Min : 3694	4037	
	110-B	35	109.7	12	18	Max : 4123	5001	4500	127.034	4	4	Max : 4166	5416	4000
						Min : 2844	4812					Min : 2916	4305	
Nitric Acid	L-Area	114	342.288	15	18	Max : 4550	5688	3750	404	3	3	Max : 3800	4400	4000
		132	396.264	19	11	Min - 3412	4266		406	6	6	Min : 3650	4560	
CAN Prilling Tower		181	815	42	42	Max : 5138	5953	3750	1060.5	28	28	Max : 5333	5694	4000
						Min : 4022	1613					Min : 4161	4850	
NP Prilling Tower		132	594.88	54	54	Max : 5777	6244	3750	625.11	12	12	Max : 3973	5694	4000
						Min : 4027	6000					Min : 3250	4028	



LOAD TEST OF PILE IN AMMONIA PLANT

MEASUREMENT OF DEFLECTION ON

A TEST PILE W



PILES UNDER NITRIC ACID PLANT
ABSORPTION AREA

FILE CAP UNDER CALCIUM AMMONIUM
NITRATE PRILL TOWER

Table 8

BILL OF MATERIALS FOR HEAVY FOUNDATION IN PAK-ARAB FERTILIZERS LTD MULTAN

PILES

PLANTS		AMMONIA PLANT		NITRIC ACID PLANT		—do—	—do—	—do—	—do—	CAN PRILLING TOWER	NP PRILLING TOWER
Area		101-E	102-E	103-E	103-D	110-H	L-Area	T-Area		22 M DIA	19 M DIA
Total Nos. of Piles		25	39	9	57	35	114	132		181	132
Concrete Ratio		1.25 : 1.5 :3	—	—	—	—	—	—		—	—
Quantity of Concrete		75.05	117.078	27.018	111.114	105.070	738.72			543.40	396.281
Cement in Bags		901	1405	324	2053	1261	5805			5003	3650
Sand Local M 3		9.55	14.93	3.46	21.82	13.40	144.61			106.04	77.60
Sand Lawrencepur M3		28.65	49.80	10.37	65.46	40.21	144.61			106.04	77.60
Crushed Stone		70.40	119.47	27.66	174.55	107.23	578.5			425.50	310.33
STEEL M. TON	1" DIA	11.945	18.634	4.30	27.235	16.723	118.9			87.00	—
	1/8" DIA	—	—	—	—	—	—			—	64.26
	3/8" DIA	1.422	2.219	0.512	3.243	1.992	—			10.90	7.95
	Total M. Ton	13.367	20.853	20.781	30.678	24.715	132.90			97.90	72.21
PILE CAPS INCLUDING PEDESTALS	Concrete Ratio	1.25 : 1.5 : 3	—	—	—	—	—	—		—	—
	Quantity of Concrete	36.22	90.624	19.454	223.775	150.440	404.46	466.78		1060.5	625.11
	Cement in Bags	610	830	180	2068	1386	3875	4447		15264	8997
	Sand Local M 3	9.63	13.06	8.86	36.14	22.98	41.18	47.51		290.48	171.22
	Sand Lawrence Pur M 3	18.84	25.73	5.49	63.52	42.68	123.52	142.65		124.49	73.38
	Crushed Stone M 3	57.03	78.41	17.00	197.49	152.73	829.42	380.18		829.95	489.22
STEEL M. TON	1½" DIA	1.203	1.852		8.707	10.050	36.909	42.939		36.733	18.534
	1" DIA	5.911	7.422	1.490	1.027	7.182	2.280	2.280		26.417	18.565
	¾" DIA	—	—	—	8.48	1.511	1.772	2.258		16.459	12.336
	5/8" DIA	—				0.565	0.447	0.480			
	½" DIA	0.251	0.292	0.101	0.552	0.609	3.491	9.456		2.498	1.194
	3/8" DIA			—		0.131	0.606	1.014		.178	0.051
	Total M. Ton	7.365	9.556	1.591	18.766	10.048	45.305	58.285		82.285	50.680

Table 6

NUMBER OF PILES TESTED IN EACH PLANT

S. No.	PLANT	AREA	Number of test piles tested	Number of service piles tested
1.	Ammonia	101-E) 102-E) 103-E) 103-D) 110-H)	2	Nil
2.	Nitric Acid	L-Area	1	(Pile No. 171)
		T-Area	1	(Pile No. 378)
1.	CAN Prilling Tower		1	1
2.	NP Prilling Tower		1	Nil

The most important feature of a pile load test is the relationship between load and the net settlement. The net settlement of the pile is the permanent settlement excluding the elastic deformation of the pile and the supporting soil-All piles being of the same length and under the same axial stress this elastic deformation may be considered approximately equal for all piles. Elastic deformation is not included in the permanent pile settlement. The net settlement in all the nine piles tested varied from 0.44 mm to 1.67 mm.

