PAPER No. 270

CONSTRUCTION OF AERODROMES IN THE PUNJAB

BY

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GENERAL

Ten years ago an aerodrome was little more than a levelled ground some 800 yards square equipped with a few buildings. The planes were light and slow. With the advance of science, producing heavier and better equipped long range aircraft, necessitated by modern warfare, it has become essential to construct suitable Landing Grounds with up-to-date methods of construction. The demands of war have, however, caused construction and development to proceed in advance of the compilation of information available on the subject. This paper has been written with the object of compiling such information and inviting criticism on the particular modes of construction adopted, though the specifications followed were mainly dependent on suitability of materials that were actually available and speed of construction demanded due to war conditions.

It is felt that at this time there is not enough literature available on the subject of Landing Grounds and should this paper form the foundation on which an Engineer can develop his initiative and build his experience, the object with which it has been written will be fully served.

The paper has, however, been written during the war time and the writer is fully conscious of his responsibility in not disclosing any information which may be of value to the enemy and to which the Army Department may object. This has naturally led to a great deal of the information being withheld which would have made the paper more complete and increased its usefulness.

Requirements of Landing Grounds. With the increase in weight, speed and ability to fly in all weather, the requirements of a modern Landing Ground have imposed a bigger strain on the Engineer's resources.

The requirements of a modern Landing Ground may be summarised as given below :—

(*a*) Runways including dispersal strips and French Drains.

(*b*) Taxi Tracks and Roads.

(*c*) Accommodation—Domestic and Technical.

(*d*) Water Supply.

(*e*) Electricity.

(*f*) Bulk Petrol Storage Installation.

These will be discussed in the following pages with special reference to requirements of different categories of Stations—Operational, Layback and Satellite.

Types of Landing Grounds. Different categories of Landing Grounds are :—

Advanced Operational	Heavy Bomber, Medium Bomber.
Layback Emergency Satellites	Fighter and Light Bomber.

Siting and Layout. Main consideration in selection of a site, apart from strategic requirements, are :—

(*a*) *Proximity to Railway and Pacca Road.* This is necessary both from strategic considerations and for convenience in construction where large quantities of materials and plant have to be handled.

(*b*) *Suitable Water Supply Arrangements.* The site should, if possible, be commanded by an Irrigation Channel. This solves the problem of water supply for construction purposes which is required in large quantities, being of the order of two cusecs per site. It is, further, easier at commanded sites to make arrangements for permanent water supply, as it only means filtration and storage to last during the maximum period of canal closures.

At sites which are not irrigated there should be some other convenient source of water supply like tube-wells, though tube-wells are both expensive and difficult to sink due to non-availability of materials during war time.

(*c*) *The soils should be free from harmful salts.* The salts disintegrate the soil and along with it the sealing coat, thus impairing the efficiency of the landing ground. High Ph value renders the soil skiddy during rainy season making landing difficult, if not actually dangerous. These remarks apply with greater force to Fair Weather Strips and Satellites.

In the case of Landing Grounds constructed by the Irrigation Branch, an Irrigation Officer was generally co-opted on the Selection Syndicate who could give advice on the spot to the best of his ability regarding the suitability of the site. For most part of the year salts are visible on the surface and where afflorescence was prominent an attempt was made to find an alternative site.

After a site had been finally selected soil analysis was done in detail and in portions under the runways where percentage of salts was above ·4 per cent or Ph value greater than 9·0 special treatment of soil had to be resorted to. This consisted of ploughing the soil 4″ deep and then compacting it with one per cent of sodium chloride solution added at optimum moisture contents. In some cases red clay had also to be added to the soil where it was deficient. The clay cum silt percentage analysis was also carried out. Where the clay cum silt contents were less than 25 per cent additional red earth was added for purposes of efficient compaction.

(*d*) *Depth of sub-soil water table.* Areas with high sub-soil water table are obviously unsuited for construction of landing grounds. In some cases, due to strategic considerations, aerodromes had to be constructed in areas of high sub-soil water level but these called for special treatment which will be discussed later.

(*e*) *Soil should be suitable for brick burning operations.* It may appear only a minor consideration but when we come to realise the enormous number of bricks required at each airfield, being of the order of 2 crores, it will be seen that it is necessary to burn bricks as close to the site of work as possible to save long lead which involves both extra time and expense in carriage, apart from the difficulty of arranging the necessary transport. There is the further advantage as the earth which will be good for brick burning will also compact well.

(*f*) *Strategic considerations.* Irrigation Engineers had nothing to do with this aspect of the problem and it was decided by the military authorities that airfields had to be selected in the particular area.

(*g*) *Hygiene.* This was also not the Engineers' concern as the Medical Officer on the Siting Board would attend to it.

Layout.

Runways. After a site has been selected and approved by military authorities the runways are actually laid out at site. Wind conditions in India usually necessitate two arms. Generally two runways are made to cross each other as it means saving in land and length of perimeter tracks. They may intersect at right angles or at an acute or obtuse angle. This, however, has the disadvantage that in case of the crossing point receiving a direct hit from the enemy, both the runways are thrown out of action. The runways are, therefore, often laid to form the shape of an L or T and in some cases don't intersect at all, being two independent runways with a taxi track joining the two at one end.

The orientation of the runways is based on considerations of prevailing wind in different times of the year and topography may govern arm locations giving rise to different shapes. Due to security reasons it is not possible to give dimensions and ruling gradients of Runways, Disperal Strips, Taxi Tracks, roads and Flying gaps, etc.

Design of Runways. Under war conditions permanence has sometimes to be sacrificed to speed and this is attained by special applications *e. g.*—

(*a*) Steel mats.

(*b*) Thin concrete runways reinforced with coir matting

(*c*) Bomboo rafts

(*d*) Gravel rolled into medium clay

(*e*) Two inch 'sand mix' bitumenised carpet.

Sort of quasi-permanent strips can also be quickly laid by 'cement stabilisation' method discussed below.

In outline the treatment consists of—

(*i*) The strips are roughly levelled to corform with permissible gradient.

(*ii*) Scarify the soil 6″ at the outside edges reduced towards the centre to allow as much as possible for the camber.

(*iii*) Prepare the sub-grade correctly to camber and grade.

iv) Compact the sub-grade adding water at optimum moisture content.

(*v*) Carry out the dry mix adding 10 per cent cement to the natural soil where it contains about 20—25 per cent clay. For very light loam the percentage of cement required would be as high as 15 per cent.

(*vi*) Add required quantity of water and carry out wet mixing.

(*vii*) Lay the wet soil cement over the sub-grade to a depth of about 8″.

(*viii*) Consolidate it down to 6″ compacted depth.

(*ix*) Finish with tamping boards followed by rolling with a light roller.

(*x*) Cure for 14 days.

Actual tests on strips constructed to above specifications have shown no appreciable subsidence when subjected to a load of 8 tons per square foot.

Permanent Construction. For permanent construction the runways have to be in cement concrete or asphalt bound macadam. As the former mode of construction was adopted on the airfields constructed by the Irrigation Department, the same will be discussed in this paper.

Loading. For purposes of design it is assumed that 7 tons per square foot is applied uniformly from an elliptical wheel impress 20″ × 45″ area 4·91 sq. ft. giving a total single wheel load of 34·41 tons. This gives a ratio of major to minor axis of wheel impress ellipse of 2·25 to 1.

Design of concrete runways. The stress distribution in a concrete slab resting on elastic foundation is a highly complex subject. The physical properties of the soil, which vary appreciably at different locations, the varying live load and changes in temperature, all combine to make the stress analysis a difficult problem. Failure occurs by tension depending on the position of the load and tension increases with sinking of the sub-grade. The bearing strength of foundation soil, therefore, plays an important part in the slab design.

Several theories have been advanced in the last few years for computing the stress in concrete slabs. The one which is based on a logical and scientific basis is however by Westergaard and this is considered to be the most reliable and up-to-date theory on the subject. This theory is described in " Modern Concrete Construction, Vol. II by Glanville " and is further discussed in detail by E. F. Kelley in his paper reproduced in " Public Roads " issues of July and August, 1939.

Some of the important assumptions made in this theory are :—

1. That the concrete slab acts as a homogeneous, isotropic elastic solid in equilibrium.

2. That the reactions of the sub-grade are vertical only and that they are proportional to the deflections of the slab.

3. That the reaction of the sub-grade per unit area at any given point is equal to a constant 'k' multiplied by the deflection at that point. The constant 'k' is termed the 'modulus of sub-grade reaction' or 'sub-grade modulus' and is assumed to be a constant at each point independent of the deflection and to be the same at all points within the area under consideration.

4. That the thickness of the slab is uniform.

5. That the load at the interior and at the corner of the slab are distributed uniformly over a *circular area of contact*. For the corner loading the circumference of the circular area is tangent to the edges of the slab.

6. That the load at the edge of the slab is distributed uniformly over a semi-circular area of contact, the centre of the circle being on the edge of the slab.

The following three conditions of loading are considered :—

1. Load applied close to the rectangular corner of a large slab.
2. Load applied to the interior of a large slab at a considerable distance from the edge.
3. Load applied at the edge of a slab at a considerable distance from any corner.

For the three positions of load the analysis results in the following equations :—

For corner loading

$$\sigma_c = \frac{3P}{h^2}\left[1-\left(\frac{a\sqrt{2}}{l}\right)^{0\cdot6}\right] \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

For interior loading

$$\sigma_i = 0\cdot275\ (1+\mu)\ \frac{P}{h^2}\left[\log_{10}\left(\frac{Eh^3}{kb^4}\right)-54\cdot54\left(\frac{l}{L}\right)^2 Z\right] \quad (2)$$

Equation (2) is simplified in the Arlington tests to

$$\sigma_i = 0\cdot31625\ \frac{P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right)+0\cdot1788\right] \quad \ldots \quad \ldots \quad (2a)$$

Assuming $L=1\cdot75\ l$
$Z=0\cdot05$
$\mu=0\cdot15$

For edge loading

$$\sigma_e = 0{\cdot}529\ (1+0{\cdot}54\mu)\ \frac{P}{h^2}\left[\log_{10}\left(\frac{Eh^3}{kb^4}\right)-0{\cdot}71\right] \qquad \ldots \quad (3)$$

In the above equation

l the radius of relative stiffness $= \sqrt[4]{\dfrac{Eh^3}{12\ (1-\mu^2)\ k}}$ ... (4)

P = load in lbs.

σc = Maximum tensile stress in lbs per square inch at the top of the slab in a direction parallel to the bisector of the corner angle due to a load P at the corner.

σi = Maximum tensile stress in lbs per square inch at the bottom of the slab directly under the load P, when P is at a point in the interior of the slab at a considerable distance from the edges.

σe = Maximum tensile stress in lbs per square inch at the bottom of the slab directly under the load P at the edge and in a direction parallel to the edges.

h = Thickness of the concrete slab in inches.

μ = Poissons ratio. If an isotropic elastic material is subjected to stress in one direction a unit deformation is produced in the direction of the force and in addition a smaller deformation is produced in the direction perpendicular to the force. The relation between these two deformations expressed as the ratio of the smaller to the larger is known as Poissons ratio. Its value is generally accepted as 0·15.

E = Modulus of elasticity of the concrete in lbs per square inch.

k = Sub-grade modulus in lbs per cubic inch.

a = Radius of area of load contact in inches. The area is circular in the case of corner and interior loads and semi-circular for edge loads.

b = Radius of equivalent distribution of pressure

$= \sqrt{1{\cdot}6a^2+h^2} - 0{\cdot}675\ h$ when $a < 1{\cdot}724\ h$.

or $= a$ when $a > 1{\cdot}72\ h$.

L = Maximum value of the radius of the circular area with centre at the point of load application within which a redistribution of sub-grade reactions is made.

Z = Ratio of reduction of the maximum deflection.

Average value of modulus of Elasticity of concrete E may be taken as 3×10^6 lbs per sq. inch though it can be taken as high as 5×10^6 lbs per sq. inch.

Sub-grade modulus 'k.' This will depend on the degree to which sub-grade has been consolidated. In case of properly compacted sub-grade as on the airfields constructed by this Department value of k may be safely taken as 400 lbs per cubic inch.

Flexural strength of pavement concrete at 28 days may be taken as 600 to 700 lbs per square inch.

To test the specifications adopted by the I. B. At the time construction of runways in the Punjab was started complete information regarding nature of loading was not available. It was, however, decided to lay 4″ thick slab in cement concrete when stone ballast was used and $4\frac{1}{2}''$ thick slab in case of brick ballast. It must be admitted that speed in construction demanded on account of the then war conditions decided in favour of thickness as small as possible even with no factor of safety. The slabs were laid on sub-grade that had been properly compacted and this accounted for no soling coat being given under concrete.

With a load of 7 tons per square foot on an elliptical wheel impress $20'' \times 45''$ value of P total load comes to :—

$$P = \frac{\pi}{4} \times \left(\frac{20}{12}\right)^2 \times 7 \times 2240 = 34000 \text{ lbs}$$

$$a = 10''$$

$$b = 10''$$

$$h = 4''$$

From equation (4) $l = 14{\cdot}2''$

From equation (1)

$$\sigma_c = \frac{3 \times 34000}{16}\left[1 - \left(\frac{10 \times 1{\cdot}414}{14{\cdot}2}\right)^{0{\cdot}6}\right] = 120 \text{ lbs per square inch which is safe.}$$

From equation 2 (a).

$$\sigma_i = 0{\cdot}31625 \times \frac{34000}{10}\left[4 \log_{10} \frac{14{\cdot}2}{10} + 0{\cdot}1788\right]$$

$$= 456 \text{ lbs per square inch, which is safe.}$$

For edge loading it is assumed that the area of contact (of the semi-circle) will be the same as for interior and corner loadings. If 'r' is the radius of the circle for interior and corner loadings then the radius of the semi-circle of equivalent area will be $r\sqrt{2}$

From equation (3) with $a = \sqrt{2} \times 10 = 14{\cdot}14''$

$$\sigma_c = 0{\cdot}529\,(1 + 0{\cdot}54 \times 0{\cdot}15) \times \frac{34000}{16}\left[\log_{10}\left(\frac{3 \times 10^6 \times 4^3}{400\,(14{\cdot}14)^4}\right)^{-0{\cdot}71}\right]$$

$$= 0{\cdot}529 \times 1{\cdot}081 \times \frac{34000}{16} \times 0{\cdot}369$$

$$= 448 \text{ lbs per square inch, which is safe.}$$

1. There are no signs of decrease of discharge although the working period has been as much as 8 months.
2. Increase in discharge in case of tube-well No. 1 is due to the installation of a bigger pumping set.
3. Low discharges in case of tube-wells No. 2, 3 and 4 are due to the smaller pumping sets and piping installed. If bigger pumps and piping were installed the strainers would yield more.

These results were recorded by Mr. C. L. Handa, I.S.E., Executive Engineer, who actually manufactured these wooden strainers and used them with success.

Before using the strainers they were tested for possible shrinkage by means of feeler gauges and no shrinkage at all was noticed over one month's submergence under water. In fact it has now been established that no shrinkage occurs along the grain.

At one site a wooden strainer was extracted after functioning for five months. The only deterioration observed was that the section of the strainer had become somewhat elliptical, but probably it happened due to the strain in extraction.

Analysis of cost of a wooden strainer five feet long is given below :—

	Rs.	a.	p.
3 cft wood from canal plantation @ 1 cft ...	= 3	0	0
Cutting and cartage @ -/3/- cft	= 0	9	0
Sawing into 4 pieces @ -/4/- each	= 1	0	0
Labour for woodwork including fitting 5 carpenters @ 2/8/- each	=12	8	0
Clamp wires	= 1	0	0
Screws	= 0	8	0
Flat Iron	= 1	0	0
Part charges of three iron clamps required for assembling pieces	= 0	3	0
Total ...	=19	12	0
Say ...	20	0	0

or Rs.4 per foot length.

For temporary work probably extending into a few years, there is no reason why wooden strainers should not be used especially during the war when large diameter metal pipes are practically unobtainable. Encouraged with the success on their working on Aerodrome construction, use of wooden strainers is being considered on a fairly large scale in connection with "Grow more food campaign." This should provide tube-well irrigation at cheap rates even during the war bringing large areas under cultivation lying barren at present.

Preparation of sub-grade. With the mode of construction adopted for paving the runways *i. e.*, plain cement concrete slabs 4″ or 4½″ thick without any soling coat, it has been shown that sub-grade plays an important part. Plain slab, without any reinforcement, has to depend on the sub-grade for its safety as failure occurs by tension, which increases with sinking of the sub-grade. As no soling coat was given, it was very necessary that the sub-grade should be compacted to maximum possible density according to latest scientific methods.

The sub-grade was ploughed 4″ deep and all roots of vegetable growth carefully removed. The formation was made to slightly higher than designed levels (to avoid any filling being necessary after compaction had been done) and the area was flooded. This was done most economically by constructing a high water level watercourse outside the 50 yards strip which also came in very useful for flooding the concrete slabs for curing purposes. As soon as the moisture content of the soil was optimum, as determined by the method outlined in Paper 257 "Densification of Canal Banks by S. I. Mahbub," it was rolled over by toothed rollers and finally finished with plain power rollers.

The sub-grade was kept ready in advance of concrete in a length of two to three chains and just before laying the concrete slabs final dressing of the surface was done to designed levels If, while doing this, the sub-grade was lowered below the designed levels in some patches it *was not* made up to designed levels by filling loose earth and additional quantity of concrete was poured to make up such inequalities. Before laying concrete, depth of the sub-grade was carefully tested by means of suitable templates to see that thickness of concrete would nowhere be less than 4″ or 4½″ as required.

Preparation of sub-grade under high sub-soil water level conditions. At one of the sites sub-soil water level was very high being within two feet of natural surface. While rolling the sub-grade with 12 ton steam roller it was noticed that the bearing capacity of the soil was not high enough and the sub-grade would be lifted in ripples as the roller passed over it creating boggy conditions. Measures like rolling ballast into the sub-grade and increasing the thickness of concrete slabs were considered to overcome the difficulty. Finally it was decided to roll the sub-grade by a repeated number of rollings with a light roller. This gave the desired results and the steam roller was altogether discarded at this site. Rollings with the light roller, weight 1·3 tons, gave dry bulk densities of the order of 1·75 which could compare favourably with any other site and slabs of ordinary thickness of 4″ were laid on the sub-grade thus compacted.

Experimental concrete slabs 4″ thick laid under the conditions described above were later subjected to actual tests. It was found that with sub-soil water level only 6″ below the bottom of the slab, it could take a load of 17 tons per square foot, applied on a 6″ square base, near the corner before it cracked. The same slab with a load of 24 tons per square foot on a 6″ square base applied at the centre neither showed any settlement nor any cracks.

Sub-grade tests. In order to check up on results actually obtained by compaction, dry bulk density of natural and compacted soil was obtained every 500 feet apart or closer. For this purpose field laboratories were set up at each site where, apart from determining dry bulk densities and penetration tests, complete mechanical analysis of soil was also carried out. Penetration tests were carried out by means of a Penetrometer, details shown in Plate IV.

In addition to penetration tests actual settlement was also observed on compacted sub-grade by means of a simple device as per details given in Plate IV. The settlement was observed on a standard bearing area of 6″×6″ with the help of a micrometer dial gauge reading up to 1/1000 inch. Typical results as actually obtained at one of the sites both for penetration and bearing tests are shown in graphs given on opposite page.

The results speak for themselves and do not need any comments.

It will be interesting to give here results of bearing tests on concreted runways as well. Tests on two of the slabs are shown in the graphs on opposite page.

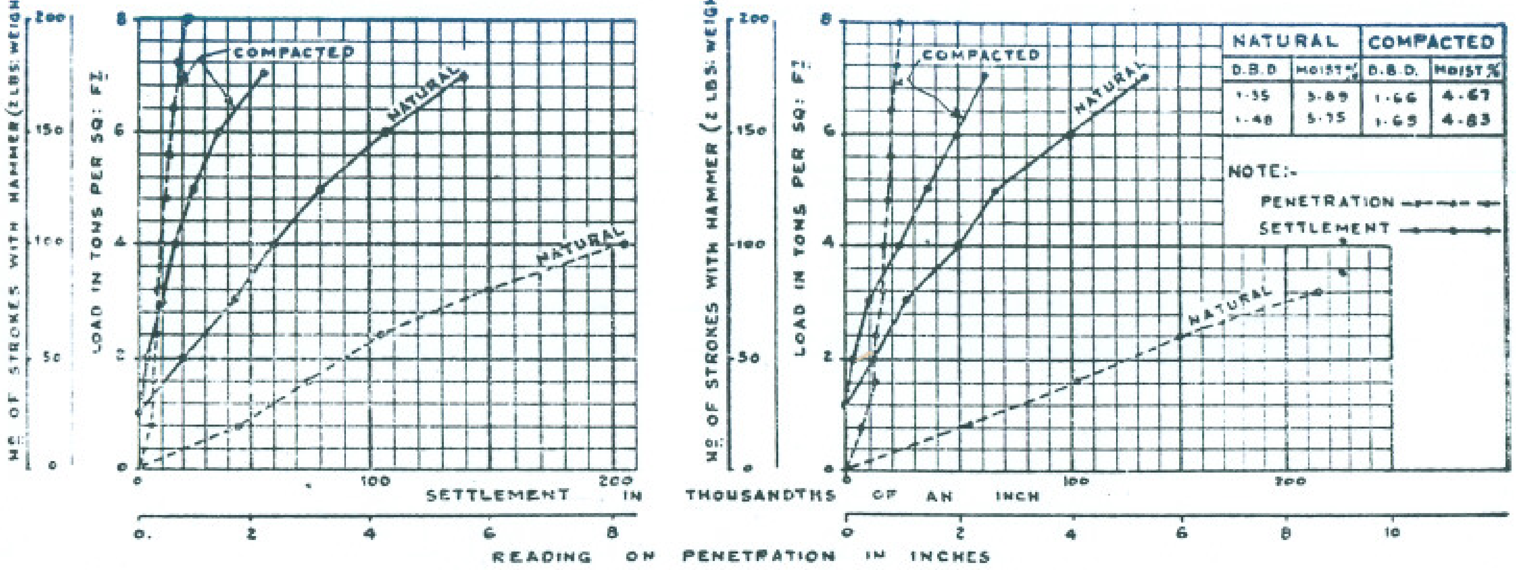
Bearing capacity tests must, for practical reasons, be on a small scale. It is, however, fully appreciated that tests on a small scale do not test the sub-grade adequately as smaller the bearing area under test, less is the transmission of load per square foot. It is, however, felt that for practical purposes the results given by field tests are fairly representative.