Testing of Steel

The steel was locally rolled and consisted of deformed bars of intermediate grade type. Each batch of steel was tested at the point of despatch and its test report was supplied to the site. In case of the piles of Ammonia and Nitric Acid Plant and CAN Prilling Tower, 1" dia steel was used whereas in case of NP Prilling Tower, size of the steel was 7/8" This was due to non-availability of 1" dia steel at the time of pouring of the piles under the prilling towers.

The test results of 1" and 7/8" dia steel used in the Prilling Towers are reproduced in Table No. 7.

Bill of Materials

As mentioned earlier, the typical pile which has been used throughout the Project was of 547 mm in diameter and 18300 mm in length. The steel in each pile consisted of 1" dia main reinforcement with helix of 3/8"

Table No. 7

S. No.	SIZE	Size of Test piece	Yield stress lbs./Sq. in.	Ultimate Tensile strength lbs./Sq.	Percentage Elongation.
1.	No. 8	8"	43,800	72,600	25.00
2.	No. 7	8"	46,000	72,400	23.40

diameter. The bill of materials for each pile consisted of the following :

(*i*) Concrete Ratio : $1\frac{1}{4} : 1\frac{1}{2} : 3$

(*ii*) Cement Bags 28 bags to 35 bags

(*iii*) Reinforcement 1" dia = 0.4833 metric ton

(*iv*) Reinforcement 3/8" dia = 0. 0568metric ton

(*v*) Sand = 42 cft.

(*vi*) Crushed stone = 83 cft. 83 cft.

The total quantity of concrete and steel which was consumed at various locations is given in table No 8 :

Cost of piling

The total cost of piling for the whole Project was Rs. 61,89,041.00 This excludes tne cost of piling done for the existing Nitric Acid Plant. The strength of the concrete was kept at 4500 psi Sq. inch while the strength of concrete in the piles used at the Prilling Towers sites was kept as 3750 lbs sq. Inch. This naturally is reflected in the cost. The cost of one pile varies from Rs. 8924 to Rs. 9934.

Acknowledgement

All the calculations are based on the structural design carried out by M/s. Progressive Consultants, Lahore. The basic loading data was supplied by M/s. Kellogg International Corporation, London and M/s. UHDE, West Germany. The author is indebted to Mr. Shahid H. Quresh, Assistant Engineer (Planning) for his assistance in the collection of relevant data.

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Role of Building Research in the Economic Development of a Nation

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Summary

One of the main causes of prosperity of developed nations is the extensive application of science and technology in almost the entire fabric of their economy. The developing countries have lately come to realize the importance of this vital ingredient of economic growth and consequently are endeavouring to mobilize their indigenous resources to boost up their developmental activities with the assistance of modern technology. But, by and large, the Research and Development activity in the construction sector, a very essential element for systematic growth of infra structure. is however still very much neglected, although investment in building research has been universally recognized as capable of paying dividends in its turn through appreciable reduction in the overall cost of construction in addition to boosting up technological capabilities of the man-power and developing new techniques/innovations alongwith improving the quality and pace of construction.

The paper, apart from discussing the need for establishing Building Research Organizations, their part in effecting/exercising quality control through sustained testing in major developing works and in creating a prospective Building Industry to meet the diversified needs of the ever growing technological age also briefly outlines the activities of the Building Research Station, Lahore ; its past

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achievements and future programme of work.

Introduction

Constant flow of scientific and technical knowledge, is an essential pre-requisite for the economic growth of any nation specially the so called under developed ones. Its mass scale use by developed countries is a continuous process which has remarkably resulted in their existing prosperity. Gigantic development programmes are launched every year in a determined effort to catch up with time. Research and Development effort is considered critical in solution of these problems and attaining the goals set in all the sectors including construction. The conspicuous absence or scarce utilization of this resource of universal recognition is, however, an obvious drag on the pace of economic development in all the under-developed countries,

The technology has, of necessity, to be based on peculiar resource endowment of a country and to be ultimately woven into the fabric of its social and cultural complex. Therefore, it becomes essential for each country to have its own source of technological innovation and improvement. The developing countries being fully alive and committed to castration of the vicious circle of under-development have come to realize its importance and are boldly accepting the formidable challange of themselves solving their various problems. But the fact remains that whereas a major portion of the budget is consumed and steadily increased every year in the construction sector, the important R and D activity is found to be more than neglected. Investment on this aspect has not kept pace with development being undertaken even when it is an established fact that it enhances the technical acumen of local talent to infuse the much needed confidence for self reliant economy.

Need for Research in Construction Field

The need today everywhere in the world, is to develop and minimise the use of indigenous materials and intellectual resources not only from cost factor viewpoint but also for reasons of appropriateness and comforts. This need can only be fulfilled if sufficient knowledge is available to all technologists and practitioners engaged in the building activity so that the limited financial resources are stretched to give optimum benefit to the most and to cut down wasteful tendencies, if any. The large vacuum between actual practice and knowledge can only be bridged and future problems/needs served through adequate research

and development facilities in the construction sector, the massive user of resources. A well organized and fully equipped Building Research Organization can play a vital role in this direction and meet the diversified needs of various specialists and builders, through the sustained efforts of engineers, scientists, planners, architects etc., undertaken with one common goal i.e. establishing the realistic place of construction Industry in the firmament of national economy, by carefully and specially studying each and every item and operation so that saving in one may not be drowned by overspending in others.