Advantages of compaction. With the sub-grade compacted as above, it will be seen, that there is no further necessity to lay any soling coats of bricks or stone before laying concrete slabs. The sub-grade which when fully compacted gives a settlement of ·04 inch only with a load of 7 tons per square foot does not need any soling coat on it. In all airfields constructed by the Irrigation Branch 1: 2: 4 concrete slabs were laid direct on the compacted sub-grade in case of runways. On taxi-tracks the sealing coat given was of brick on edge in 1: 5 cement mortar laid on ¼″ thick cement plaster on compacted sub-grade. This meant saving in large quantities of materials required for soling both on runways and taxi-tracks. Every inch of thickness saved from a 2,000 yards runway saves about 4,500 tons of material. Taxi and dispersion tracks have the area of about two runways, and most airfields have two runways. So every inch saved meant a saving of about 18,000 tons per landing ground.

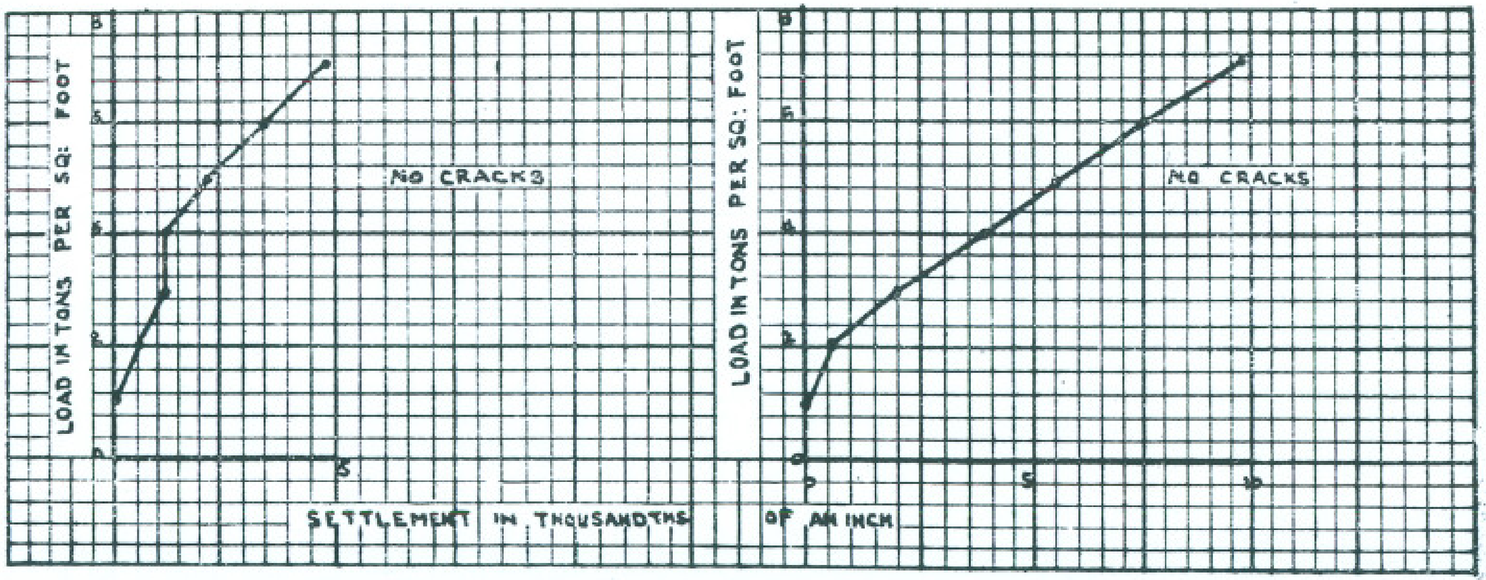
Concreting.

Aggregate and design of mix. Before concreting was started the materials available to form the aggregate were carefully examined to see if they were suitable for the purpose. Ballast was obtained mostly from Sikhanwala Quarry and some from Baghanwala, Khanki and Marala, while at one airfield runways were completely constructed from shingle obtained

PENETRATION TESTS ON NATURAL & COMPACTED SOILS



BEARING TESTS ON CONCRETE SLABS



from torrents crossing the Upper Jhelum Canal. Sand was obtained from canal distributaries in the locality or by making local pits and some sand was carried from river Chenab near Wazirabad and Chiniot.

As sand obtained from local sources was not often coarse enough, the samples were analysed in the Research Institute and sand with a fineness modulus of less than 1·5 was always rejected. Correct proportions of the materials to be used were arrived at by designing the densest mix for the materials actually available as per details given below :—

Fineness modulus of sand was of the order of 1.75 and proportions of $\frac{3}{4}''$ bajri to $1\frac{1}{2}''$ ballast in the ratio of 54 : 12.

Densest mix to give the crushing strength of 2,800 lbs per square inch at 28 days is given by

one bag of portland cement : $\frac{183}{XW_o}$ cft. of sand

: $\frac{76}{XW_1}$ cft. of $\frac{3}{4}''$ aggregate : $\frac{341}{XW_2}$ cft. of $1\frac{1}{2}''$ ballast

X is determined as given below :—

(*i*) Take 57 lbs of $1\frac{1}{2}''$ coarse aggregate and 12·5 lbs of $\frac{3}{4}''$ coarse aggregate and mix them.

(*ii*) Take 30·5 lbs of dry sand.

Mix (*i*) and (*ii*) and determine the loose (unrodded) volume of 100 lbs of mixed coarse and fine aggregate. This is the value of X.

W_o = Weight of one cft. of loose (unrodded) dry sand.

W_1 = Weight af one cft. of $\frac{3}{4}''$ bajri.

W_2 = Weight of one cft. of $1\frac{1}{2}''$ ballast.

Value of X as actually determined on a representative sample came to 0·84 cft.

W_o came to 85 lbs, W_1 97 lbs and W_2 93 lbs.

With these values the mix came to
one cft. of cement : 2·05 cft. of sand : 0·74 cft. of $\frac{3}{4}''$ bajri : 3·49 cft. of $1\frac{1}{2}''$ ballast.

Bulking of sand to be actually determined and allowed for.

As ballast received from the quarry was usually not clean, suitable arrangements were made at all sites for washing it thoroughly before use.

Laying concrete slabs.

Treatment of sub-grade. As concrete was to be laid on sub-grade made in earth it was necessary to guard against the sub-grade absorbing moisture from the bottom layers of concrete and thus rendering it spongy. The following alternatives were adopted.

(*a*) Water proof paper. Single thickness paper was found good enough for the purpose and gave very good results. Cost based on Rs.15-8 per Roll of 1,000 sft works out to Rs.1-9 $^0/_0$ sft.

(*b*) 1 : 6 cement plaster on the sub-grade.

As plastering need not be very accurate, paying half the labour rate of the ordinary cement plaster, cost per $^0/_0$ sft. works out to Rs.3-4 $^0/_0$ sft.

(*c*) Thin layer, say 1/8″ thick, of 1 : 4 cement and sand slurry laid a couple of hours before placing concrete. This slurry is poured direct from cans on sub-grade well moistened. Cost works out to about Re.1 $^0/_0$ sft.

(*d*) Treating the sub-grade with linseed oil.

Using one gallon linseed oil per $^0/_0$ sft of sub-grade cost works out to about Rs.2-8 $^0/_0$ sft.

(*e*) The cheapest stuff used was furnace oil. This was applied direct to the sub-grade with satisfactory results and cost came to about Rs. 0-13-0 per cent sft.

All the above methods were used depending on availability of materials.

Layout of mixers and Bins. As construction of a large number of airfields was simultaneously taken in hand it was not possible to arrange for all the concrete mixers required, in case hand mixing was to be avoided altogether. Again, the number of small portable mixers available in the Department was also limited and in places like turning circles and hard standings where lead from cubic yard mixers installed along the runways would be excessive, hand mixing had to be done in certain areas. One layback station was done entirely by hand mixing.

All available mixers in the Department were commissioned and twelve one cubic yard mixers were constructed specially for this work in the Irrigation Workshops, Moghalpura. The mixers having fixed hoppers special arrangements had to be made to feed them. This was done by running the dry mix in N. G. wagons going up a ramp to the level of the hopper and the empties coming down. Mixed concrete was carried in tip wagons along the length of runways. Details of a typical layout are shown in Plate III. On this plate details are also shown of arrangements for washing ballast. This is done by means of hydrants along the ballast bins, necessary head being provided by the overhead wooden tank.

Laying concrete. Concrete was hand shunted to site of work by means of N. G. Trucks, dumped on iron sheets from where it was carried in mortar pans or hand barrows and deposited in the slabs.

Concrete was laid in alternate slabs normally of size 30′ × 15′ (see Plate VII). Form work consisted of wooden members 3″ × 4″ in section, securely held in position by iron bolts with M. S. flats. After concrete had been laid for some width it was tamped by heavy wooden tampers shown in Plate VI. These could be conveniently worked by two men.

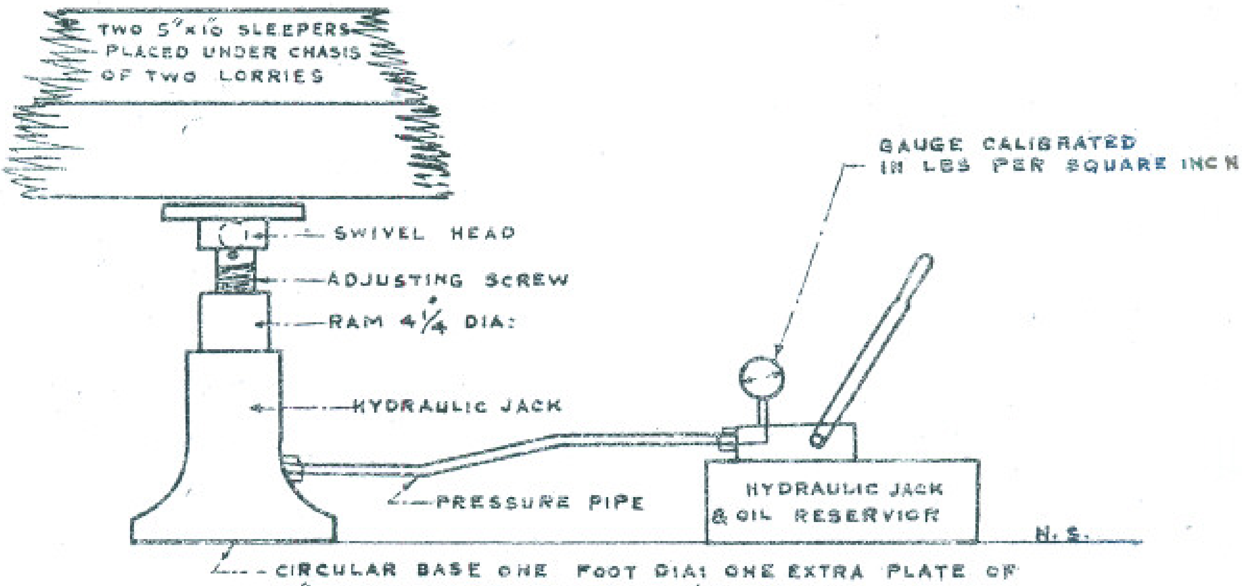
Excessive tamping or floating of unformed concrete in one operation or the performance of these operations at the wrong time is frequently the cause of objectionable segregation particularly if the concrete is too wet. The result is that excess water and 'fines' are drawn from the body of the concrete to form a weakened layer subject to high shrinkage stresses on drying and readily susceptible to crazing or scaling.

Water cement ratio of concrete was controlled by taking slump tests every morning and afternoon to serve as a guide for amount of water to be used (see Plate VI for details of slumpcone). A slump of $\frac{3}{4}''$ was aimed at. Excessive tamping was avoided, no floating of the surface with iron hand floats was permitted. It was however found that best results were obtained by treating the surface with canvas belting with wooden handles on either side which enabled it to be worked in a saw action. Edges of the slabs were finished with a curved edging tool (see Plate VI) to form the groove in which bitumen was later run after the concrete was completely cured and thoroughly dried up.

Testing concrete. Quality of concrete turned out was kept under close supervision by making test cubes taken at random out of concrete batches every day and sending them to Rasul after keeping them under water for about a week. The cubes were crushed when they were 14 and 28 days old.

Record was kept of the particular slabs that were formed with the concrete under test. In case of results of crushing tests being unsatisfactory, as they were sometimes, the slabs concerned were put to actual loading test to bear a load intensity of 7 tons per square foot—the load to be transmitted by a heavy bomber.

This was done by means of a Hydraulic Jack designed and constructed in the Irrigation Workshops, Moghalpura. Line sketch of the same is given below :—



Jack is placed on the area to be tested and resistance obtained by means of lorries full of ballast which are stationed on either side of the jack with sleepers placed under the lower portion of the chasis. After placing the jack in position the swivel head is screwed up tightly to save excessive pumping.

The pipe and pump are placed in a convenient position, the relief valve is closed and the jack gradually pumped up. The pressure as recorded on the gauge in lbs per square inch is converted to tons per square foot with the help of the graphs shown opposite :—

Numerous slabs have been tested on various aerodromes by means of the hydraulic jack or by applying load directly on a test cube 6″×6″ and it is gratifying to note that not a single slab showed any signs of cracks when loaded at the centre to 7 tons per square foot. On one slab where the hydraulic jack circular base test was applied at the corner at a distance of 7½″ from adjacent sides a hair crack did appear at a pressure of 7 tons per square foot. It should, however, be noted that in order to "hold the pressure" at 7 tons per square foot it was necessary to pump to a pressure of 7·4 tons per square foot. The pressure transmitted by the hydraulic jack was undoubtedly in a series of impulses—which was a severe test. The tests included in particular those slabs where test cubes had given low results of crushing strength. It was established beyond doubt that results of crushing strength, where low, were due to defective curing due to time taken in transit.

Alternate Slab Construction. It will be outside the scope of this Paper to go into the theory of thermal expansion and contraction of concrete. The question has been dealt with at length in Punjab Engineering Congress, Paper No. 181 by Kanwar Sain.

In concreting runways on airfields constructed by the Irrigation Department expansion joints were not put in anywhere. To begin with, it was very doubtful if the materials required like bitumen would be forthcoming in such large quantities as needed for all the aerodromes on account of limited stocks then available in the country. On going further into the question the necessity for expansion joints did not commend itself to any great degree.

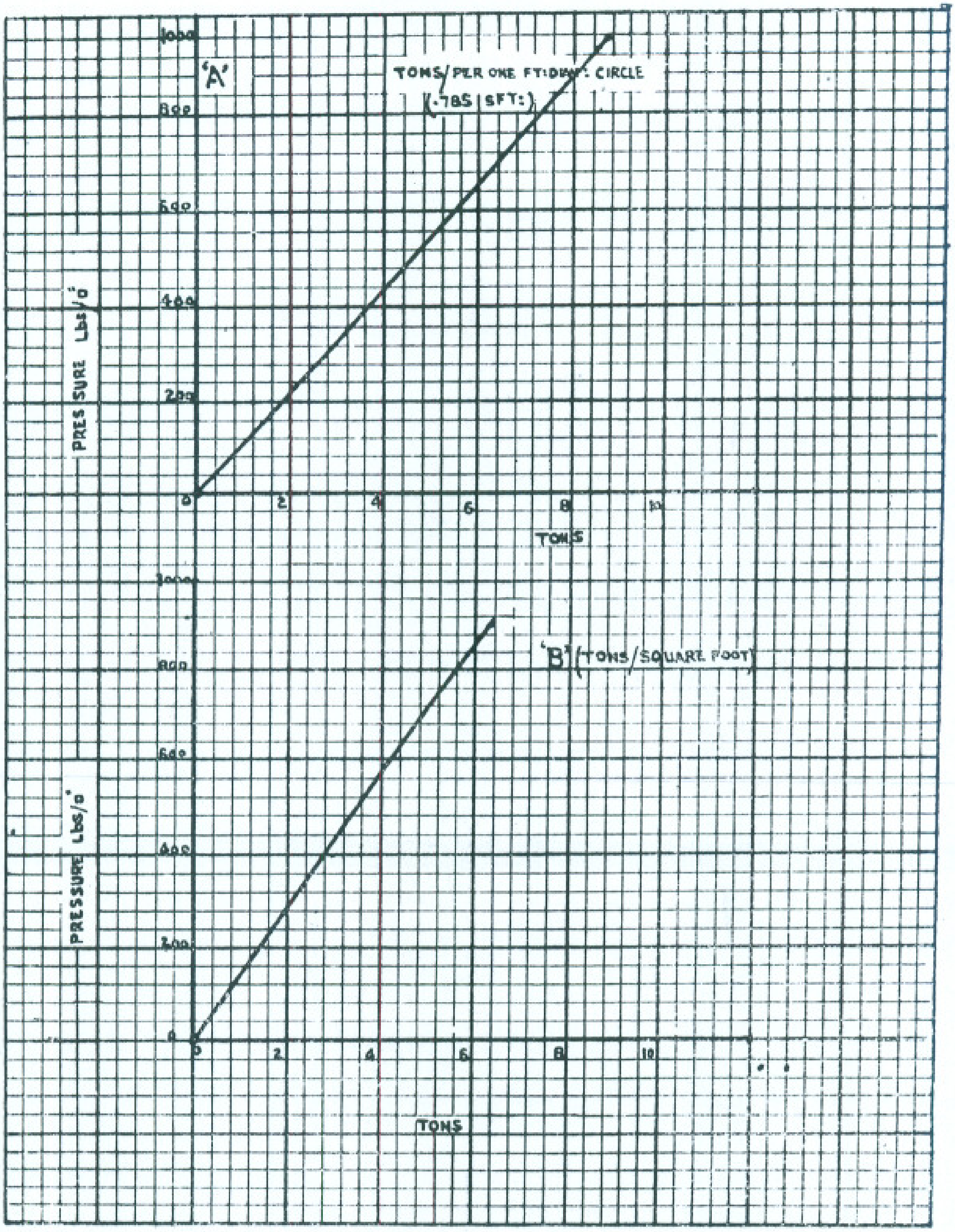
When concrete sets and is allowed to dry it shrinks. On subsequent wetting it expands but does not completely recover its original volume. The initial shrinkage on drying out therefore is partly irreversible but mainly reversible. *This is shown diagrammatically in the figure given below.

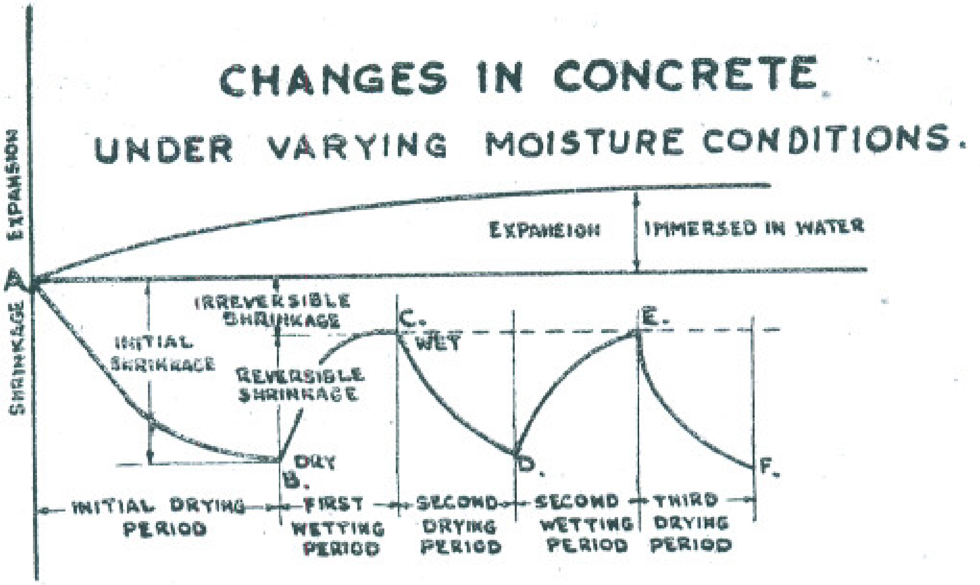
AB represents initial drying shrinkage and BC expansion due to wetting. Subsequent drying and wetting reproduce practically reversible movements, CD shrinkage, DE expansion and so on.

The length regained by wetting after initial drying (represented by point C) is about 22 per cent below the original, *i.e.*, 78 per cent of the shrinkage is regained.

*Modern Concrete Construction by W. H. Glanville.

HYDRAULIC JACK





According to Glanville, shrinkage expressed as percentage change in length for concrete with water cement ratio of 0·6 and 5 cwt of cement per cubic yard, is 0·065. Shrinkage for a 30 ft. long slab will come to 0·234 inch and reduced by 22 per cent as shrinkage which is not regained, balance is 0·183.