Building activity is repetitive in character and research findings consequently have a cumulative effect. A small saving even in one item of work may well pay off for the entire research expenditure in many instances. Investment in Building Research has therefore, always been recognized to be quite profitable and fully justified, Most of the countries in world have established national research Organizations directly or indirectly concerned with the science of building., which continue to expand to suit the changing pattern of demands. It is estimated that at least about 300 institutes in about 57 countries of the world exist in the field of building research. In the U. S. A. alone, in addition to Government Departments/Technical Universities and mono-discipline specialised research institutes, substantial work is also done by private societies/associations.

Building Research Versus Testing/ Quality Control

An essential factor in the development of new materials and commodities is properly organized experimentation. One of the necessary steps in the production of materials for engineering uses or in the manufacture of finished commodities for industrial purposes is control of the quality of a product. The industrial as well as technical sectors are becoming test oriented to maintain their standards. Architects, builders, engineers, industrial designers and managers all rely more and more on tests as basis for making many important decisions.

Testing of materials essentially involves knowledge of accepted methods of testing, training in methods of observation, appreciation of the significance of data derived from tests, knowledge of standards and specifications, acquintance with the technical periodical literature and other sources of recorded data on properties of materials, and practices in preparing giving the results of investigations/studies.

The extensive use of experi-

mental studies preliminary to the design and construction of new structural elements and the use of testing procedures for control of established processes of manufacture or construction are significant and well-recognized features of any technical development.

The principal function of construction materials is to develope strength, rigidity, and durability adequate to the service for which they are intended. This is ascertained by tests leading to information on the quality of a product and development of new or better information on known materials or even developing new materials. The Government which spends a great deal of its budget in one form or an other on construction activity has obviously to be interested in obtaining value for the money invested by ensuring the desired efficiency of the whole process from inception to satisfactory completion of the finished unit, fit for the intended purpose. This in addition to settlement of disputes regarding failures and substandard quality almost invariably calls for detailed investigations involving a series of tests before reaching the final conclusions. A building research Organization has thus to play its due role in carrying out of the testing to ensure the desired quality control of the materials to be used and the completed items of work for the assistance of concerned departments, field engineers and/or the construction agencies.

Building Research and Industry

Recent advances in science and technology resulting from the integrated efforts of various Research Organizations have made the manufacture of many new building materials possible through the use of agriculture and industrial waste materials. Introduction of these new products has however, been somewhat slow because of the non-existence of an assured long term demand and lack of understanding on the part of prospective users of their durability and ultimate maintenance costs under local conditions. The slow development of the building materials industry is on account of a lack of appreciation of its crucial role in the development process.

The organization of a new efficient building materials and products industry and improvement of the conventional materials are greatly bound to influence the tempo of productivity in the building industry. The impact of an efficient building material industry on the economy of a country is now universally recognized. Shortage of such materials in most of the developing countries has already produced an adverse effect on the construction activity. The deve-

lopment programmes, in many cases, have been delayed for want of adequate supply of materials suiting to local conditions. The establishment of new domestic building materials industries and the expansion of existing ones are thus most essential for reactivation of the development process. A prospective building industry would not only provide a momentum to the development programme currently being undertaken but would also supply a variety of new types of materials to be either cast-in-situ of prefabricated/prestressed according to the demand of the "Situ". The industrial prefabrication of buiiding units is to open new avenues by revolutionising the building industry as it would not only accentuate the tempo of construction but also add new dimensions to the concept of strength and durability. It would also be a step further towards solving the ever increasing housing shortage in the big cities and towns, and also to provide low cost rural houses.

For an industry to function, it is imperative that it should be able to produce successfully an artical for which there is a consumer capable of paying a price that makes the production profitable. In Pakistan, a few prospective builders have recently come forward and are taking adequate steps to produce the precast/prestressed building components on a commercial scale. The units being presently produced include prestressed concrete girders/battens of different sizes and dimensions, reinforced cement concrete slabs, planks, beams, boundary wall columns, electric poles, man-hole covers, plain cement concrete tiles, etc. Chip board, particle board and hard board etc, are also being produced from baggasse for use in joinery and dry wall construction, for prefabricated partition panels, flooring, wardrobes, cupboards and kitchen furniture etc., These boards in different forms, under certain limitations may also be used as beams for the roofs, roof covering, wall panels floors etc. The factory produced building units are attracting new customers and the day is in sight when, after their good performance being established, these would make a major break through in the construction activity of the country.