Against this, expansion due to heat worked out at an average value of thermal expansion of concrete of $5{\cdot}5 \times 10^{-6}$ comes to :—

Say concrete is laid at 100°F and has extreme range of 30°F to 170°F

Change in temperature = 70°F

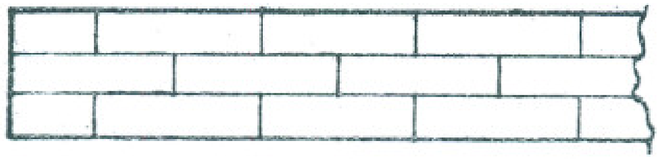
Expansion over 70°F $= 5{\cdot}5 \times 10^{-6} \times 70 \times 30 = 0{\cdot}14$ inch.

In order to have a value of 0·183 inch a variation of temperature of 93°F would be required. It will thus be seen that no expansion joints are required in a concrete slab if construction is carried out on alternate slab system.

Construction joints are however necessary to localise the cracks due to contraction and for this purpose size of slabs was fixed as $30' \times 15'$. Experience has shown that about three joints are necessary in a length of 100 feet and width is governed by considerations like convenient size of tampers to be handled across the width of the slab and quantity of concrete in each slab, etc. The runway slabs were therefore laid generally of size $30' \times 15'$ (see Plate VII) in alternate slab construction with butt joints and edges slightly curved to form the groove into which a seal of bitumen could be run. This sealing of the joints, involving as it did the proper clearing of the sand used in the curing of the concrete as well as the drying of the concrete sides, was considered most important to prevent subsequent moisture reaching the sub-grade on which so much depends. Owing to the enormous magnitude of the work this is probably a weak point in the general form of construction adopted.

The runways constructed by the Irrigation Branch with no expansion joints have now been through one cold and one hot weather. Excepting a few solitary failures at one of the sites there has been no trouble at any of the sites due to slabs bulging due to expansion with heat. These few failures are under investigation but it is definite that they are not due to absence of expansion joints.

Staggering of joints. Plate VII will show that in setting out the slabs both transverse and longitudinal joints have been carried through. This probably produces a weak spot at the junction of the four corners. To obviate this, it was suggested that the layout of the slabs should be arranged to break the transverse joints as shown in the sketch below :—



There is no doubt that by staggering transverse joints we avoid four contiguous corners but this can only be done efficiently by providing expansion joints which would have meant more time and money apart from the difficulty of obtaining the materials required for the purpose. Also chances of moisture getting through and ruining the sub-grade are there with expansion joints. With the mode of construction adopted there is sufficient frictional resistance along various joints on account of continuous concrete contact to develop cracks in the adjoining slabs in line with transverse joints. With cracks thus developed we will only double the number of contiguous corners and thus introduce further points of weakness.

It is interesting in this connection to quote from " Principles of Road Engineering by Collins and Hart Volume 6."

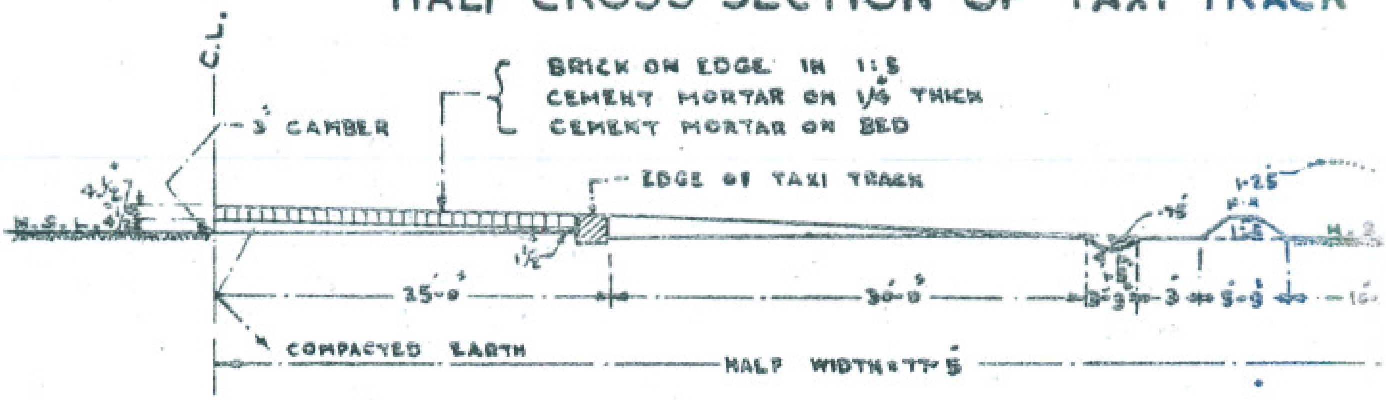
" Frequently transverse joints are staggered on each side of a longitudinal one in order to prevent their having four contiguous corners. This often results in frictional resistance along a longitudinal construction joint where there is a continuous concrete contact, sufficient to form transverse cracks in the adjoining slab in line with such transverse joints. This occurred on the Esher-Hampton Court Road. When the longitudinal joint is an expansion type, the staggering of the transverse joints may be successful."

Taxi Tracks and Roads. Taxi tracks in general were to be designed for the same static load as the runways. As they are not subjected to the transverse forces arising from non-rotating wheels landing at high speed and from emergent breaking, they can be of lighter specifications than the runways. For the work done under pressing circumstances use could be made of a light specification.

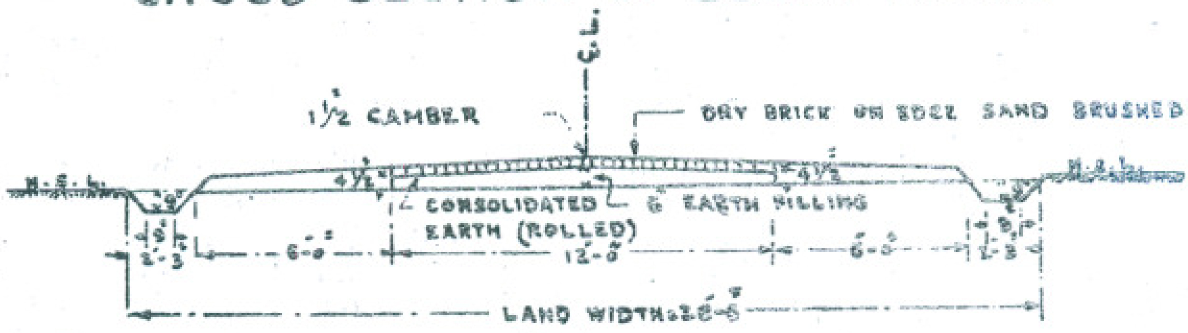
Taxi tracks and roads leading to various groups may be several miles in length and availability of material and speed of construction were the main considerations that governed the particular specifications adopted. At the time of construction of taxi tracks on these aerodromes cement was difficult to obtain but coal was easily obtainable. It was, therefore, decided to lay taxi tracks in brick on edge cement masonry 1 : 5 on compacted sub-grade.

With the sub-grade properly compacted, it could take the load of 7 tons per square foot in the dry and it was only necessary to seal it against moisture finding its way into the sub-grade and throwing it out of use during the monsoons. For this $\frac{1}{4}''$ thick coat of cement plaster was laid on the compacted sub-grade on which brick masonry was done. For lorry roads same specifications were adopted except that the sub-grade was only consolidated and not compacted. Cross sections of taxi tracks and lorry roads as adopted are shown below :—

HALF CROSS SECTION OF TAXI TRACK



CROSS SECTION OF LORRY ROAD.



Drainage.

To enable an aerodrome being used in all weather conditions, it is necessary in the interest of safety of the aircraft to have an efficient drainage system to cope with storm water. French drains have therefore to be provided along runways that discharge into soakage pits about 1,000 ft. apart. Overflow from the soakage pits as well as drainage from side of taxi tracks and roads is led into some natural depression in the vicinity from where arrangements can be made to pump up the water, if necessary, into some irrigation channel close by. To determine the capacity of such drains run off of 8 cusecs per square mile has been taken. Each aerodrome has its own problems in this direction and no typical layout can be given. A pure gravity system was, however, adopted at all sites designed to lead the storm water away to a point where it would be at least one foot below the edge of the runway.

Design of French Drains. Plate VIII shows the original design of French drains as supplied by the Army Department as well as the revised design worked out here. The former type of drain is objectionable in ways more than one. It means removing all the ballast and relaying it every time the drains have to be cleaned. Further with loose ballast on top being thrown about with the impact of a plane going over it, there is every danger of damage being done to its wings. To minimise this, spawls coated with tar and bitumen were substituted for 1″ ballast in the top layer. The tiles spanning the ducts are also not strong enough to carry the load of a heavy bomber as transmitted through the ballast.

The flume type of drain is neater in construction and admits of easy cleaning by removing the top slabs. Calculations for its design are given at Appendix A. It is admitted that a few assumptions have been made in the design which may not be supported very well by theory and it would have been more satisfactory if the top slab had been designed as a reinforced concrete slab with reinforcement going into the side walls to make it act as a box culvert. It was not possible to obtain all the steel required under war conditions and the design was adopted as practical tests carried out in the field showed it safe with a load of 7 tons per square foot.

Soakage Pits. The following simple formula was supplied by Mr. Haigh for determining the capacity of soakage pits.

$$Q = 4\ K\ R\ H$$

where Q = Discharge that the pit can soak into sub-soil.

K = Transmission constant of the sand *i. e.*, the velocity in ft. per second under one foot of head through the sand.

R = Radius of the pit.

H = Working head available *i. e.*, the depth from the water surface at the termination of the drain to the sub-soil water table.

Samples of sand below sub-soil water level were actually tested in the Research Institute at Lahore and it was found that for fairly coarse sand in the Punjab value of K varies from 0·0001 to 0·0003. Taking 0·0002 as mean value of K and H as say 20 feet, value of Q the discharge that the soakage pit, 10 feet in diameter, can cope with comes to $4 \times \cdot 0002 \times 5 \times 20 = \cdot 08$ cusec, say 0·1 cusec.

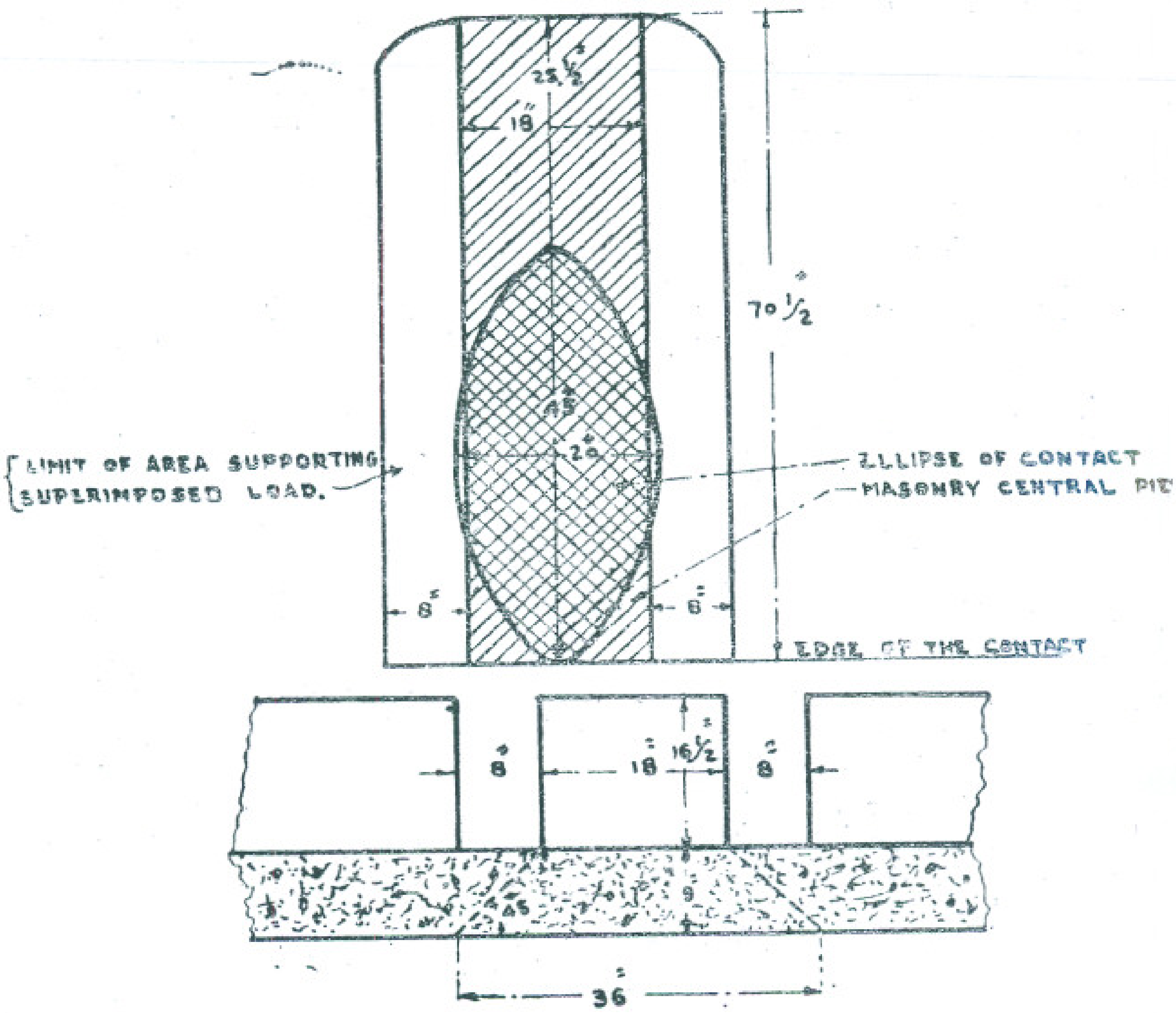
For an intensity of rainfall of half an inch per hour, our French drains have to carry a discharge of 1·1 cusecs at the tail end of a 1,000 ft. run (see Appendix A). This would mean constructing soakage pits 10 feet diameter every 100 ft. apart to cope with rainfall of half an inch average intensity. This is obviously very expensive.

It had been originally intended to dispose of the storm water from French drains in soakage pits 1,000 ft. apart along the edge of the dispersal strip—at some airfields these pits had actually been constructed before it was finally decided to introduce a gravity drainage system. In those cases the overflow from the pits was led into the branch drains. Actually, soakage pits are not required and should be dispensed with in future construction.

Drainage Culverts. For crossing drainage and irrigation watercourses under taxi tracks, roads and runways, design for a drainage culvert on lines of the flume type side drain was worked out. The capacity of the culvert was adapted to the discharge required by introducing multiple barrels to suit the case. Details are shown on Plate VIII. In this case 9″ deep concrete is required in the foundation to keep the punching shear within safe limits as per calculations given below :—

Consider the wheel load as a whole with the wheel at one end of the culvert.

Let the load disperse through masonry and concrete through all conceivable axes. This is shown in the sketch below :—



Loading:—

Live load = 34 tons

$$\text{Load of masonry} = \frac{33}{24} \times \frac{18}{12} \times \frac{69}{12} \times \frac{120}{2240} = 0{\cdot}64 \text{ tons}$$

$$\text{Load of concrete block} = \frac{8}{12} \times \frac{7\frac{1}{2}}{12} \times \frac{69}{12} \times \frac{150}{2240} = 0{\cdot}17 \text{ tons}$$

$$\text{Foundation concrete} = \frac{36}{12} \times \frac{69}{12} \times \frac{3}{4} \times \frac{150}{2240} = 0{\cdot}89 \text{ tons}$$

Total ... = 35·70 tons

$$\text{Bearing pressure} = \frac{35{\cdot}70 \times 144}{36 \times 69}$$

= 2·06 tons per square foot, which is safe.

Buildings.

Due to security reasons it is not possible to give details of accommodation provided at different airfields.

The buildings constructed to hutted scale had their walls in sundried bricks, floors in cement concrete on hard core or flat brick set in sand cement pointed and roofs laid in ballies with pharras $\frac{3}{4}''$ thick, 3″ wide, $5\frac{1}{2}''$ centre to centre. On the pharras thus spaced majri chattais from Peshawar side were laid with 3″ of earth and 1″ covering mud plaster.

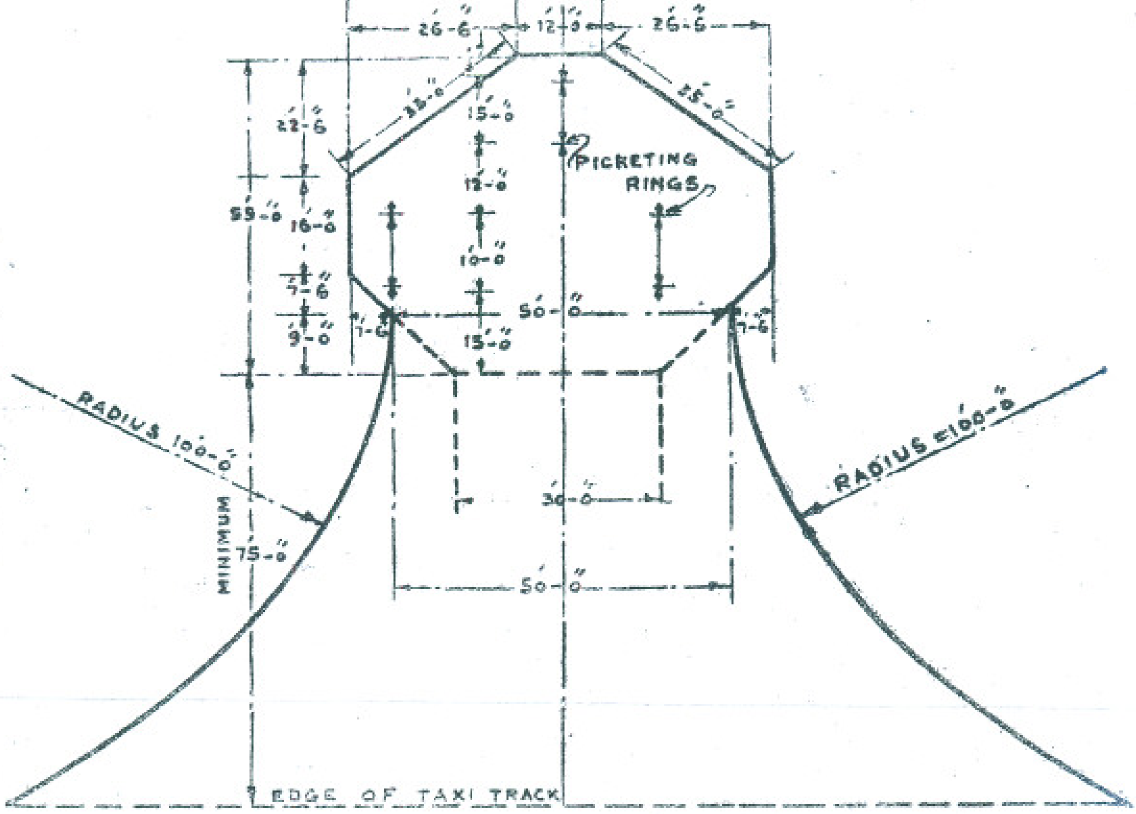
Pacca buildings had their floor in cement concrete on hard core and roofs laid in R. C. slabs or tiles on battens and R. S. joists. In some cases R. C. slabs were covered over with sand to make the buildings blast proof. Several buildings had blast proof protection given by means of walls in B. B. in cement 18″ thick. Some of the buildings were semi-sunk below ground level and given protection against blast from splinters by means of earthen pushtas. Use of steel structures even for roofs of buildings like workshops and Hangarettes was avoided as far as possible and wooden trusses were substituted. On Maintenance Hangarettes belfast trusses made in wood covered a span of 70 feet and workshop roofs with a span of 39 feet had either a wooden kingpost truss in hard wood or an undertrussed beam specially designed for use in the Aviation Circle.

Some idea of the cost of buildings can be had from page 33 wherein cost under various sub-heads of aerodrome construction has been given.

The buildings were dispersed but for obvious reasons details cannot be supplied. Hardstandings as per sketch given below are required to be constructed in some of the groups and off the taxi tracks. These were laid either in cement concrete to the specifications of runways or in brick masonry to the same specifications as the taxi tracks.

Detailed estimates and indents of stores required for construction of buildings to the last hinge and glass pane were worked out in the Circle Office and supplies arranged through the Military Department. List of important stores for buildings required for an Operational Station is given below.

TYPE 'F' HARDSTANDING



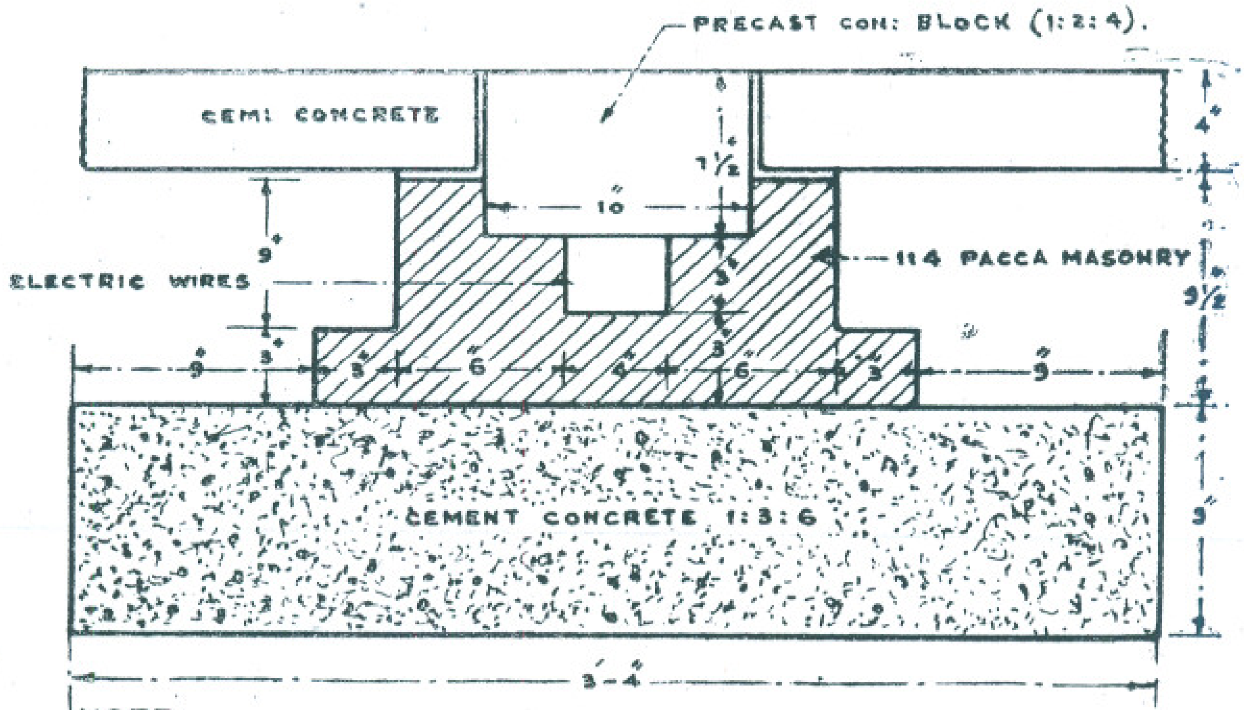
S. No.	Description.	Unit.	No. or Quantity.
1	Ballies 6" diameter 12' to 16' long	No.	2,400
3	,, 3" to 5½" diameter 12' to 16' long	No.	54,000
3	Chattai	sft.	5,25,000
4	Timber Deodar	cft.	66,000
5	M. S. Round ¼" diameter	cwt.	10
6	do 3/8" diameter	,,	135
7	do ½" diameter	,,	200
8	M. S. Flat 1½"×1/8"	,,	5
9	Bolts and Nuts ½" diameter 18" long with flat washers 4"×4"×¼"	,,	200
10	Bolts and Nuts ½" diameter 24" long with flat washers 4"×4"×¼"	,,	35
11	Nails Wire French of sizes	,,	300
12	Hinges butt steel of sizes	No.	11,900
13	Bolts doors towers of sizes	No.	9,000
14	Hoop iron 1½"×1/16"	lbs.	4,300
15	M. S. Flat 1½"×¼"	cwt.	80

Electricity.

For military reasons it is not possible to give details of groups to be fitted with electricity and the type of current with voltage to be supplied or the capacity of the generating sets.

Distribution. By means of Low Tension Transmission line electricity will be distributed to the important technical buildings.

Originally it was laid down that at no point should electric wires cross the taxi tracks overhead. A design was therefore worked out for electric cables to be laid underground at points of crossings of taxi tracks based on the design for drainage culverts. It is illustrated in the sketch below :—



NOTE:—SPIDERS SIZE 4"×3" TO BE PROVIDED THREE FEET APART. THESE TO BE CUT FROM OLD OUTER COVERS, FROM GROUP LORRY TYRES, AND HAVE HOLES TO SPACE THE WIRE EQUIDISTANT FROM SIDES OF DUCT & FROM EACH OTHER.

ALL WIRES & SPIDERS TO BE BURRIED IN BITUMEN.

Later on it was agreed that overhead crossing may be permitted provided minimum distance of the lowest point of the sag above the top of taxi track was not less than 30 ft.

Permanent Water Supply.

Normal daily requirements at all categories of Operational and Layback landing grounds are about 20,000 gallons a day. For satellite stations the daily consumption may be taken as 4,000 gallons.

Types of Water Supply. Excepting satellites or stations reduced to fair weather category where some of the existing Persian wheels in the domestic area could be brought into commission after cleaning the wells, the following types of water supply arrangements were made depending on the conditions available at site.

1. Supply obtained from the upper water bearing strata by shallow tube-wells and pumped by hand power using wheel and plunger pumps. This was possible only at sites where water obtained from shallow hand pumps was, after tests, declared fit for human consumption. The number of hand pumps installed was liberal. For supply to bath houses and cook houses the water was pumped into small masonry tanks above roof level to give the necessary head for distribution. Arrangements will be made to chlorinate the water inside storage tanks. For military reasons it is not possible to give a typical layout of the domestic area showing location of hand pumps and storage tanks.

2. **Deep tube-well supply pumped into a high level tank and distributed from there**. Actually this mode of water supply was not adopted at any site. It was intended to be adopted at two of the sites where tube-wells were being sunk for construction requirements but the length of pipe line required, in view of dispersal between various buildings, was found prohibitive and ultimately it was decided to resort to shallow hand pumps as described above.

3. **Supply obtained from existing Municipal Mains**. This was possible at one site only where the existing municipal supply was made use of.

4. **Settling tanks cum filtered supply from local irrigation channels chlorinated and pumped into High Level Tanks.** This mode of water supply was adopted at sites where good drinking water was not available to a depth of even 500 feet below ground level but the area was commanded by irrigation channels. The scheme is discussed below :—

Capacity of settling tanks. Take daily consumption = 25,000 gallons. We must provide for canal closures for say 30 days. The capacity of the settling tanks therefore should be 25,000 × 30 = 7,50,000 gallons = 1,20,000 cft. Provide three tanks 80′ × 100′ × 5·0′.

Filter beds. Take capacity of filter beds as 12,000 sft. of filtering surface for each million gallons of water to be filtered per day[1]. This will give 35 gallons per hour per square foot of the filtering surface. According to this, the area required for 25,000 gallons to be filtered in say 12 hours comes to 600 sft.

On the other hand, taking capacity of some filters as 1 to 2 gallons per square foot per hour[2] the area required comes to 1,400 sft. Two filters 35′ × 20′ were therefore required. Actually a third filter bed of the same size was also provided to serve as a spare unit for cleaning, etc.

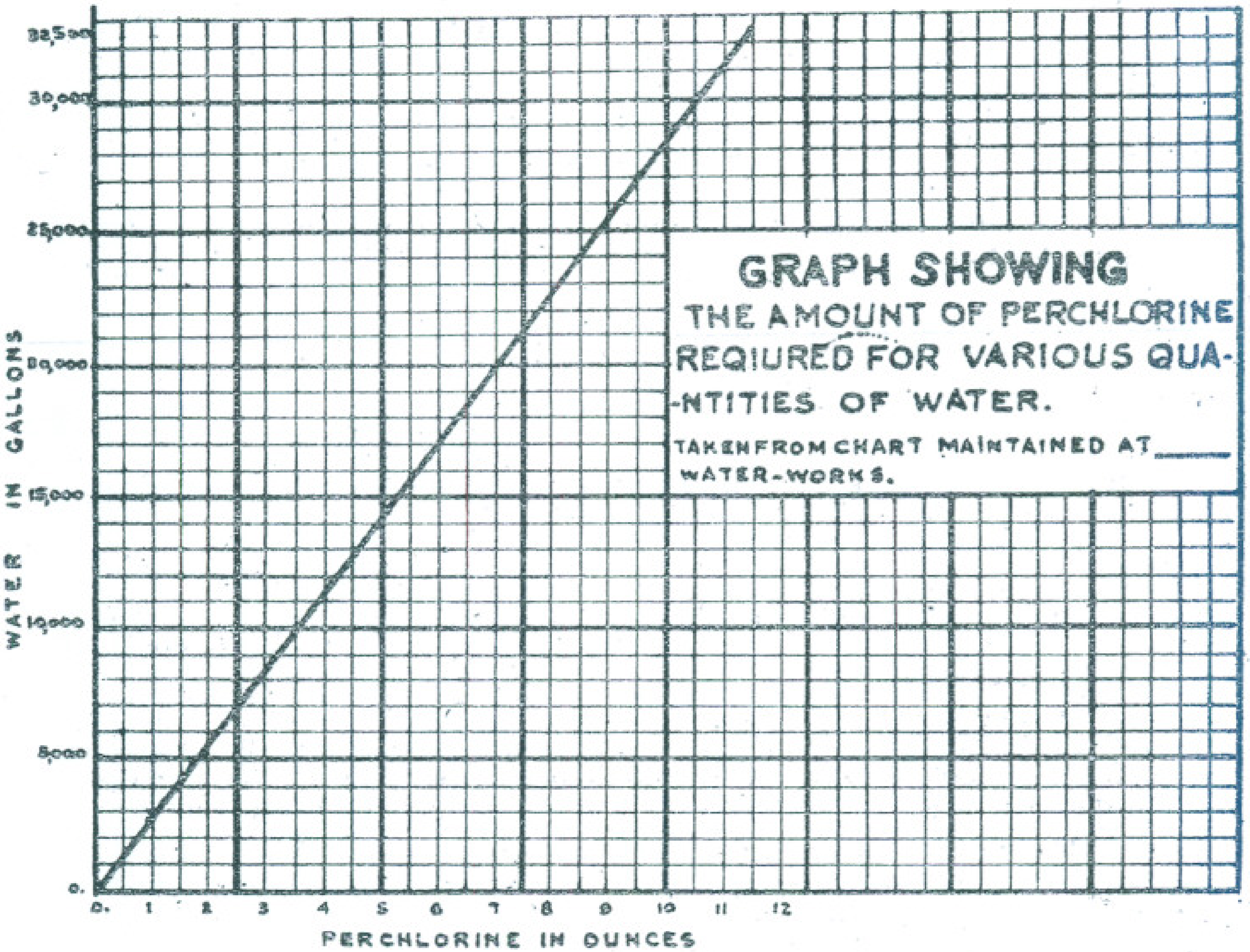
The filters consisted of the following materials :—

1.	Dry brick drains on a cement plastered floor.	
2.	Gravel 1″ gauge	... 6″
3.	Gravel ½″ gauge	... 6″
4.	Gravel ¼″ gauge	... 6″
5.	Coarse sand	... 12″
6.	Fine sand	... 18″
	Total	... 48″ or 4 feet.

1. Fannings treatise on Hydraulics and Water Supply Engineering.
2. M. E. S. Hand-Book, Volume IV.

Chlorinating chamber or clear water well. The size of the chlorinating chamber will depend on the number of hours the pumps are required to work. It was considered desirable to arrange for full day's requirements *i. e.* 25,000 gallons being treated. Two chlorinating chambers, as shown on Plate IX, were therefore provided. Further details of the scheme are also shown on this plate.

The simplest method of chlorinating is by use of bleaching powder as is being done at some of the municipal waterworks. A chart showing quantity of this chemical required for various quantities of water in the chlorinating chamber is shown below :—



Overhead service tanks and Water Tower. With scarcity of steel these days R. C. tanks or steel tanks were out of the question. Wooden tanks as per details given in Plate X were therefore designed and constructed locally. Such tanks were also used for washing ballast during construction. Nine tanks with a capacity of 2,674 gallons each (total 24,066 Gallons) have been provided.

The tanks were mounted on a masonry structure (details given in Plate XI) with their bottom 20 feet above ground level to give sufficient head for distribution. Design was worked out in detail and cross bracing with arches was found necessary to make the structure safe against wind pressure. Calculations concerning design of the water tower are tedious and need not be reproduced here.

As the detailed scheme was worked out for some of the sites it may be of interest to give here a list of important stores required for waterworks (settling tanks cum filtered supply) for one site.

STATEMENT SHOWING REQUIREMENTS OF STORES FOR WATERWORKS.

S. No.	Name of articles.	Quantity for one site.
1	W. I. Pipe 6″ diameter	470 lft.
2	G. I. Pipe 3″ diameter	200 lft.
3	Sluice Valves 6″	13 No.
4	Flanges 6″	46 No.
5	Bends right angle 6″ diameter	11 No.
6	do 3″ ,,	12 No.
7	Tees 6″ diameter	8 No.
8	1st class deodar timber	860 cft.
9	M. S. Rods 1″ diameter	6 cwt.
10	do 5/8″ ,,	2 cwt.
11	do 1½″ ,,	1 cwt.
12.	Bolts and Nuts 3/8″ diameter 5½″ long	120 lbs.
13	do 3″ ,,	200 lbs.
14	do 4″ ,,	75 lbs.
15	do 6″ ,,	20 lbs.
16	Angle iron 2½″×2½″×¼″	21 cwt.
17	Flat iron 3″×¼″	2 cwt.
18	do 2″×½″	9 cwt.
19	A. C. Ridging	95 lft.
20	Wire gauze	165 sft.
21	Wooden screws 1½″ long	23 gross.
22	do ¾″ ,,	10 gross.

STATEMENT SHOWING REQUIREMENTS OF G. I. PIPES FOR MAIN AND SERVICE CONNECTIONS OF WATERWORKS.

Pipes 3″	2,500 rft.
Pipes 1″	3,300 rft.
Pipes ¾″	1,950 rft.

FITTINGS REQUIRED FOR WATERWORKS—STORES FOR MAIN AND SERVICE CONNECTION.

Bends or Elbows.

3″	7 No.
1½″	6 No.
1″	12 No.
¾″	52 No.

Shower bath roses.

50 Nos.

Sockets.

¾″	100 Nos.
½″	100 Nos.

Tees.

3″×3″×1″	3 No.
2″×2″×1½″	2 No.
2″×2″×¾″	8 No.
1½″×1½″×1½″	1 No.
1½″×1½″×¾″	5 No.
¾″×¾″×½″	24 No.
3″×3″×2″	1 No.

Reducers.

3″×2″	2 No.
2″×1½″	3 No.
1½″×1″	5 No.
1½″×¾″	2 No.
1″×¾″	7 No.
¾″×½″	200 No.

Wheel Valves.		Stop Cocks.
3" 6 No.	... ...	¼" 3 No.
2" 12 No.		
Bib Cocks.		Crosses.
¾" 44 No.	... ...	1½" 11 No.
½" 54 No.		

Bulk petrol storage installation.

It would be mere reproduction of orders issued and policy laid down by the Military Department to give any details in this connection which cannot be disclosed for military reasons. The subject will not therefore be discussed in this Paper nor would it be of any great interest to a Civil Engineer.

Stores and plant for one operational station.

Some idea of the magnitude of the work involved may be had from the quantities of principal materials required for construction of one Operational Landing Ground, which are given below :—

STATEMENT SHOWING QUANTITIES OF MATERIALS REQUIRED FOR ONE OPERATIONAL STATION

1	Stone ballast	8,40,000 cft.
2	Bricks	2,16,00,000 Nos.
3	Cement	13,893 Tons.
4	Timber	78,800 cft.
5	Building materials	Principal stores given on page 23.

The above is by no means an exhaustive list of all the stores required for construction of one Operational Station as stores like coal, kerosene oil and lubricants for machinery, etc., are not included.

It may be of interest to give here a list of important Plant required for construction of one Operational Station.

This is given below :—

1	Steam Road Roller	1 No.
2	Rollers toothed } bullock drawn	4 No.
3	Rollers plain } bullock drawn	4 No.
4	Concrete mixer cubic yard	3 No.
5	,, ½ or ¼ cubic yard	1 or 2 No.
6	Pumping sets 3 to 8 B. H. P.	4 No.
	Light Railway Materials and other transport.	
7	Track	2½ miles.
8	Tip wagons	50 No.
9	Lorries	50 to 75 No.
10	Bullock-Carts	30 No.

Transport.

In order to conserve the transport machinery in the country to the best of advantage for the war effort and to exercise effective control over abuse of mechanical transport by way of overloading and defective maintenance, the Government of India introduced a scheme popularly known as the 'Group System.' The scheme consisted mainly of hiring by Government of vehicles at a fixed monthly basic rate plus a bonus for additional mileage, Government being responsible for supply of petrol, oil lubricants, tyres, spare parts and maintenance and for the return of the vehicle in the same condition in which it was received subject to fair wear and tear. The personnel consisting of drivers, cleaners, managers and clerks were also paid by Government at a basic rate plus bonus for extra mileage.

Rate of hire charges. These need not be given here in detail for various types of vehicles. To give an example, for heavy duty rear wheeled lorries the flat rate for any mileage up to 2,000 was Rs.325 for 1940-41 models and for every mile exceeding 2,000 miles in any calendar month or proportionately for broken period, additional one anna. Idle time was also to be paid on certain terms.

The owners were allowed an advance up to Rs.750 for repairs or the fitting of tyres or a new body. The advance was to be recovered in subsequent monthly instalments.

Pay and bonus to Personnel. The personnel attached to each group were allowed very good rates of pay and bonus in addition. The basic pay of drivers was not to exceed Rs.75 per mensem and their number varied from two per vehicle to three for two lorries. The basic pay of cleaners was Rs.25 p. m. Fitters were engaged at a basic pay of Rs.75 p. m. and there were two fitters per group of 10 to 20 lorries. The manager of the group also drew a pay of Rs.75 p. m. and in addition we had the manager's clerk at Rs.30 p. m. and one home clerk at Rs.50 p. m. The personnel were in addition allowed free ration or an allowance of Rs.15 p. m. in lieu thereof. They were also paid gratuity and in addition were allowed free accommodation and medical attendance.

Supervising Staff. The whole-time transport staff consisted of :—

(*a*) Area Maintenance Officer
(*b*) Senior Transport Officers
(*c*) Aerodrome Transport Officers
(*d*) Clerical Staff.

Each S. T. O. and A. T. O. was given one clerk but where the number of vehicles was large the A. T. O. could be given another clerk. The clerks were paid at Rs.75+Rs.15 ration allowance.

Running Expenses. For proper upkeep and efficient maintenance of the vehicles contracts were given to certain recognised firms under an agreement executed by the Area Maintenance Officer. The rates for maintenance were :—

(*i*) For every vehicle working at a site in a radius exceeding 25 miles but not exceeding 100 miles from the nearest workshop of the dealer @ -/1/- per vehicle per mile.

(*ii*) For every vehicle working at a site in a radius exceeding 100 miles but not 200 miles @ -/1/3 per vehicle per mile.

(*iii*) For every vehicle working at a site in a radius exceeding 200 miles @ -/1/6 per vehicle per mile.

These rates apply to units of 50 or more vehicles formed in specified ways otherwise the rate paid shall be -/-/3 per mile in addition to the above rates.

These rates do not include cost of (*i*) tyres (maintenance or renewal), (*ii*) spare parts, (*iii*) oils (*iv*) greases or (*v*) labour for repairs rendered necessary by accidents.

Government provided the dealers, as far as reasonably possible, with water for washing the vehicles, a covered shed with hard floor sufficient to house 25 per cent of the total vehicles employed, a lock up store-room, lighting arrangement, quarters and facilities for obtaining supplies for the dealers personnel. This naturally pushed up the cost of running the lorries a good deal making carriage by group lorries an expensive item of our estimates. Analysis of rate per mile of lorries run at three of the sites is given below :—

S. No.	Particulars.	Job A.	Job B.	Job C.
		Group Lorries.		
		Rs a. p.	Rs. a. p.	Rs. a. p.
I	Total cost	4,28,694 0 0	2,28,866 0 0	3,53,417 0 0
	Total milleage	5,87,209	2,50,439	4,05,147
	Rate per mile	0 11 8	0 14 7	0 14 0
II	Analysis of rate per mile run.			
1	Petrol	0 3 2	0 3 6	0 4 0
2	Mobil oil	0 0 6	0 0 4	0 0 6
3	Tyres and tubes	0 0 6	0 0 10	0 0 11
4	Spare parts ...	0 2 3	0 3 4	0 1 11
5	Body repairs	...	0 0 1	...
6	Pay, bonus and gratuity of personnel	0 2 2	{ 0 5 7 }	0 3 0
7	Pay and bonus of owners ...	0 1 8		0 2 4
8	Maintenance charges by dealers	0 0 8	0 0 9	0 1 3
9	Compensation for 42 vehicles ...	0 0 8	not yet paid	
10	Idle time payments ...	0 0 1	not yet paid	
11	Temporary accommodation for crew	Charged to runways.	0 0 2	0 0 1
	Total ...	0 11 8	0 14 7	0 14 0
III	Comparison with Thal Schedule.			
		Rs. a. p.	Rs. a. p.	Rs. a. p.
1	Total expenditure on group lorries	4,28,694 0 0	2,28,866 0 0	3,53,417 0 0
2	Cost as per Thal Schedule according to lead involved for carriage of materials ...	1,44,880 0 0	89,949 0 0	98,163 0 0
3	Percentage above Thal Schedule	196%	154%	206%

In addition, Government had also to pay compensation to lorry owners, when disbanded, under obligation to return the vehicles in the same condition as received subject to fair wear and tear. This added further to the cost of working Group Lorries.

Mileage Scheme. As will be seen from the analysis of cost given, the Government of India Group Lorry Scheme proved very expensive. Apart from the expense, the scheme did not work very well on account of the dual control. Probably it would have been easier to work it if the lorries had been taken over and maintained by one central Government Agency. On the recommendation of the Superintending Engineer, Aviation Circle, later on however, it was decided by Government that an alternative scheme called the Mileage Scheme be given a trial. According to this scheme, the flat rate of lorry miles was supposed to cover all charges including cost of petrol, oil, lubricants, tyres, spare parts, maintenance, drivers, cleaners, lorry hire and supervision charges, etc., on behalf of owners.