Activities/Work done by Building Research Station, Lahore

Building Research Station, Lahore carries out applied research in public interest and mostly deals with the problems faced by architect, engineer, builder and manufacturer with the principal object of reducing the cost of construction and exploiting the use of indigenous resources without adversely affecting the safety or stability of the structures. It also functions as a Central Testing Labo-

ratory for the purpose of quality control and endeavours to establish bilateral contact with similar organizations to obtain research literature on reciprocal basis to acquaint field engineers, architects and contractors with the technical innovations and advances made elsewhere in the world. The work done by the Station is disseminated through printed papers and other publicity media throughout the country to encourage use of the research results in actual practice.

A brief resume, of the work done so for by this Station alongwith its future programme may be of some interest in this context.

(1) Manufacture of Cement Concrete Blocks

Cement blocks of various proportions using crush screenings obtained from one of the sites near Rawalpindi, as mixed aggregate, were prepared and tested. The crushing strength of the blocks (1 : 10) was found more than the strength required even after applying a liberal safety factor and also was well within the requirements prescribed in the BSS. The crush dust which is a by-product of the crushed aggregate is available at the crusher sites at very cheap rates and may be usefully and economically utilized as a potential building material, specially in the northern areas of Pakistan, where the cost of bricks is quite exorbitant.

(2) Zed Tile Roof

The roof generally costs more than 20% of the total outlay of a building. Substantial economy can be found. To meet the demand of the low-income group, a Zed tile roof was introduced. In this case $2\frac{1}{2} \times 2\frac{1}{2}$ ft. curved concrete tiles 1 in. thick are laid on RCC battens placed at intervals of 2 Ft. 7 in. centre and haunches filled with base concrete. The production of the 60 lb. concrete Zed tile is very simple as it can be cast even by the unskilled labour with the help of a frame fitted with hessian cloth. These tiles can also be battery-cast so as to cut out the wooden frames. The titles which have adequate strength/durability have been laid at many places in actual construction enveloping a plinth area of about 69000 sft.

(3) New Bricks

A variety of sizes exists for the conventional burnt clay bricks in almost through the World. Consequently a study was initiated to see theoratical advantages in respect of productivity, consumption of mortars and number of bricks in a given area for all possible sizes of bricks. It was noticed that modular bricks are generally cheaper than non-modular bricks and that the best

possible size from the stand point of economy, practicability, productivity and manufacture was $7\frac{5}{8}" \times 3\ \frac{5}{8}" \times 3\frac{5}{8}"$ inches giving a nominal size of $8 \times 4 \times 4$ inches after allowing $\frac{3}{8}"$ in. thick mortar joints. For the confidence of the brick maker, two trials were run in the existing kilns and about one lac bricks were got manufactured successfully each time.

The new size has been accepted by the Pakistan Standard Institution as the future size and full specifications as well as testing procedure have been outlined with the assistance of the Building Research. The erst-while Government of West Pakistan (Communications and Works Department) had also accepted the new size for all future works but the commercial production has not started owing to conservative nature of brick industry. As recognized in the ECAFE Seminar, the Government Departments in the developing countries (who are the major consumers of bricks) will have to give a lead and prescribe the use of these bricks. Once the new bricks are available the old conventional size will slowly die out automatically. By using the modular bricks 25% saving in mortar and 10% saving in number of bricks is achieved and also there is higher rate of productivity.

(4) Brick Making Machine

A manual brick machine has been evolved at the Building Research Station to produce modular bricks. The machine requires only a semi-dry mixture for making bricks. The machine primarily is meant to produce solid units but it can also be used to produce hollow bricks with large holes. The initial trials have shown that a crew of 4 men can produce about 2000 bricks per day. These bricks being semi dry, require much less time to dry for which a covered shed is recommended so as to eliminate damage due to rains. The principal advantage of this machine is that it does not require skilled moulders.

(5) Polythene

Polythene which is locally manufactured has been introduced to the building industry by the Building Research Station. The Station itself used it as damp proof course in walls as well as in roofs. Generally 3 to 5 guage polythene is suitable for damp proofing. This material has gone into practice very rapidly and is at present being used extensively at many places.

(6) Wood Work

Wood work in a building consumes roughly 1/4th of the total cost of the building. The conventional frames of doors and windows are thick. Specifications were developed for postfabric technique in which the

size of the chowkhat is reduced. The technique suggested is to leave bolts in the masonry as well as in the lintel and to fix individual sides of frame at site with nuts after completion of plaster. The top of nut is concealed by nailing a wooden strip to form a rebate. This allow thinner section of frame and results in about 16% overall saving in the timber requirement.

(7) Design of Concrete Mixes

A nominal mix of 1 : 2 : 4 by volume is used for all concrete works in this country as specification do not specify concrete by strength. It has, however, been observed that the strength of 1 : 2 : 4 concrete varies considerably. The laboratory tests carried out from time to time in the last two years indicate a wide variation in the strength of the concrete ranging from 1300 p. s. i. to 5000 p. s. i. after 28 days. A study was therefore carried out to design concrete mixes in the Laboratory for various types and grading of aggregates using Ravi sand which is very fine, good strength of concrete can be obtained.