Average rates to be paid as given in the model agreement supplied by the War Transport Department of the Government of India which are subject to modification to suit the local conditions are :—

		Average Rate.	
(*i*)	For lead less than 3 miles in one direction	0-10-0	for each mile run.
(*ii*)	Lead more than 3 and not more than 5 miles in one direction ...	0-9-0	do
(*iii*)	Lead more than 5 and not more than 10 in one direction ...	0-8-0	do
(*iv*)	Where lead is more than 10 miles in one direction	0-7-0	do

Provided that the rate shall be subject to a minimum of about Rs.14 for any day on which the vehicle is in a condition to be worked for 8 hours between 8 a.m. and 8 p.m. but it is not fully employed. Provided further, that in any calendar month Government shall not be bound to make payment in respect of more than 27 days if on the remaining days the vehicle was unemployed for any reason whatsoever.

Rates. The work of constructing aerodromes in the Punjab was started more or less simultaneously by the M. E. S., B and R and Irrigation Branches of P. W. D. This meant construction on an unprecedented scale in the province and with other military works in progress at the time the problem of procuring labour became acute and good deal of labour had to be imported from outside. Soaring prices of food stuffs added further to difficulties with the result that daily wages of coolies had to be increased to make them earn a living wage.

Under these circumstances it could not be expected to complete the works with the speed demanded by the military at ordinary Schedule of Rates. Special rates had therefore to be sanctioned for the work of aerodromes. For buildings the rates paid were Thal Schedule plus 50 per cent. Earthwork on runways, dispersal strips and taxi tracks was paid at Thal Schedule plus 100 per cent. For all other items rates paid were Thal Schedule plus 15 per cent subsequently raised to Thal Schedule plus 25 per cent with exception of the following items peculiar to runway construction that were paid at special rates given below :—

1.	Dressing the surface under runways, approach road and taxi strip (for uncultivated areas) ...	0-7-0 % sft.
2.	Taking out roots and breaking clods ...	0-3-0 % sft.
3.	Compaction	3-6-0 % cft.
4.	Running bitumen in joints, including cost of fuel and cleaning joints	0-0-9 lft.
5.	Concreting (machine mixed) including laying of forms and curing	4-10-0 % sft.
	(*a*) Concreting (hand mixed) including laying of forms and curing	4-13-0 % sft.
6.	French drain (extra)	0-1-2 lft.
7.	Tile roofing of French drains	2-5-0 % sft.
8.	Filter of the drains	1-2-0 % cft.
9.	Washing ballast with power pump	0-9-0 ,,
10.	Washing ballast with mashaks	0-14-0 ,,
11.	Ploughing three times	8-0-0 per acre.
12.	Dressing Dowel of Perimeter drains	0-4-0 chain.

On the lorries employed under the group system loading and unloading of materials was done by Government. In order to economise on petrol and to conserve use of motor transport as far as possible, it was laid down that for carriage done by contractors by means other than motor transport, loading and unloading will be paid in addition to ordinary rates for carriage.

Bonus on concreting. In order to give further fillip to the work of concreting the runways which were required to be completed at record speed, certain bonus rates were offered for the work of concreting the slabs on the runways.

Taking percentage bonus as equivalent to percentage number of days saved in completion of concreting of runways at the basic rate of progress, it can easily be shown that

$$\text{Bonus} = \frac{100\ (q-2500)}{q}\ \%$$

where q = average quantity of concreting actually done per day, and Basic average progress of a cubic yard mixer as 2,500 cft in a ten hours working day.

Basic progress for a $\frac{1}{4}$ cubic yard mixer was fixed at 1000 cft. per day and for hand mixed concrete at 2000 cft. per day. Where $\frac{1}{4}$ cubic yard mixer was given in addition to hand mixing or cubic yard mixer the higher basic progess would count for purposes of bonus.

In calculating bonus any delays which may occur due to causes beyond contractors' control like mechanical break downs, etc., were to be deducted from the total period.

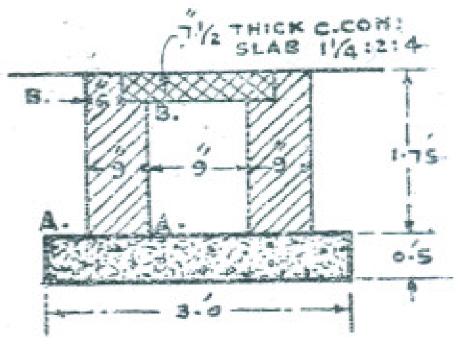
Cost of an Operational Aerodrome. Some idea of the cost of an *Operational* Aerodrome constructed under these conditions may be had from figures given below as actually pertaining to one of the sites.

1.	Land acquisition and compensation	4,18,000
2.	Cleaning and preparing strips	2,000
3.	Runways	13,40,000
4.	Taxi, Dispersal and Lorry Roads	5,60,000
5.	Accommodation	12,45,000
6.	Drainage	10,000
7.	Water Supply and Electricity	2,25,000
8.	Camouflage	1,87,250
9.	Furniture	76,000
		42,78,240
	Contingences @ 5%	2,13,910
	W. C. Establishment @ 2%	75,690
	Planning	75,690
	Audit and Account charges @ 1%	37,840
	Total ...	46,81,380

Acknowledgment The writer gratefully acknowledges free use made of notes by Mr. James L. Roy. He is also thankful to Sardar Bahadur Sardar Raghbir Singh for supplying some valuable field data. Other sources on which he has drawn have also been duly acknowledged in the Paper.

APPENDIX 'A'.

Alternative Design of Flume Type Drain.



In the sketch shown there is no possibility of overturning taking place. This is analogous to a road culvert which is stressed when a road roller approaches it. There is compact filling on both sides.

Live load of 7 tons per square foot will cause tension in the mortar joints. The critical sections are A A and B B.

Section A A.

Earth pressure at A A $= W\ H\ \dfrac{1-\text{Sin}\ \varnothing}{1+\text{Sin}\ \varnothing}$

$= 100 \times 158{\cdot}75 \times \dfrac{0{\cdot}426}{1{\cdot}574}$

$= 4280$ lbs.

Area which takes up tension $= 9'' \times 12''$

$\therefore$ Tensile stress in mortar joints $= \dfrac{4280}{9 \times 12} = 40$ lbs./sq. inch.

Section B B.

Earth pressure at B B $= 100 \times 157{\cdot}6 \times \dfrac{0{\cdot}426}{1{\cdot}574}$

$= 4265$ lbs.

Area which takes up tension $= 6'' \times 12''$

$\therefore$ Tensile stress $= \dfrac{4{,}265}{6 \times 12} = 59$ lbs. per square inch.

These stresses are well within safe limits.

Test against punching of foundation concrete.

Load on one foot length of the wall $= \dfrac{13\frac{1}{2}}{12} \times 1 \times 7$ tons.

$= 7{\cdot}8$ tons.

Perimeter of wall which will tend to Punch through the foundation $= 2\ (9+12) = 42$ inches.

$\therefore$ Punching stress $= \dfrac{7{\cdot}8 \times 2240}{42 \times 6} = 70$ lbs./sq. inch.

against a safe stress of 120 lbs./sq. inch.

Depth of foundation.

Area of contact of a tyre is an ellipse.

Major axis = 45″

Minor axis = 20″

Giving an area of 4·9 sft. weight per sft = 6·95 tons.

Since the planes are not likely to move across the French drain with a great velocity, no impact is taken into account.

Total load over a wheel = 6·95 × 4·9 = 34 tons.

In the crosswise direction dispersion can take place over the width of the foundation *viz.* 3·0 ft.

In the longitudinal direction dispersion is considered to take place at 45° *i.e.*, over a length of

$$45'' + 27'' + 27'' = 99''$$

$$= 8{\cdot}25 \text{ ft.}$$

$$\therefore \text{ Intensity of pressure on foundation} = \frac{34}{3 \times 8{\cdot}25}$$

$$= 1{\cdot}38 \text{ ton/sq. foot.}$$

Depth of foundation by Rankine's formula is

$$d = \frac{P}{W} \left\{ \frac{1 - \text{Sin } \varnothing}{1 + \text{Sin } \varnothing} \right\}^2$$

where P = intensity of pressure on foundation

$$\therefore d = \frac{1{\cdot}38 \times 2240}{100} \times \left\{ \frac{0{\cdot}426}{1{\cdot}574} \right\}^2$$

$$= 2{\cdot}25 \text{ ft.}$$

The depth is the same as actually adopted. Earth of the dispersal strip side of the French drain is rolled. The angle of repose is likely to be greater than 35°, which will reduce the safe depth of foundation considerably. With an angle of repose of 37° the safe depth of foundation works out to 1·9 ft. only.

Hydraulic examination.

An intensity of ½″ per hour rainfall will be taken as the basis for the design of capacity of the drain.

Length of a reach of drain = 1000 ft.

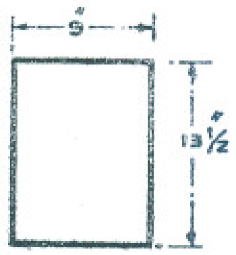
Flow will occur from 75 ft. wide strip of the concrete runway and 20 ft. wide strip of the dispersal track

∴ Width of strip = 100′ say

$$\text{Discharge at outfall} = 1000 \times 100 \times \frac{0{\cdot}5}{12} \times \frac{1}{60 \times 60}$$

$$= 1{\cdot}16 \text{ cusecs.}$$

Hydraulic mean depth $R = \frac{\text{Area}}{\text{Wetted perimeter}}$.



$$= \frac{1 \cdot 13 \times 0 \cdot 75}{3}$$

$$= 0 \cdot 282$$

Slope S = 1/1000

Coefficient of Rugosity N = 0·016 for lined channel

∴ By Manning's formula

$$V = \frac{1 \cdot 486}{N} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

$$= \frac{1 \cdot 486}{0 \cdot 016} \times 0 \cdot 282^{\frac{2}{3}} \times (0 \cdot 001)^{\frac{1}{2}}$$

$$= \frac{1 \cdot 486}{0 \cdot 016} \times 0 \cdot 432 \times 0 \cdot 0316$$

= 1·27 ft. per second.

∴ Discharge which the drain can carry

= 1·13 × 0·75 × 1·27

= 1·1 cusecs which is fairly close to the anticipated discharge.

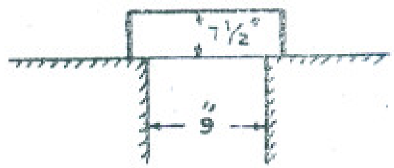
Tension in Roof Slab

The roof slab is proposed to be made of precast units of $1\frac{1}{4}$: 2 : 4 cement concrete

Clear span = 9″

Effective span = 12″

Intensity of load = 7 tons./sq. ft.



Load on 8″ width including 2″ slit $= 7 \times \frac{8}{12}$

= 4·67 tons.

Bending moment taking partial fixation 50% on account of short span $= \frac{1}{2} \times \frac{WL}{8}$

$$= \frac{4 \cdot 67 \times 1}{16} \times 12 \text{ inch tons.}$$

= 3·5 inch tons

Tensile stress in concrete $f = \frac{My}{I}$

$$= \frac{3 \cdot 5 \times 2240 \times 3 \cdot 75}{6 \times \frac{7 \cdot 5^3}{12}} = 140 \text{ lbs per sq. inch.}$$

DISCUSSION

Mr. A. R. Khanna in introducing his paper apologised for a number of reservations made in presenting the paper from security reasons. Plates I and II as well as the portion dealing with ruling gradients and dimensions and certain definitions had to be deleted.

Continuing further, he remarked that the paper detailed the specifications adopted by the Irrigation Branch for constructing Runways which had to be completed with the greatest possible speed and discussed various reasons that led to these specifications being adopted. These consisted of 4″ or $4\frac{1}{2}$″ thick cement concrete on compacted earthen sub-grade. This was probably the lightest specification adopted so far, for permanent construction. The design was safe, for a heavy Bomber giving a load intensity of 7 tons per square foot, as indicated in the paper.

From the calculations given on page 7 it would appear that with flexural strength of concrete as 700 lbs per square inch the factor of safety came to about 1·5 only. In America the Engineering Manual issued by the War Department specified a factor of safety of 1·75 with flexural strength of concrete as 700 lbs per square inch. The difference was due to the fact that the Irrigation Department had not given any soling coat under their runways and had relied entirely on the strength of the sub-grade that had been compacted to a high degree of dry bulk density. This meant a large saving in materials and cost as every inch of soling coat in the case of a Standard Station that had two 'pacca' runways and several miles of taxi tracks meant 18,000 tons of materials.

Continuing, the author pointed out that as the work was required to be done under great speed this risk, if at all it was a risk, had to be taken. The quality of the work was ensured by adopting various measures which had been discussed in the paper.

In the end, he pointed out the following misprints in the paper:—

(*i*) Page 7, line 10 from bottom

instead of $\frac{34,000}{10}$ as printed it should

read $\frac{34,000}{16}$

(*ii*) Page 36, last line 35 should read 3·5

(*iii*) Plate XI. Top plan

Overall dimension should read 36′—$10\frac{1}{2}$″

instead of 36′ — $1\frac{1}{2}$″

Dimension 21′ — $10\frac{1}{4}$″ should read 12″ — $10\frac{1}{4}$″

Mr. Roy remarked that at the time the construction of Airfields was commenced about two years back, speed was of paramount importance.

One of the major aspects of that consideration was the obtaining and the handling of materials with India's limited resources. That had a direct bearing on the selection of the design adapted, *viz.*, a 4″ thick stone cement concrete slab on a compacted earthen sub-grade. On page 12 the author had shown what every inch of thickness saved on the runways and taxi tracks—a tremendous figure, when the large number of Airfields in his Circle alone were considered. The total saving was even greater than that. They therefore had to pin their faith to the above design —in the circumstances. Such tests as they had been able to perform, both on the sub-grade and on the finished surface led them to believe that the runways and taxi tracks would stand up to the desired load of 7 tons per square foot over an area of about 5 square feet. All planes had landed with safety so far, but everything depended on the sub-grade being dry when the load was applied. Concrete slab construction was a form of rigid road construction. If the sub-grade gave way the slab above would fail. The vital importance of sealing the sub-grade where the paving itself was insufficiently strong to carry the load could thus be appreciated. On the Runways of a Standard Airfield there were at least 33 miles of joints to be sealed with bitumen mastic. Owing to the closeness of the slabs, complete filling of the joints and adhesion to the concrete was difficult. The joints were dried and cleaned and painted with kerosene oil prior to applying the bitumen. Nevertheless, small holes which permitted rain water to percolate through to the sub-grade were almost unavoidable. He expressed the opinion that on a compacted soil sub-grade a plastic seal as produced by a premix tar macadam might have more in its favour such as water-tightness, cost and ease with which it could be repaired.

There were other points which deserved attention but time did not permit, *e.g.*, the advisability of heavier construction of the hardstandings which were subjected to greater strain than were the runways.

Mr. Mahbub remarked that Mr. Khanna had written a very useful paper on Aerodrome Construction. It had been stated on page 17 that the sealing of joints between the concrete slabs was considered most important to prevent subsequent moisture reaching the sub-grade. It had also been mentioned that this was probably a weak point in the general form of construction adopted.

These observations indicated the behaviour of a properly compacted sub-grade had not been fully appreciated. Mr. Mahbub explained that after all the voids in the soil were filled with water, the volume of voids for a given pressure was called the natural volume of voids. The greater the pressure in the soil, the smaller was the natural volume of voids in it and *vice versa.* Settling would thus take place if the actual volume of voids in the soil was greater than the natural volume when the soil became wet and apparent cohesion ceased. It followed therefore that if a sub-grade was compacted to the natural volume of voids corresponding to the pressure to which it would be subjected, as it normally should be, any entry of additional moisture would not have any harmful effect and would not cause any settlement. If, however, the soil was not compacted to the required natural volume of voids, some settlement might be caused on the addition of moisture. This also accounted for the observations made by Mr. Handa which indicated that there was a maximum moisture content in compacted sub-grades which was not affected by rise in spring level. At this stage, all the voids in the soil were filled with water and any addition displaced an equal quantity of water without causing any further separation of the soil particles.

On page 13, Mr. Khanna had given some calculations to determine the proportion of densest mix to give a certain crushing strength. These, Mr. Mahbub remarked, were not very intelligible, and he asked Mr. Khanna to throw more light on these calculations. The mix worked out by him was 1 : 2·05 : 4·23. It would be interesting to know whether this mix was actually adopted or the standard 1 : 2 : 4 mix was adhered to.

Again on page 14, the typical layout of mixers, shown in Plate III had been mentioned which was, as far as the speaker was aware, adopted on all the Aerodromes in the Aviation Circle. He presumed that Mr. Khanna must be knowing that on the Aerodromes constructed in the U. J. C. a portable wooden platform, with slopes on either side, was used for feeding the mixers. This could be easily moved about, thus avoiding long leads and increasing the outturn. It would have been of interest if Mr. Khanna had also given details of this layout and compared the two with regard to cost and the outturn of concrete.

Mr. R. R. Handa remarked that no mixers were provided for the aerodrome that he had to construct. The whole concrete work was done by hand mixing. He recommended the adoption of the following points in this connection :—

(*a*) No pains should be spared to construct a well-designed water-course as breaches dislocate work very badly.

(*b*) All earthwork and compaction should be finished before concreting was taken in hand and if this was not possible, compaction should be at least 10 days ahead of actual concreting.

(*c*) It was advisable to stack at least 60 per cent of the ballast and sand before starting the work to avoid any dislocation in labour arrangements.

(*d*) When brick ballast was being used, pains should be taken in washing ballast, as otherwise sorkhi which sticks to the surface of the ballast would reduce its strength.

(*e*) Curing was also of great importance.

Proper layout of bins for ballast and sand with mixing platforms for each set and water storage reservoirs was essential. On the aerodrome that he constructed, the ballast stacks were 300′ apart, all on one side, with their floor with an outward slope of 1 in 10.

With the use of brick ballast, he found that in order to obtain the requisite strength of concrete after curing for about 28 days, the ratio of $1\frac{1}{4}$: 2 : 4 was necessary, as indicated by the tests of cubes sent to Rasul.

On the job he had, he made syphons with semi-circular arch roof such that the top of arch was 1′ below the bottom of taxi track masonry, with the usual syphons at both ends. His intention was that these syphons on account of their low level, should also be used for the passage of storm water. During monsoons, the watercourse was needed for the aerodrome. As soon as there was any rainfall, the demand for water ceased and all that the overseer in charge had to do was to send a man to the head of the watercourse to close it. Before the drainage water arrived at the particular sites, he could connect the drains with the syphon and disconnect the watercourse. The disadvantage of this system was the silting up of the syphons, which could however, be cleared periodically.

Mr. C. L. Handa drew attention to the fact that while testing the runway slabs under load, it was important to note that the test area considerably influenced the load that was transmitted to the sub-grade. Thus for a test area of 6″ x 6″ the intensity of load on the sub-grade, would only be half of what it would be if the test area was increased to 12″ x 12″. Similarly for the actual area of contact of aeroplane represented by an elipse of 45″ x 20″, the load intensity would be about $3\frac{1}{2}$ times of what it would be with a 6″ x 6″ test area.

As against the use of the circular ramps overlaid with tramway line for feeding the concrete mixers the speaker had used a ramp with a slope of 1 in 10 for direct loading by coolies. This had proved equally good and also saved tramway track and plant.

Regarding the washing of ballast, the speaker had found that in the absence of steep pipes, wooden troughs could be used with great advantage.

The speaker thought that 1 : 5 mortar had proved too weak for lorry road construction and was crumbling under heavy traffic.

Commenting on the group lorries, the speaker said that except for the Canal Department, all other agencies in this business had no fixed responsibility in the efficient working of the scheme and therefore the combined effect of these was to make the whole show extravagant. For handling such large carriage jobs, it was essential that the payment should have been based on the quantity of material delivered and the owners and other personnel should have been made to suffer for any inefficiency.

Mr. Jesson showed a plan of a runway which he had to construct.

He mentioned that in the kallar reach he decided to excavate the kallar to a depth of 1′ and fill in with sand. The point arose as to whether the sand foundation should be boxed in. The military authorities considered that cross box walls in the 150′ width were not necessary, but they eventually decided to divide the runway into boxes 60′ x 50.′ The box walls consisted of pacca brick masonry 9″ wide resting on a concrete foundation.

In the reach affected by kallar the foundations of the walls penetrated the kallar soil. It was accordingly decided to encase the wall in sand which had been mixed with salt in the proportion of 2 pounds of salt to 2 cubic foot of sand. As the temperatures were very high, precast expansion joints were put in, one at the centre and one at each end of the 150′ width. These joints were made of a mixture of 60 parts of sand to 40′ parts of bitumen.

Lt.-Col. Blench remarked that the idea of compaction had appeared to the engineers engaged on construction of aerodrome and the sub-grades were now being compacted, thus avoiding expensive soling coats.

As for the expansion joints, he said that the treatment of the subject as detailed on page 17 of the paper was interesting. It was a deviation from the accepted principle that concrete slabs must be given expansion joints but it had been shown in the paper that their necessity actually did not exist.

He wanted to know further if wooden strainers, which was another new idea adopted by the Irrigation Branch, were actually considered a success.

Mr. D. C. Khanna remarked that from a perusal of the paper it seemed that the absorption and evaporation losses had not been taken into account while fixing the capacity of storage in settling tanks. He added that it had been mentioned that the filters were proposed to work far 12 hours daily. The normal practice was to work the filters throughout the 24 hours as unless this was done the standing water on the filter-bed would drain away to the clear water or chlorinating chamber. This could, however, be avoided by shutting down the outlet from the filter after the filter had been worked for 12 hours. He wanted to know if any such arrangement had been done and expressed the opinion that the process of filtration would be much more efficient if the filters were worked continuously.

He went on to state that the storage and sedimentation tanks would have to be much deeper if provision had been made for evaporation and absorption losses, which would have involved complication in their design in waterlogged areas. In larger schemes it was a common practice to pump the raw water from the storage and sedimentation tanks into a high level raw water storage tank of suitable capacity and let this water flow by gravity on to the filtered beds which could be built partially above ground level thereby reducing the depth of clear water reservoirs. This system was useful in localities where spring level was high. He added that rainforced brick-cum-concrete reservoir would have been better than the wooden overhead reservoir as it would have been absolutely water-tight and more lasting.

Mr. G. R. Nangea then went on to describe some of the problems faced by the B. & R. branch on the aerodrome construction in their charge. One of the main problems was the acute shortage of water supply. There were only a few wells in the area and the water-line was 50′ below the level of the plain. The yield of most of these wells was 1500 to 2000 gallons per 24 hours. Sometimes bores put at a depth of 200′ did not result in any appreciable improvement.

As the top clay was absent in the bed of *nallahs* so it was decided to dig a 30′ diameter well in the sandstone bed as close up the bank as possible. A 25′ high earthen dam (with a proper spill cut in the sandstone bank) was constructed upstream and this created a lake about a mile in length with 10′ depth of water which saturated the sandstone bed and ensured enough static head to help quick recoperation. To increase the infiltration area, in some cases, galleries were dug in the sandstone sides or holes bored 50′ deep put in the bed of the well. The yield of each of these wells was over 30,000 gallons per 24 hours.

The sub-grade was prepared with proper camber, ponded and rolled with 10 ton Steam Road Rollers. On one of the aerodromes constructed by the B. & R. branch cement concrete specification with staggered joints was adopted while others were completed in built-up spray grout work using Mexphalt 80-100 penetration. The expansion joints in the case of cement concrete were thoroughly cleaned up to the bottom and filled up with mexphalt and sand.

The taxi-tracks were built of 4″ stone-soling and 2½″ stone wearing coat consolidated as built-up spray grout.

In places where the percentage of sand content in the soil was excessive it was decided to do *gilafi* work on all exposed walls and to cement or lime-point them. This was done as rains play havoc on the sun-dried brick-work. He went on to add that the 'group lorry scheme' as originally initiated proved very costly.

Mr. H. A. Harris remarked that the system adopted for the execution of works in the two branches was different. In the I. B. it was done on a work order basis whereas in the B. & R. for all works exceeding Rs. 5,000 the execution was almost universally done through the contract-system on a percentage tender for item rates. For all air field buildings however, the B & R. followed the M. E. S. system and provided a plinth area rate in their contract.

He stated that the total expenditure on a completed airfield would be in the neighbourhood of 38 lacs.

Three specifications had been adopted for runways as detailed below:—

(*i*) 6″ soling with 4″ metal consolidated to built-up spray penetration with 4 spray coats of bitumen, aggregating to between 60 to 70 lbs per 100 sft. The cost of this specification had worked out to Rs. 47 per cent sft.

(*ii*) 4″ soling with $2\frac{1}{2}$″ wearing coat with 4 spray coats, aggregating to 60 lbs. per cent sft. This had cost approximately Rs. 31 per cent sft.

(*iii*) 4″ cement concrete slab 1 : 2 : 4 mix laid over a compacted formation—cost Rs. 46 per cent sft.

The plinth area rate for some of the buildings was as follows :—

	Rs.	a.	p.	
Workshop with Belfast trussed roof ..	3	9	0	per sft.
Officers' quarters.	2	8	0	,,
Office and Sergeants' Mess	2	3	0	,,
Stores including shelves	2	6	0	,,

In replying to the discussion, Mr. Khanna remarked that there were conflicting views regarding the care to be taken in sealing the joints of slabs of runways.

Mr. Roy was of the opinion that no pains should be spared in sealing the joints and in view of the magnitude of the work involved he seemed to be inclined to favour premix tar macadam in preference to concrete runways.

Mr. Mahbub on the other hand had explained that for a properly compacted sub-grade moisture would not do any apprecia ble harm.

The following two points had to be considered in actual practice :—

First, imagine a heavy bomber landing on a runway during or just after a heavy downpour. The sub-grade was compacted to natural volume for this load with the result that additional quantity of water would not be absorbed in the voids of the compacted sub-grade and would need to be expelled. This would naturally need some time. If the landing took place before the required time lag, failure would occur.

Secondly, theoretically it was very well to say that every portion of the sub-grade should be compacted to the natural volume but with the varying conditions of soil from place to place it was very difficult, if not impossible to ensure this being done on a rush job like this. Certain standards of compaction had to be followed and these could not be varied at every step. Hence it was necessary to seal the joints on the principle of " Safety first."

Regarding the other points raised by Mr. Mahbub, Mr. Khanna remarked that he never attempted to give detailed calculations for the densest mix. The formula as given on page 13 of the paper was derived for the particular samples of sand and ballast with fineness modulus of 1·75 and 7·33 respectively according to the principles explained in the Congress Paper No. 250 by Mr. Holman.

He went on to say that he could not get an opportunity to visit the aerodromes constructed by the Upper Jhelum Canal and was therefore unable to give an opinion about particular arrangement adopted there.

Replying to Mr. R. R. Handa, Mr. Khanna remarked that the greater the distance from the Railway Station, the longer would be the lead involved in carriage of materials like cement, timber, slack coal etc. This meant increased cost apart from the difficulties of transport.

As for the water supply arrangement, he thought he had said enough in the paper. The sites like Mr. Handa's which were commanded by Canal water were in a much happier position than the uncommanded sites where tube wells had to be sunk.

Mr. Handa had mentioned that the mix of $1\frac{1}{4} : 2 : 4$ was adopted for brick ballast where hand mixing was done. This was necessary to obtain the specified crushing strength of 2800 lbs sq″ at 28 days.

This raised the important point of hand mixing versus machine mixing. There was no denying the fact that machine mixed concrete was always preferable to hand mixed and from this points of view hand mixing was resorted to only when no more concrete mixers were forthcoming to be employed on the work.

Replying to **Mr. C.L. Handa's** remarks, Mr. Khanna went on to say that he had already stated on page 12 of the paper that tests on a small scale did not test the sub-grade adequately, as the smaller the bearing area under test, the less was the transmission of load per square foot. For practical purposes the results given by field tests were considered fairly representative.

As for the ramp of 1 in 10 for direct loading by coolies his experience was that coolies soon got tired with this arrangement which ultimately retarded the progress. This was the reason why practically every where in the Aviation Circle circular ramps overlaid with tramway line were used.

It was probably true that 1 : 5 cement mortar had proved too weak for lorry road construction.

The Group lorries were of great use for carriage of materials. As he had stated on page 31 of the paper it would have been easier to work the scheme if the lorries had been taken over and worked by one central agency instead of the dual control that made things a little bit difficult.

Regarding **Mr. Jesson's** remarks it was difficult to comment on the particular design adopted for the sub-grade on the particular Emergency Landing ground in question, in the absence of full details.

The idea of dividing the runway into smaller compartments on a *kallar* like seemed good. One foot of sand should be sufficient to prevent *kallar* coming up.

It had been shown by calculations on page 17 of the paper that for a range of temperature of 93° F above and below the temperature at which concrete was laid, necessity for expansion joints did not exist. Surely temperatures in Bahawalpur State did not extend over a bigger range.

Referring to the remarks by **Lt.-Col. Blench,** he stated that it was gratifying to note that the idea of compacting the sub-grade had appealed to the engineers engaged on construction of landing grounds on a large scale, as this would lead to saving in money and transport of the materials required for soling.

Similarly by adopting alternate slab construction and avoiding use of expansion joints large quantities of bitumen have been saved.

As for the wooden strainers these had proved a complete success and were being used now on a large scale in thousands of tube wells being sunk by the Irrigation Branch.

Replying to **Mr. D. C. Khanna** the speaker remarked that the tanks used for storage purposes were of wood where there would be no absorption as the tanks had to be kept always full of water. There would no doubt be some losses due to evaporation which would also be very much reduced as the tanks are covered with a wooden roof. This was clear from the drawing given on Plate X.

The losses in this case would therefore be very small as compared to an open masonry or concrete tank. These would easily be off-set against the liberal figure of 25000 gallons of daily consumption which was later on restricted to 20,000 gallons only. The capacity of the tanks was therefore ample.

Sluice valves had been provided as was clear from the list of stores given on page 27 of the paper.

As for the capacity of filters, these were given as 1 to 2 gallons per sq : ft : If the lower figure was taken, the filters would need to be worked more or less continuously. In any case in view of divergent figures for the capacity of filters, as given by different authorities, no risk could be taken in the size of the filters.

The suggestion put forward by Mr. D. C. Khanna for construction of storage reservoirs in areas of high spring level was useful.

Economy in steel, so scarce during war days, led to the adoption of wooden over-head tanks as opposed to concrete tanks. It was believed that the wooden tanks constructed according to the design given in the paper, when properly tamped, were reasonably water-tight, though personally he did not have the opportunity of seeing them actually in use.

He went on to say that the account given by Mr. Nangea of the particular specifications adopted by the B. & R. and the difficulties encountered during course of construction, especially of making water supply arrangements, were interesting.

As expansion joints had been used by him on the concrete runways he could afford to stagger the transverse joints. But all this meant more money and time in construction. The quantity of Bitumen required for all the aerodromes, if expansion joints had to be provided every where, would run into very large figures.

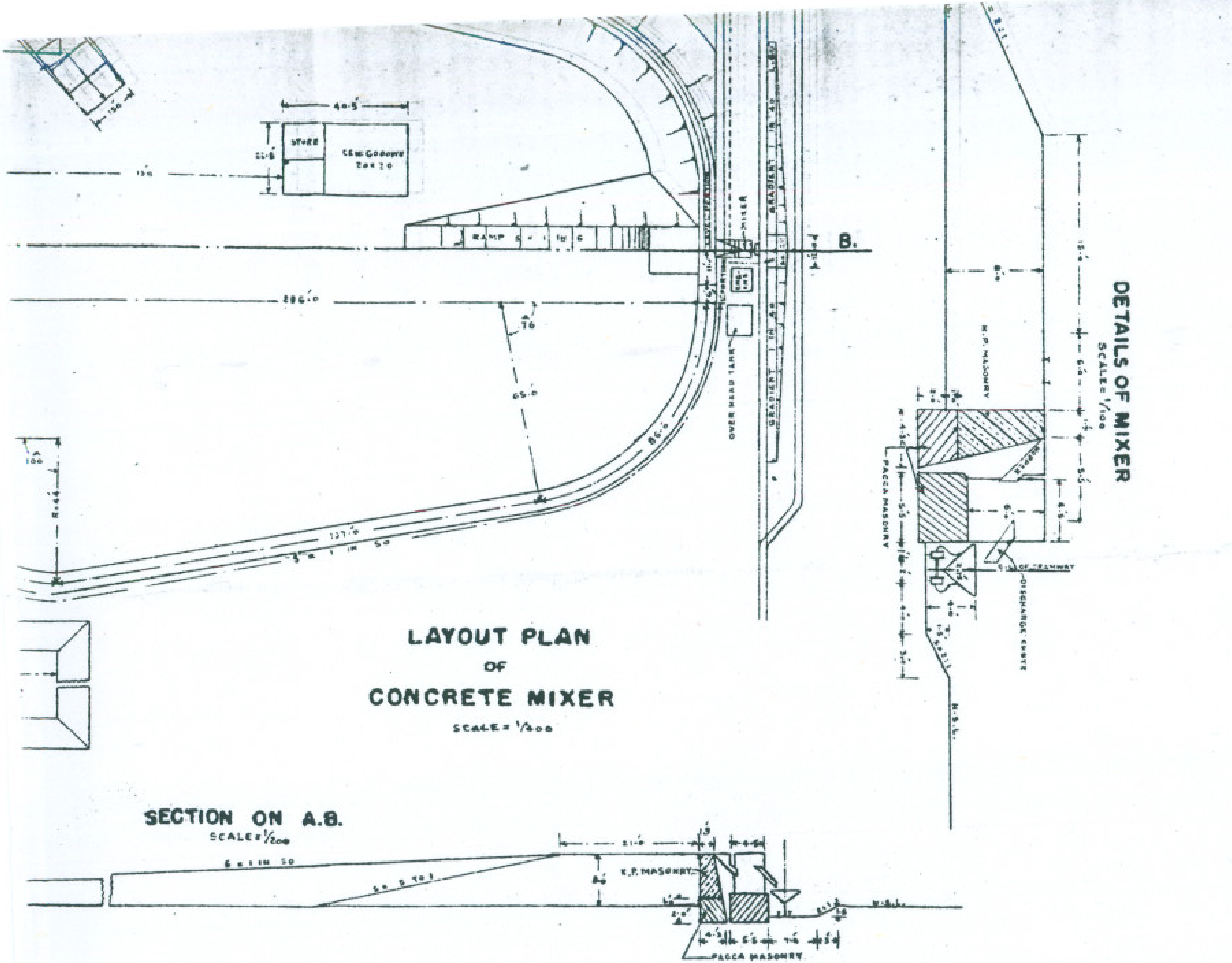
It would have been interesting to know the figures of cost for the completed aerodrome in that case.

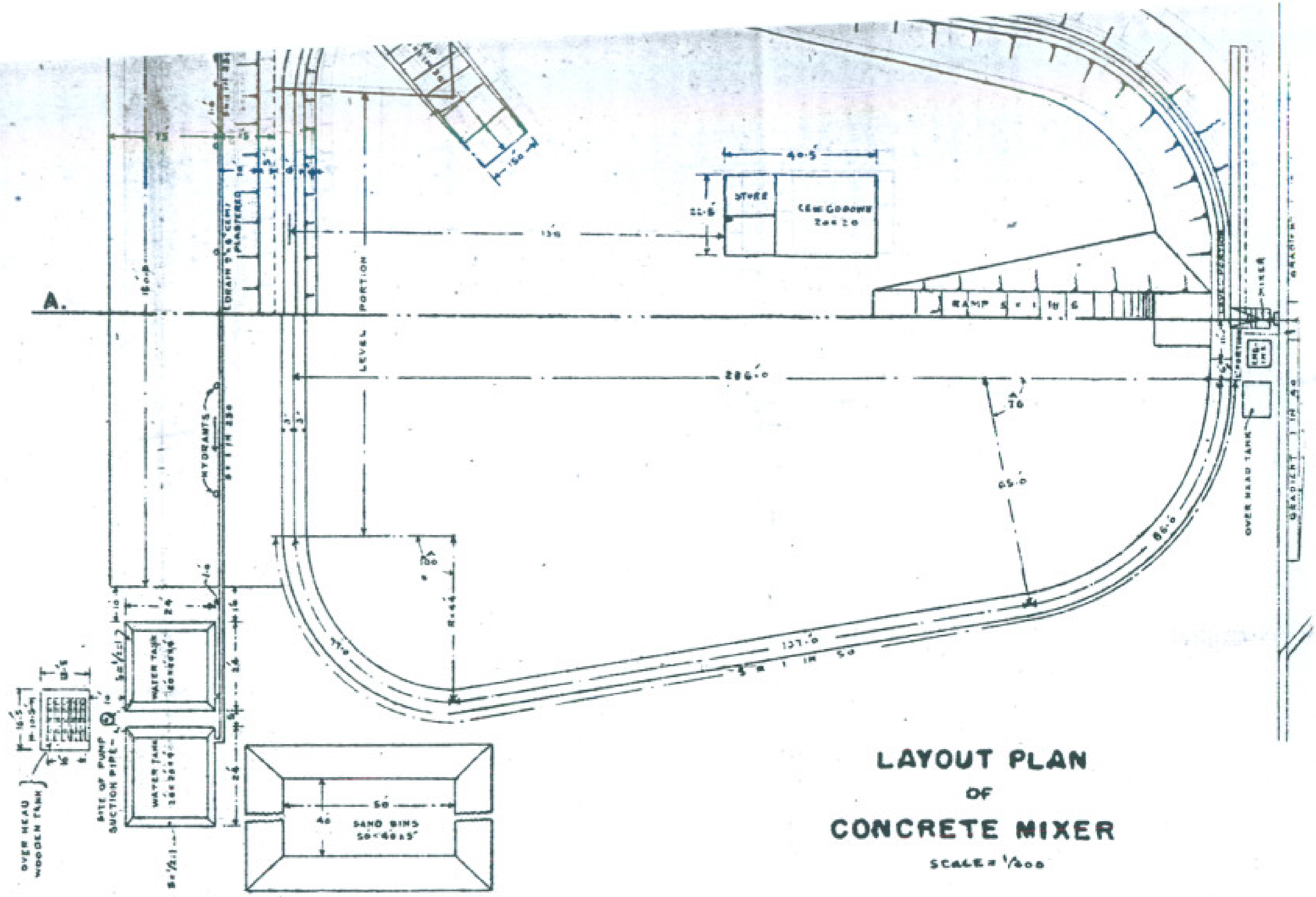
Replying to **Mr. Harris,** he added that the B. & R. Branch did very well in following the M. E. S. system and giving out contracts for buildings on plinth area rates. This naturally avoided all accounts complications which had been a source of great nuisance in the Irrigation Branch. With the work order system where every individual item of these buildings had to be separately recorded, the work involved was very laborious.

He has afraid he had not got with him the figures for over-all rates to compare them with the B. & R. Comparison might be possible only in case of buildings and runways. Further, it was not clear if compaction of sub-grade had been done by the B. & R., by which he meant compaction as distinct from mere consolidation of earth work, according to the details given in the paper. This was because with proper compaction of sub-grade there was no further necessity to lay any soling coat as per items (*a*) and (*b*) given by Mr. Harris.

Labour rates as paid by the Aviation Circle had been given on page 32 of the paper and the cost of a completed operational Aerodrome under various sub-heads has been given on page 33. Here again a strict comparison of the rates paid in the two Branches of P. W. D. was not possible in view of difference in leads involved in carriage of materials and of coal required for burning bricks. For the aerodromes constructed by the Irrigation Branch stone ballast and even sand in some cases had to be carried by rail over long distances. It might be added that the cost of accommodation as given on page 33 of the paper included cost of constructing hardstandings as well. This was because hardstandings had been grouped with 'accommodation' in Engineer-in-Chief's Technical Instructions.

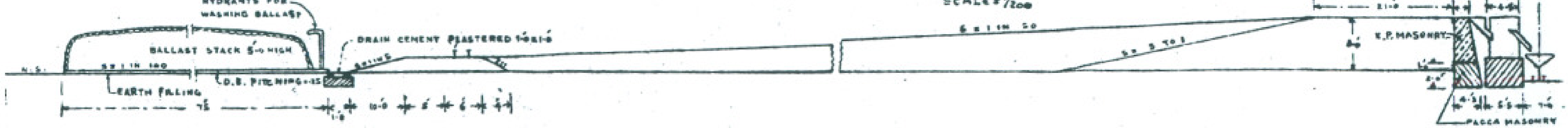
Again, Mr. Harris had not made it clear if the probable figure of 38 lacs for one completed aerodrome was for an operational station as distinct from a Lay back where only one runway was required in pacca and further if the figure included cost of Camouflage and Furniture which were M. E. S. responsibility, also for land contingencies, work charged establishment, planning, Audit and Account Charges.

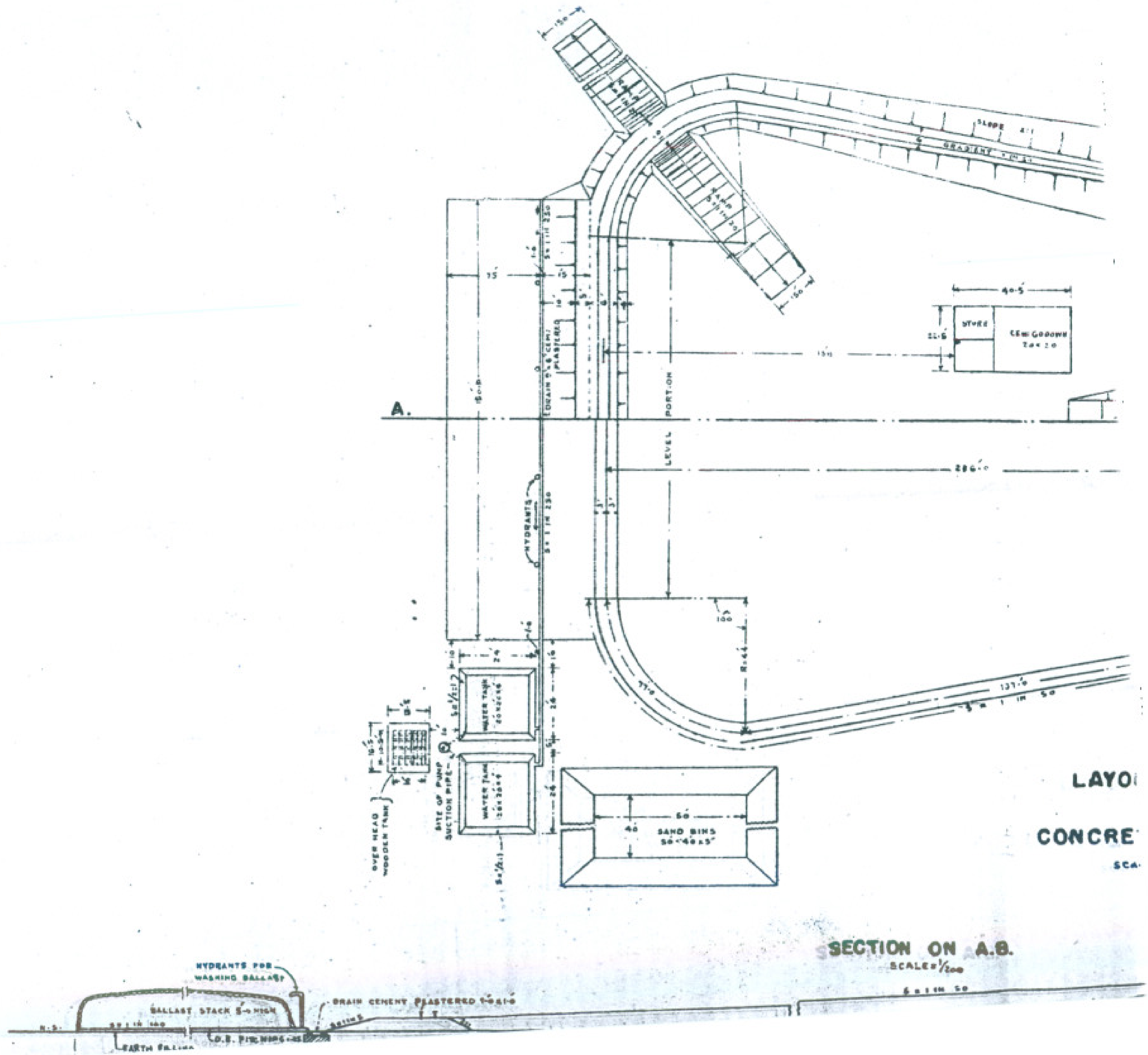

LAYOUT PLAN
OF
CONCRETE MIXER
SCALE = 1/200
DETAILS OF MIXER
SCALE = 1/100
SECTION ON A.B.
SCALE = 1/200
RAMP
GRADIENT 1 IN 40
MIXER
OVER HEAD TANK
STORE
CEM. GODOWN
K.P. MASONRY
PACCA MASONRY
HOPPER
DISCHARGE CHUTE
N.S.L.
B.