(8) Sun Shade Table and sun break Protractor

The Building Research Station has developed a Sun shade table to study the efficiency of louvers and also to investigate the shade pattern on a building in any orientation at any latitude of the place. The table is provided with solar paths for equator which can be tilted to any angle to form the latitude of the place. The table is capable of rotation on any one of the 3 axis so that the tip of shade of a standard pin fitted on the solar path touches the desired time and date on the equatorial sun path curves. The model of a building fixed to the table by means of a fiy nut in the orientation required to be studied, shows the efficiency. The light source used in this case is the sun which is a dependable source of light in the tropics.

A sunbreak protractor which can directly give the dimensions of the louvers in different orientations has also been developed. The protractors devised by other organizations only measure the horizontal and vertical shadow angles and further calculations have to be made for the design of louvers. This involved lot of time and hence a new protractor giving ready solution for the dimensions of overhang and louvers required to shadow has been developed.

(9) Gypsum

Gypsum is a building material of great antiquity and has a long and important history as a load bearing component of buildings. Although it is abundantly available, yet is not

being put to any practical use in the present day practice in the construction Industry of Pakistan. Tests have shown that most of the indigenous gypsum and their plasters are generally fit for building purposes as such while others could be rendered so.

Having found that plasters of Paris being manufactured by local manufacturers were generally quick setting and not conforming to standard specifications for use in the construction works, efforts were made to determine most suitable conditions of heating temperature and time by subjecting the powdered gypsum rocks to various temperatures for definite periods.

Gypsum fibrous units of various sizes for partition walls and false ceilings were manufactured and costs of these elements and gypsum masonry worked out and compared with corresponding bricks masonry. Attempts were also made to use sand with plaster of Paris to reduce cost of these units.

Low unit weight materials from plasters of Paris have also been experimented and a material of as low a density as 30 lbs. per cft, has successfully been produced. Work on finding out suitable composition of the plaster, water and foaming agent for a particular density, testing of foamed products for their engineering properties and finding out the cost per sq. ft. of the finished products is in progress alongwith the study of flexural behaviour of normal, foamed and/or reinforced gympsum units.

(10) Expanded Clay Aggregates

Natural stone aggregate is not available within easy reach in several important cities i.e. Lahore, Sahiwal, Multan, Bahawalpur and Rahimyarkhan etc. It has to be transported from distant quarries with heavy expenses which increases the cost of the concrete considerably. The Building Research Station has been keen to explore avenues of replacing these aggregates with artificial ones to cut down the cost and increase thermal resistance as well. The expanded clay aggregates which have established themselves as reliable concrete aggregates in the advanced countries promised some future. But the question to be determined was whether the Pakiston Clays which are predominantly silty will easily bloat. The laboratory tests carried out indicated that most of the clays could expand or bloat as such or by the addition of a specific quantity of organic matter with the clay before firing.

When it became obvious that a number of clays did possess bloating properties, it was necessary to fire bigger samples so as to have sufficient material for testing and also to gain

experience of firing on a larger scale before commercial production. The test results of concrete made with this produced aggregate have shown that the crushing strength of light weight concrete (1 : 2 : 4 mix by volume) is more or less equivalent to the usual dense concrete. The expanded clay aggregate promises a great future for the building industry. Its production is a feasible and profitable proposition both for the manufacturers and the users.

(11) Earth as Building Material

Earth or mud, have been employed for ages past in various forms in rural construction. There is no dearth in Pakistan of the right kind of earth, which as a building material will undoubtedly be cheaper than burnt bricks, stone, concrete, etc. The Building Research Station Lahore has endeavoured to apply and mobilize the existing knowledge about the use of earth as a building material to find out how, through the application of the scientific/engineering principles, some already known and some yet to be discovered, the present day acute shortage of village houses may be solved.

A single room demonstration rural dwelling unit using earth as the main building material in the form of of moulded sun dried brick for masonry walls and a continuously curved thin shell shaped vault roof to be cast in-situ, was built at the Research premises. As a safeguard against the damaging effects of standing rain water nearby and heavy down-pour, the structure was provided with burnt brick masonry in cement mortar upto plinth level. In addition, pillars of the same specifications were introduced at the four corners of the building as well as at the middle of the walls and door Jambs as pre-cautionery measures ; the intervening gaps were of course. To lend it further structural stability and to award off the possibility of any mishap, iightly reinforced brick masonry tie course 9 in. deep using veriical bricks was provided at the top portion of the walls which also functioned as supporting lintel for the door.

The vault was laid in one layer of 4½ in. thick sun dried brick masonry with the help of an improvised segmental form work of local timber and old iron sheets. The lower layer of roof was laid in two stages by shifting and utilizing the same shuttering/centring after the first half had been completed. The vault was made monolithic by suitable interlocking of bricks at the junction points. Water proofing of the roof was achieved by introducing a layer of polythene sheet as vapour barrier beneath the top mud plaster prepared wheat straw. After the plaster had dried out, hot asphalt

mixed with kerosene oil was sprayed on the exposed surface in two layers to provide it further protection against rain. White washing two coats was done to the entire outer surface of the building to improve its general appearance. It has faced two rainy seasons and seems to have withstood the vagaries of the weather quite well, as no signs of leakage or even seepage etc. have been noticed so far. It is anticipated that the structure will have a reasonable span of life with due maintenance and care.

FUTURE PROGRAMME

(1) Mortars

Lime has been discarded for mortars in Pakistan although advanced countries who produce much more cement, prescribe its use in conjunction with Cement.Sand mortars as a necessary additive for all masonry work. The advantages of cement-lime-sand mortars briefly include reduced shrinkage, less curing and easy workability. Lime which is seldom used in putty form in the advanced countries is rather made as a dry hydrate in a powder form and used just like cement. The non-availability of dry hydrate in the local market is perhaps one of the reasons why it has gradually lost its popularity. There is a need for developing this industry in Pakistan not because it saves cement but also imparts desirable qualities to the mortars. The usual 1 : 6 Cement-Sand mortar can be replaced by 1 : 3 : 12 cement-lime-sand mortar for brick work and plaster to give saving of about $7\frac{1}{2}$ percent in cost and 50% in the requirement of cement for mortars. The durability and strength of various mortars (Cement-lime-sand ; cement and/or lime surkhi) is being investigated at a uniform or a near uniform workability so as to prescribe various mortars for various types of works.

(2) Fibrous Concrete

Fibre reinforced concrete made of portland cement containing fine or fine and coarse aggregates and some slender fibres dispersed uniformly throughout, appears to have an assured future in building industry particularly in thin sheet or shell type used in many cases where the placing of steel bars is either very inconvenient or impossible. It has been imported to provide outstanding performance for thin pavement sections and offer a high first crack strength, ability to carry loads after cracking, ability to resist cracks and ductility.

Keeping in view the ever increasing use of this material in the advanced countries, a research programme for producing and testing different type of fibrous concrete products has been initiated.

(3) Pozzolanic Materials

Pozzolana is a siliceous or siliceous and aluminious material which in itself possesses little or no cementitious property but will, in finally divided form and in the presence of moisture, chemically react with lime to form compounds possessing cementitious properties and can be used to partially substitute cement for the purpose of economy. Red clay sample collected from Choa Saidan Shah in District Jhelum, aluminious/chida clays and fly ash etc. are being evaluated in this context.

(4) Concrete Curing Compounds

When water is added to cement, certain complex chemical reactions take place which result in the setting and hardening of cement. Mixing water is usually more than sufficient to fill the inter-grain space and for the initial hydration of cement. This water is however lost by evaporation by the action of sun, wind and the heat generated during its setting process and if it is not recouped periodically the concrete strength would be adversely affected. Early drying out of the water not only would weaken it but also cause unduly large volume changes in concrete and as such it is to be kept/moist/cured until it attains the required strength. The moist curing is by far regarded as the easiest and most convenient method and is extensively used. Many cases may. however arise when it is impracticable to specify water curing, because of lack of adequate supplies of water, possible serious interference with other works caused by curing water run off, or lack of facilities to provide economically continuous application of water during the specified curing period. In such cases, accelerated artificial curing by means of membrane forming compounds may become inevitable. Efforts are, therefore, being made to experiment and develope locally available compound formations which could be used for the purpose.

(5) Development of Rice husk ash Cement.

The bulk of rice husk in Pakistan is either used as fuel for the rice mill boiler or simply disposed off by burning in large heaps. The burnt rice husk ash residue has been reported to be predominantly a very reactive form of silica. This ash which is a total waste material and rather presents problems in disposal, can be gainfully utilized as a raw materials for producing rice husk ash-lime cement. Such a cement prepared by fine grinding a dry mixture of rice husk ash and hydrated lime, with an additive has been reported to be a hydraulic setting cement which can substitute Portland cement in many ordinary applications

particularly in masonry and plastering works. A study of the technical feasibility of producing this type of cement has been taken up.

(6) Foam Concrete

Foam concrete promises a great future as a structural/acoustical material. It, however, is not popular because of complicated steam curing process which may not be easily recorded to as per existing field working conditions. Efforts are afoot to produce these units from local materials under normal curing for non-load bearing, sound and heat absorption purposes, where strength considerations are not so important. A number of blocks/cylinders of various sizes in a density range of about 30-60 lb. per cft. have been produced and are being subjected to strength and shrinkage tests etc.