LAYOUT PLAN
OF
CONCRETE MIXER
SCALE = 1/400

SECTION ON A.B.
SCALE = 1/200





LAYO
CONCRE
SCA
A.
LEVEL PORTION
HYDRANTS
STORE
CEM. GODOWN
SAND BINS
WATER TANK
WATER TANK
SITE OF PUMP SUCTION PIPE
OVER HEAD WOODEN TANK
SECTION ON A.B.
HYDRANTS FOR WASHING BALLAST
BALLAST STACK 5'-0" HIGH
DRAIN CEMENT PLASTERED
EARTH FILLING

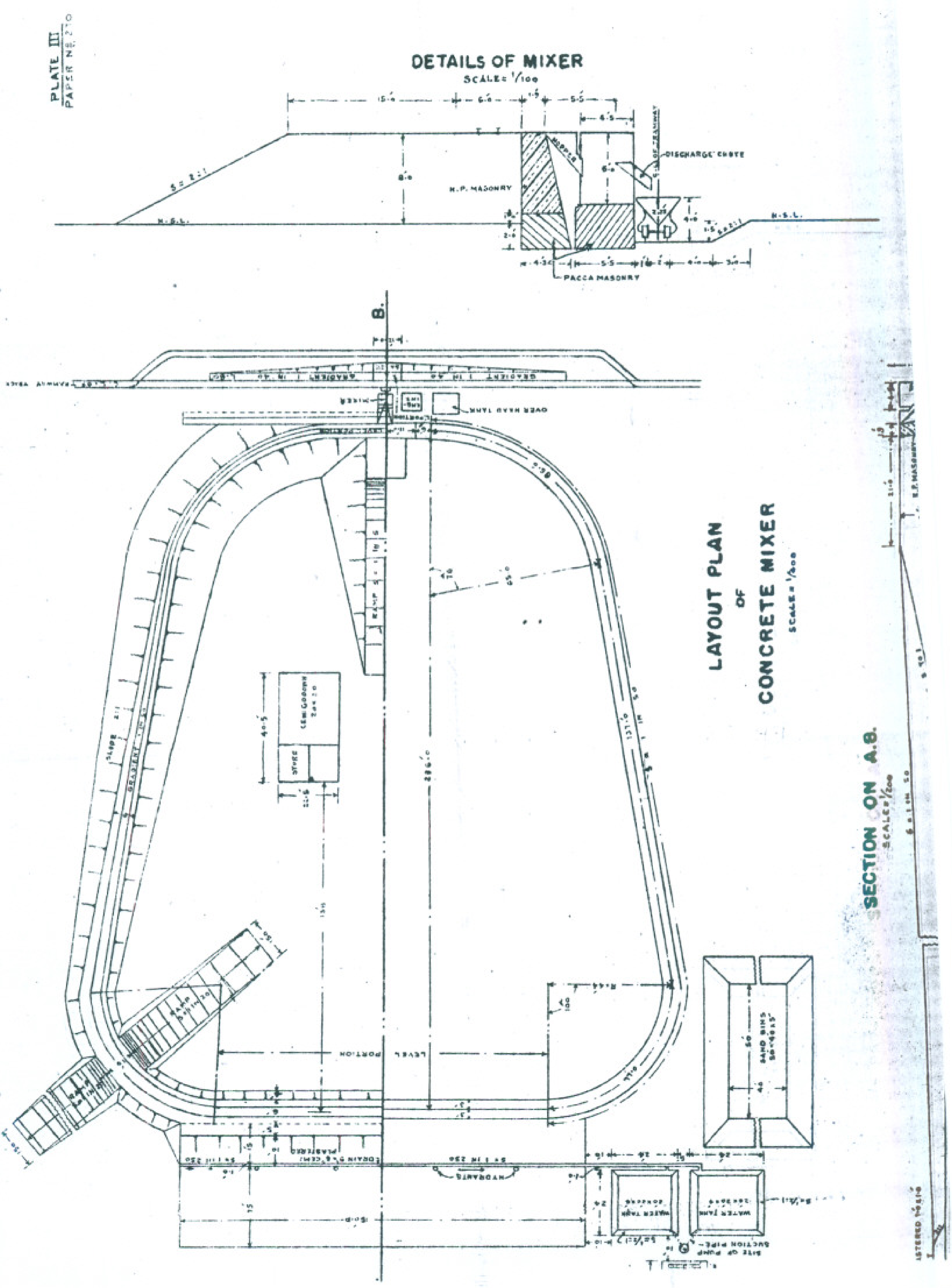
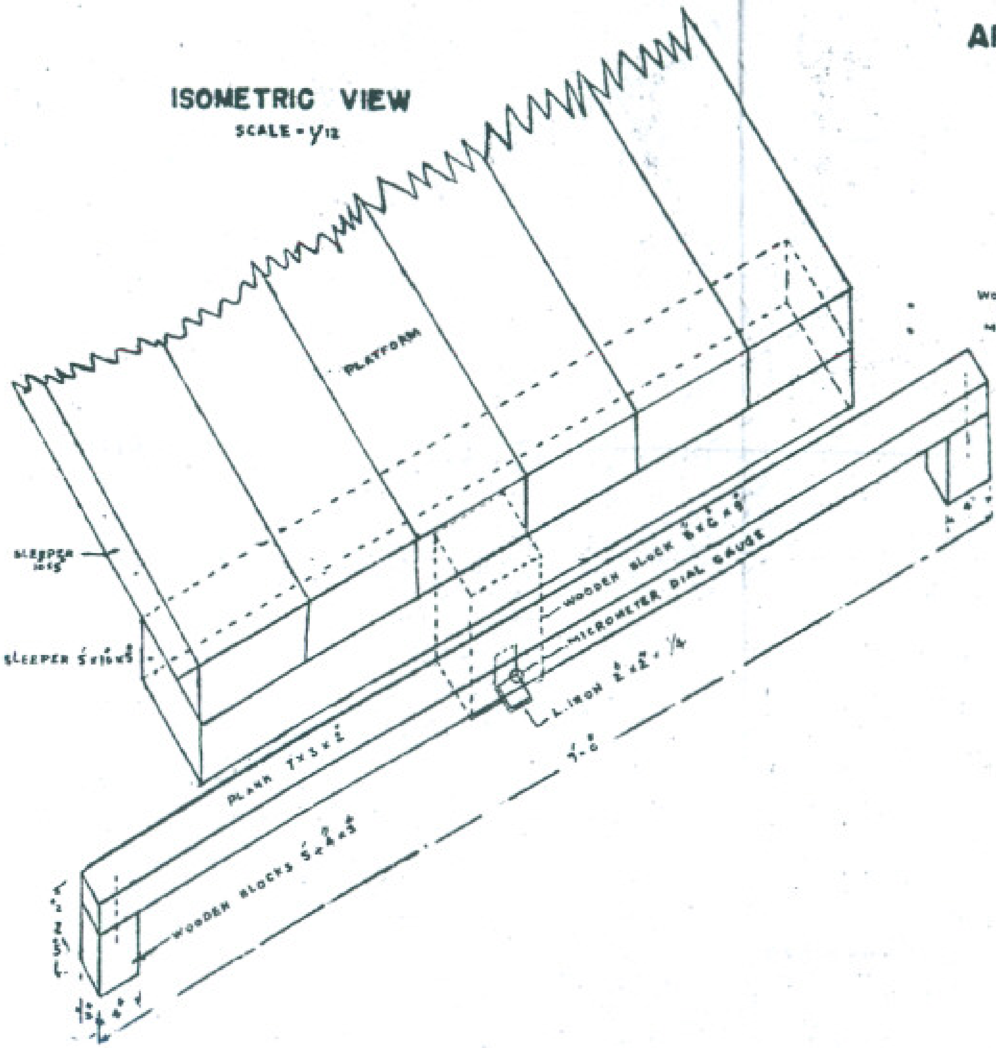
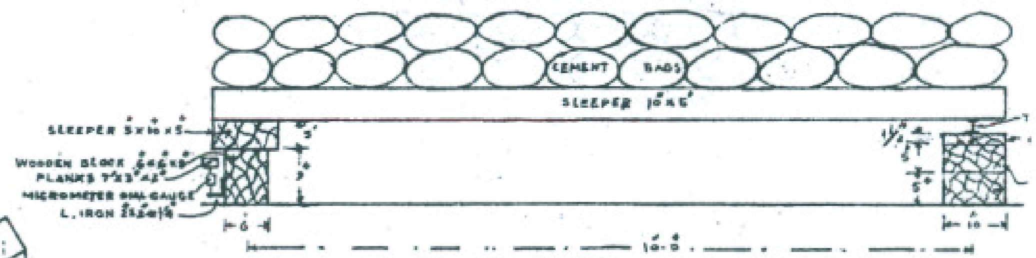


PLATE III
PAPER No. 210
DETAILS OF MIXER
SCALE = 1/100
H.P. MASONRY
HOPPER
DISCHARGE CHUTE
PACCA MASONRY
H.S.L.
LAYOUT PLAN OF CONCRETE MIXER
SCALE = 1/200
MIXER
OVER HEAD TANK
CEM. GODOWN
STORE
LEVEL PORTION
SAND BINS
WATER TANK
HYDRANTS
SECTION ON A.B.
SCALE = 1/200

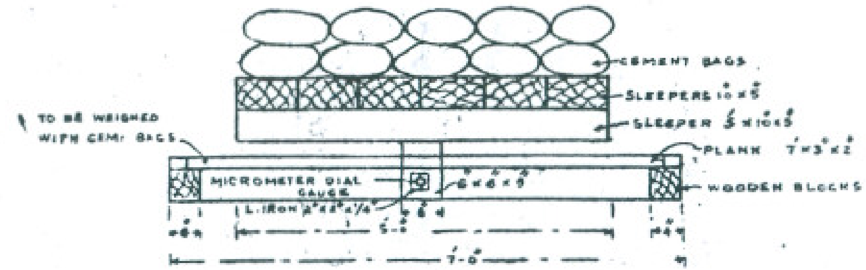
APPARATUS FOR MAKING BEARING TESTS ON SOILS AND PAVED SURFACES



ISOMETRIC VIEW
SCALE = 1/12

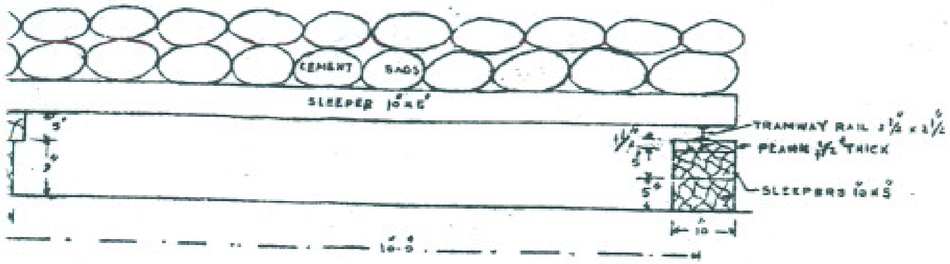


SIDE ELEVATION
SCALE = 1/25



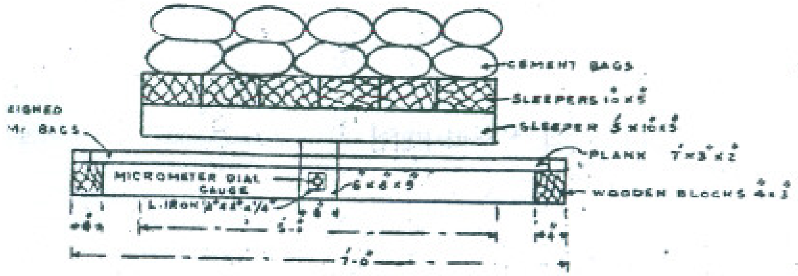
FRONT ELEVATION
SCALE = 1/25

R MAKING BEARING TESTS
ND PAVED SURFACES



SIDE ELEVATION

SCALE 1/25



FRONT ELEVATION

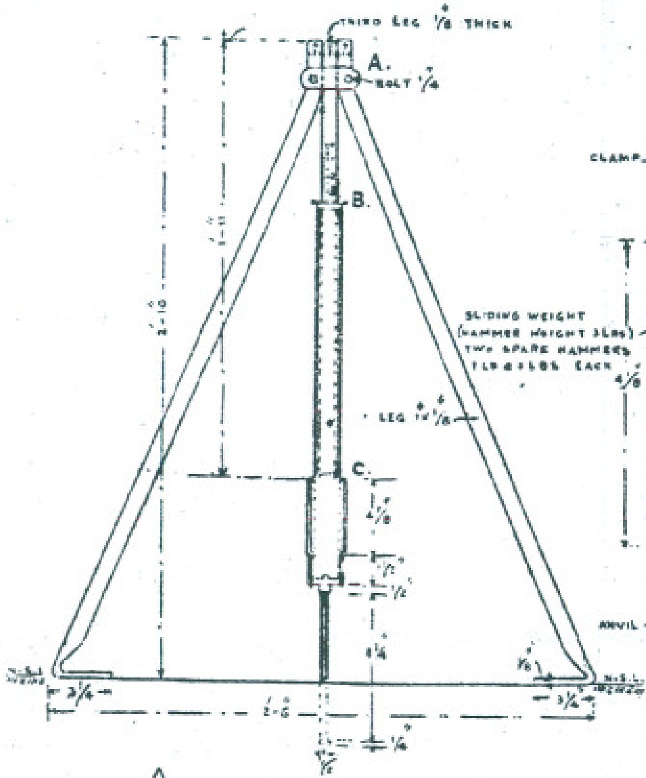
SCALE 1/25

PENETROMETER

PLATE IX
PAPER No 290

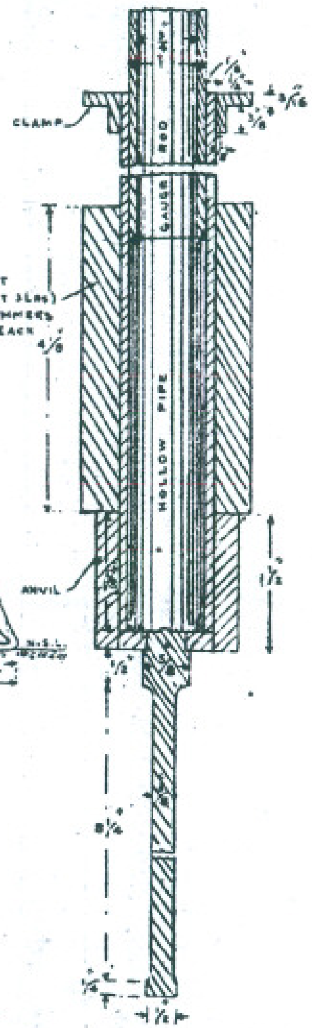
ELEVATION

SCALE 1½"=1 FOOT



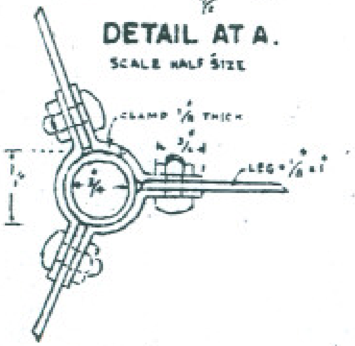
DETAIL AT B.&C.

SCALE HALF SIZE



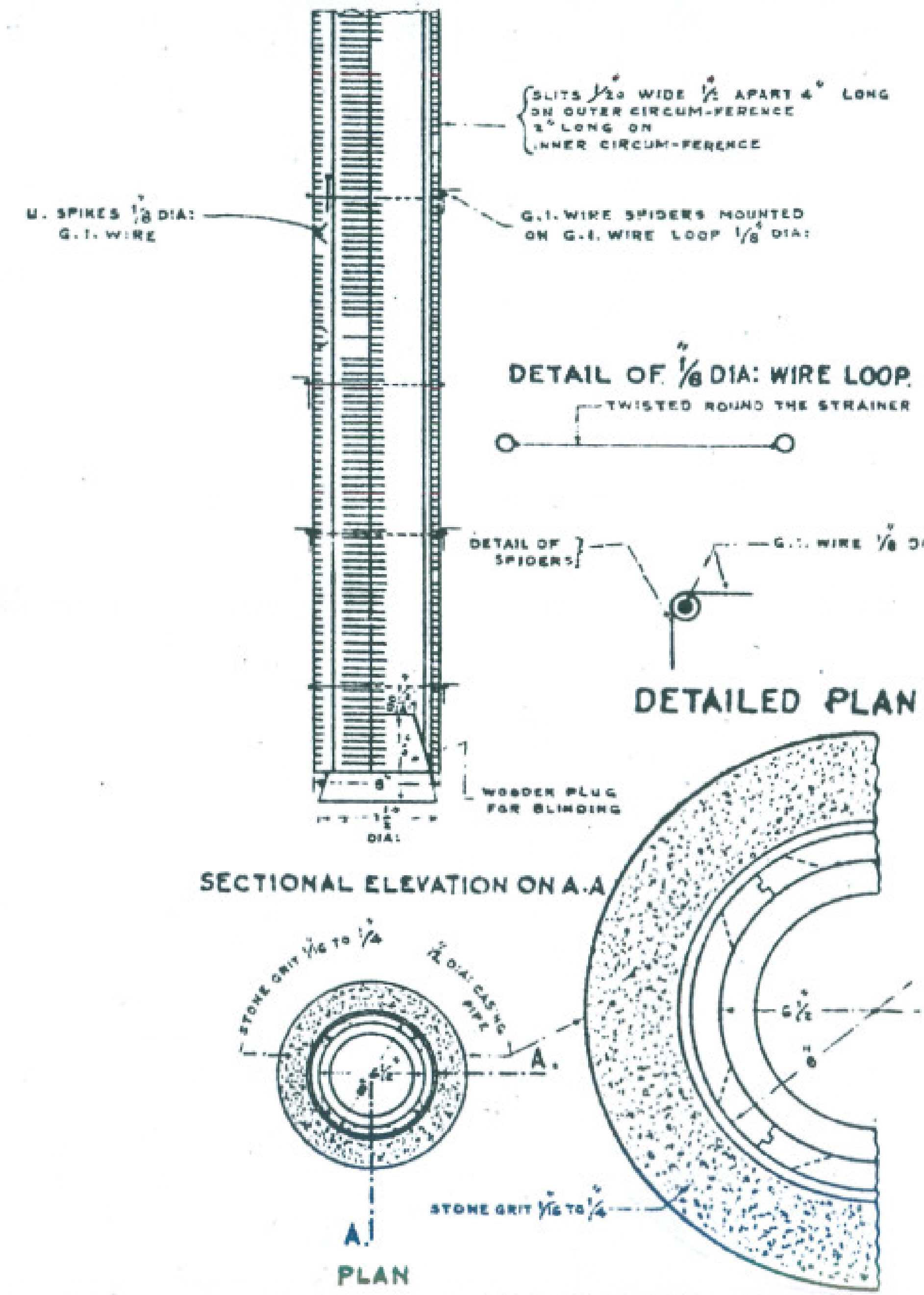
DETAIL AT A.