(7) The Treatment of Rising Damp

Dampness in walls of old/historical buildings is causing a good deal of trouble and efforts are afoot to arrive at an effective technique to combat this menace where no dpc was initially provided. Isolated damp sites at the Lahore High Court Building have been selected where electro-osmotic damp proof and chemical injection techniques have been installed. The drying out tendency of the sections of the walls are being observed to be able to put forth some recommendations/specifications for overcoming the problem.

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paragon lahore

CODE OF ETHICS

PAKISTAN ENGINEERING CONGRESS

بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِيْمِ

In the name of God, the Beneficent, the Merciful.

WHEREAS Allah enjoineth upon his men to faithfully observe their trusts and their covenants;

that the practice and profession of engineering is a sacred trust entrusted to those whom Nature in its magnificent bounty has endowed with this skill and knowledge;

that every member of the profession shall appreciate and shall have knowledge as to what constitutes this trust and covenant, and

that a set of dynamic principles derived from the Holy Quran shall guide his conduct in applying his knowledge for the benefit of society.

Now, therefore, the following Code of Ethics is promulgated. It shall be incumbent upon the members of the Pakistan Engineering Congress to subscribe to it individually and collectively to uphold the honour and dignity of the engineering profession:

١- إِنَّ اللّٰهَ يَأْمُرُكُمْ أَنْ تُؤَدُّوا الْأَمٰنٰتِ إِلٰى أَهْلِهَا وَإِذَا حَكَمْتُمْ بَيْنَ النَّاسِ أَنْ تَحْكُمُوا بِالْعَدْلِ إِنَّ اللّٰهَ نِعِمَّا يَعِظُكُمْ بِهٖ

"Allah commands you to render back your trusts to those to whom they are due, and that when you judge between people, you judge with justice. Allah admonishes you with what is excellent". iv : 58

1. You shall be honest, faithful and just, and shall not act in any manner derogatory to the honour, integrity or dignity of the engineering profession.

٢- أَوْفُوا الْكَيْلَ وَالْمِيْزَانَ بِالْقِسْطِ وَلَا تَبْخَسُوا النَّاسَ أَشْيَاءَهُمْ وَلَا تَعْثَوْا فِي الْأَرْضِ مُفْسِدِيْنَ

"Give full measure and weight justly and defraud not men of their things, and act not corruptly in the land making mischief". xi : 85

2. You shall use your knowledge and skill of engineering for human welfare, and render professional service and advice which reflects your best professional judgment.

٣- وَلَا يَجْرِمَنَّكُمْ شَنَاٰنُ قَوْمٍ عَلٰى أَلَّا تَعْدِلُوْا اِعْدِلُوْا هُوَ أَقْرَبُ لِلتَّقْوٰى

"And let not hatred of a people incite you not to act equitably. Be just; that is nearer to observance of duty". v : 8

3. You shall not injure maliciously, directly or indirectly, the reputation or employment of another Engineer, nor shall you fail to act equitably while performing professional duty.

٤- أَوْفُوْا بِالْعُقُوْدِ

"Fulfil the obligations". v : 1

4. You shall faithfully observe and fulfil all your obligations.

٥- وَلَا تَأْكُلُوْا أَمْوَالَكُمْ بَيْنَكُمْ بِالْبَاطِلِ وَتُدْلُوْا بِهَا إِلَى الْحُكَّامِ لِتَأْكُلُوْا فَرِيْقًا مِّنْ أَمْوَالِ النَّاسِ بِالْإِثْمِ وَأَنْتُمْ تَعْلَمُوْنَ

"And swallow not up your property among yourselves by false means, nor seek to gain access thereby to the judges, so that you may swallow up a part of the property of men wrongfully while you know". ii : 188

5. You shall not abuse your position or power, nor accept illegal gratification of any sort.

٦- وَقُوْلُوْا قَوْلًا سَدِيْدًا

"And speak straight words." xxxiii : 70

6. You shall express your opinion on engineering or other matters in a frank, open and straightforward manner.

٧- اِجْتَنِبُوْا كَثِيْرًا مِّنَ الظَّنِّ إِنَّ بَعْضَ الظَّنِّ إِثْمٌ وَّلَا تَجَسَّسُوْا وَلَا يَغْتَبْ بَّعْضُكُمْ بَعْضًا

"Avoid most of suspicion for surely suspicion in some cases is sin; and spy not nor let some of you backbite others". xlix : 12

7. You shall not criticise another engineer's work without his knowledge, nor malign, or injure his professional reputation.

٨- وَلَا تَقْفُ مَا لَيْسَ لَكَ بِهٖ عِلْمٌ إِنَّ السَّمْعَ وَالْبَصَرَ وَالْفُؤَادَ كُلُّ أُولٰئِكَ كَانَ عَنْهُ مَسْئُوْلًا

"And follow not that of which thou hast no knowledge. Surely the hearing and the sight and the heart, of all these it will be asked." xvii : 36

8. Your professional advice shall be based on full knowledge of the facts and honest conviction, and you shall not write articles or advertise in self-laudatory language or in any manner derogatory to the dignity of the profession.

٩- وَتَعَاوَنُوْا عَلَى الْبِرِّ وَالتَّقْوٰى وَلَا تَعَاوَنُوْا عَلَى الْإِثْمِ وَالْعُدْوَانِ وَاتَّقُوا اللّٰهَ

"And help one another in righteousness and piety, and help not one another in sin and aggression and keep your duty to God." v : 2

9. You shall help one another in upholding and doing what is right, and shall not associate with those who transgress and those who indulge in unethical practices.

١٠- وَأَمْرُهُمْ شُوْرٰى بَيْنَهُمْ

"And whose affairs are decided by counsel among themselves." xlii : 38

10. You shall decide matters of common professional interest by mutual consultation.

١١- وَاعْتَصِمُوْا بِحَبْلِ اللّٰهِ جَمِيْعًا وَّلَا تَفَرَّقُوْا

"And hold fast by the covenant of God all together and be not disunited." iii : 102

11. You shall strive individually and collectively to enhance the prestige of the engineering profession by ordering your conduct in accordance with this Code of Ethics, and shall not be disunited.

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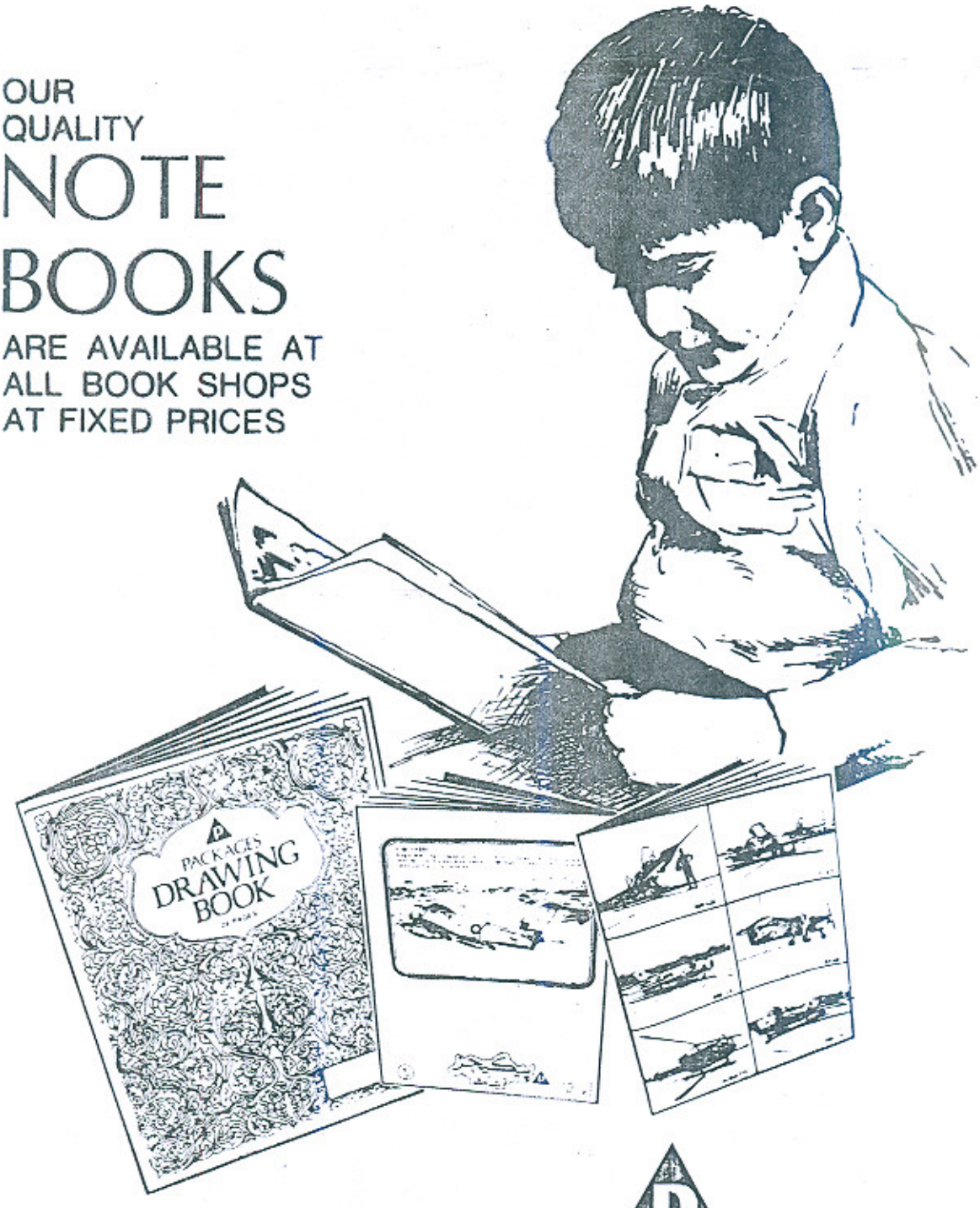

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