SCALE HALF SIZE



SKETCH OF 8" DIA: WOODEN STRAINER

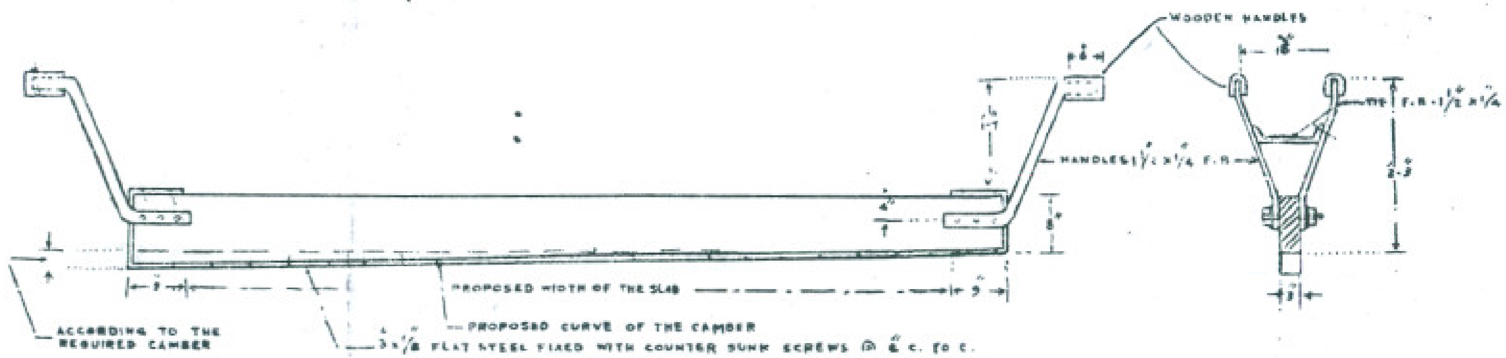
PLATE V
PAPER No 270



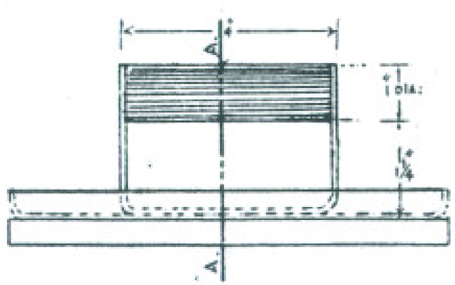
PUNJAB ENGINEERING CONGRESS 1944

DETAILS OF CONCRETE TAMPER, EDGING TOOL

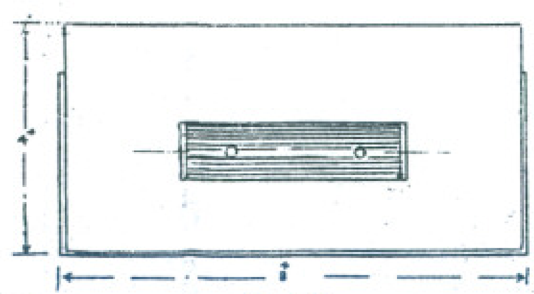
HAND TAMPER (HALF WIDTH)



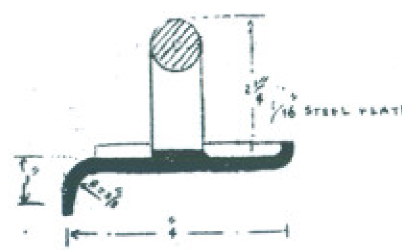
EDGING TOOL



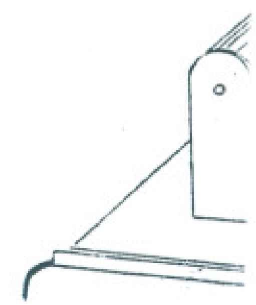
ELEVATION



PLAN



SEC: ON A. A.



PERSPECTIVE V

PLATE VI
PAPER No. 270

DETAILS OF CONCRETE TAMPER, EDGING TOOL AND SLUMP CONE

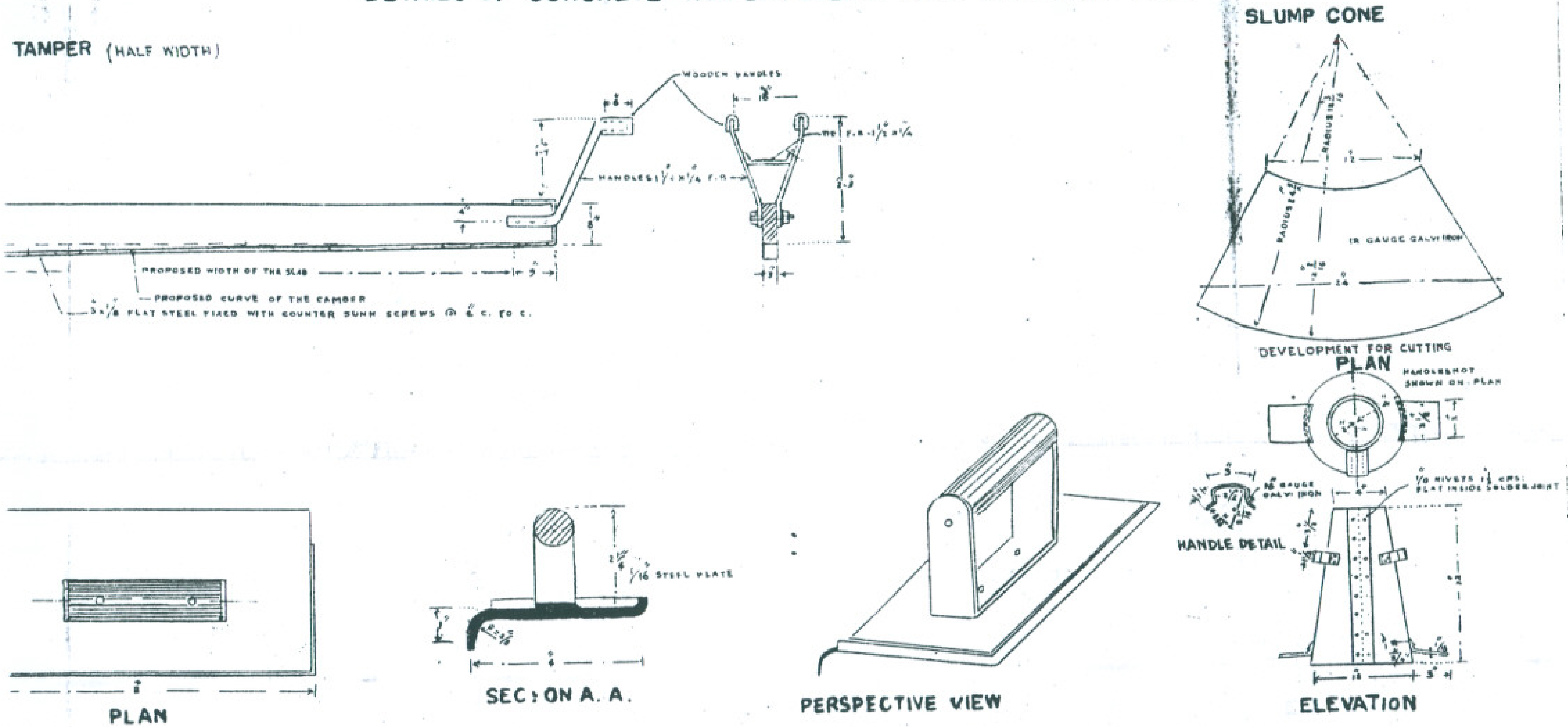
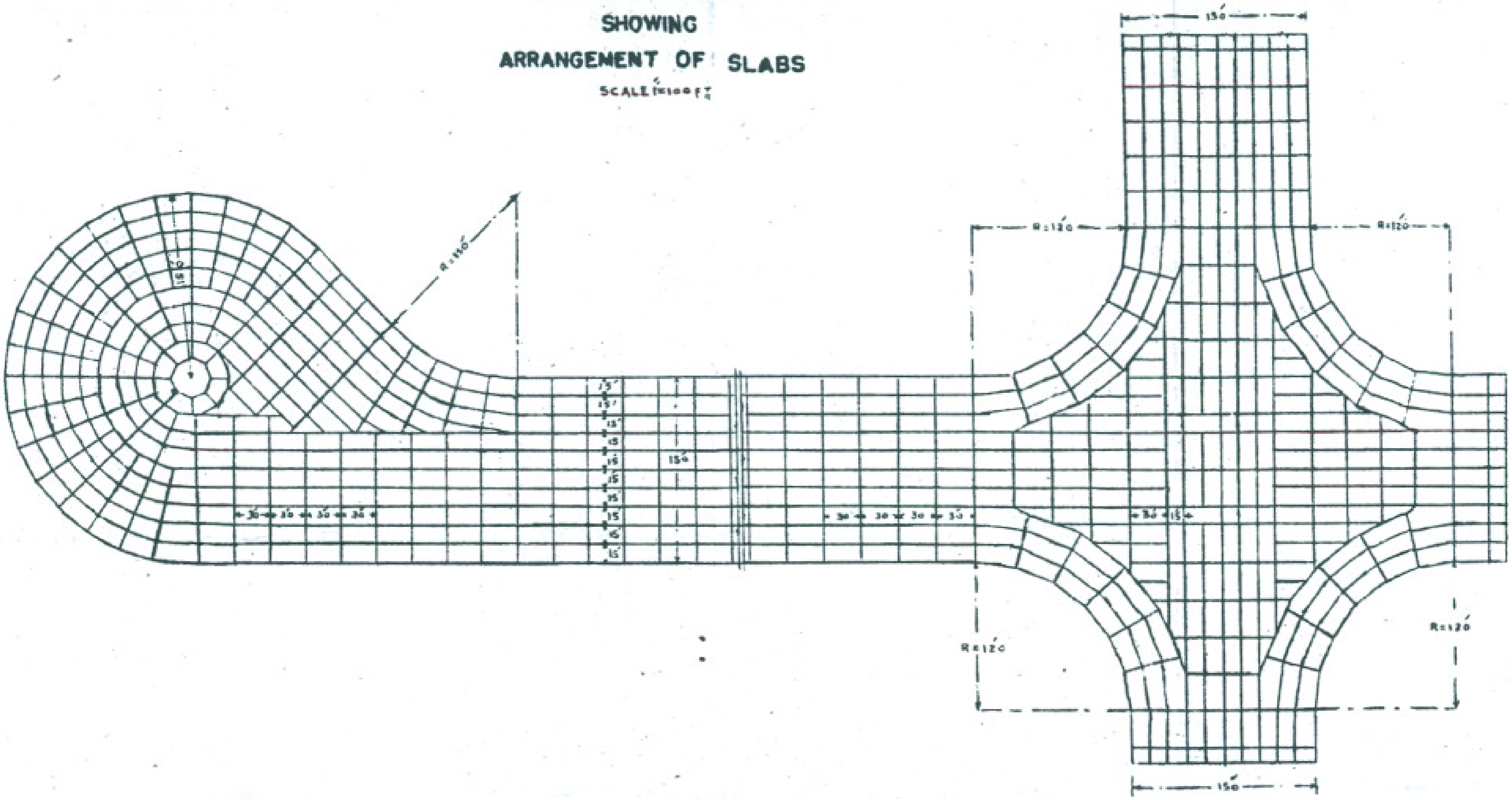


PLATE VII
PAPER No. 270

SKETCH OF RUNWAYS SHOWING ARRANGEMENT OF SLABS

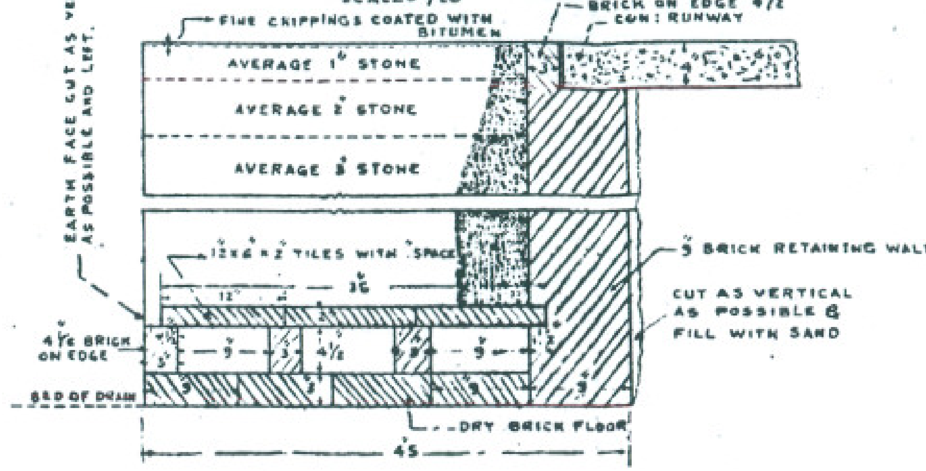
SCALE 1" = 100 FT.



PUNJAB ENGINEERING CONGRESS 1944

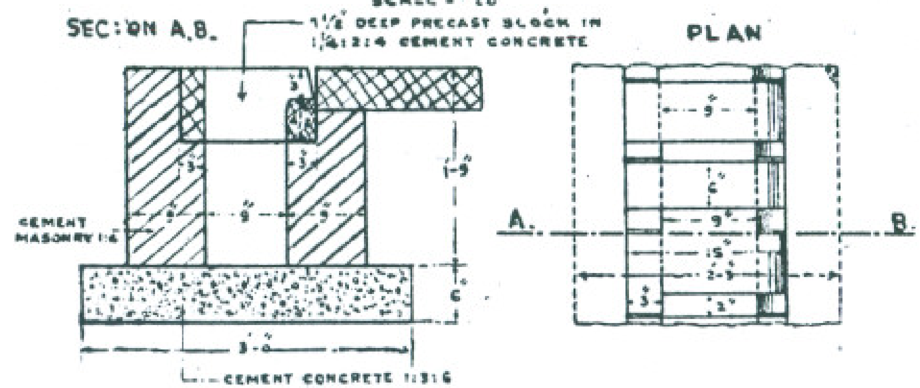
ORIGINAL DESIGN OF FRENCH DRAIN

SCALE = 1/20



REVISED DESIGN OF FLUME TYPE DRAIN

SCALE = 1/20



DESIGN OF CULVERT UNDER TAXI TRACK

SCALE = 1/20

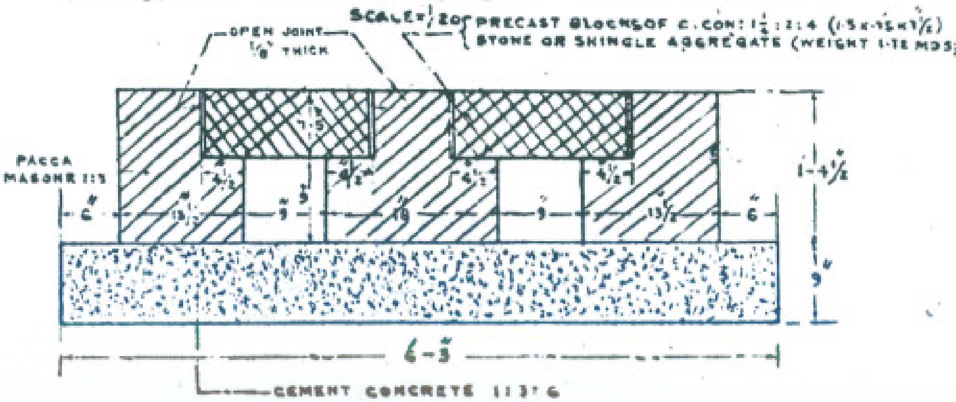
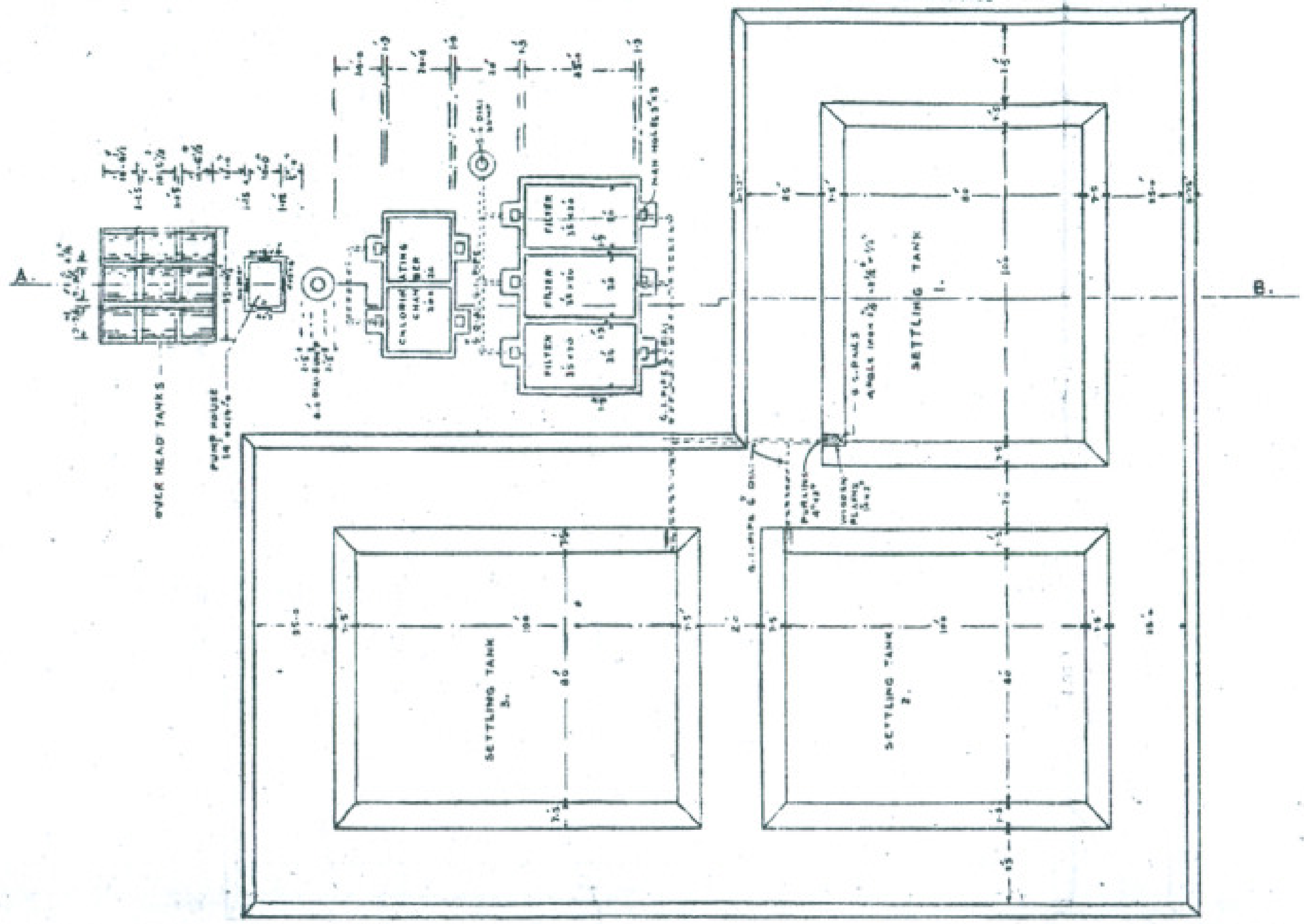


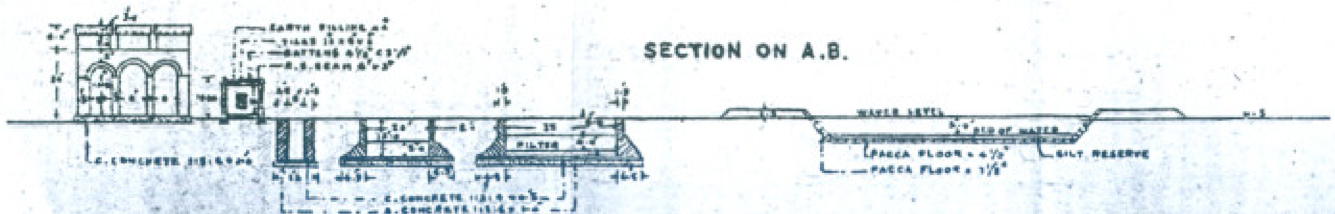
PLATE IX
PAPER No. 270

DETAIL OF WATER SUPPLY ARRANGEMENT SETTLING TANK CUM FILTERED SUPPLY

SCALE: 1/500



SECTION ON A.B.



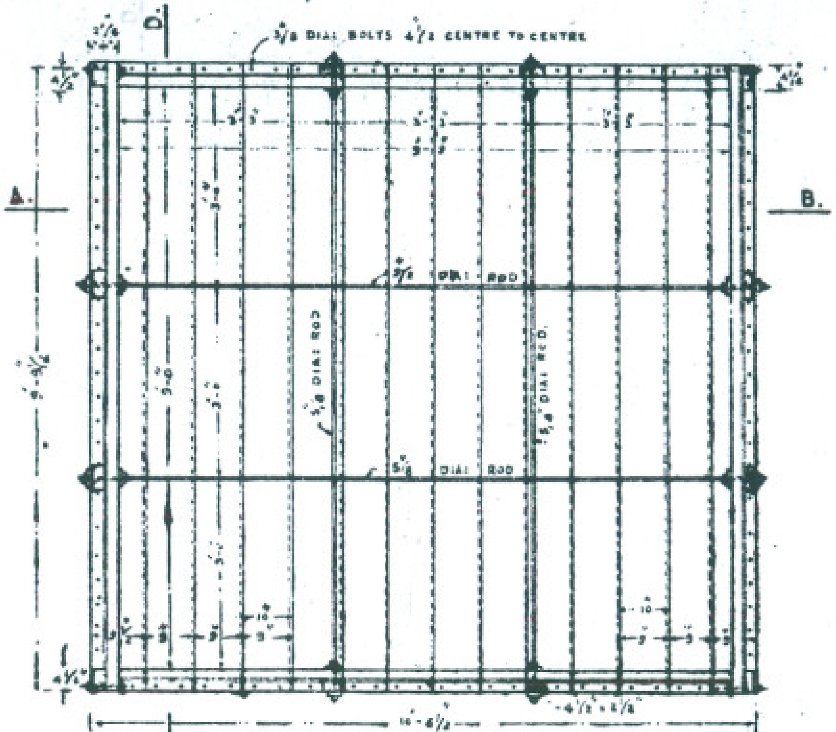
PUNJAB ENGINEERING CONGRESS 1944.

PLATE X

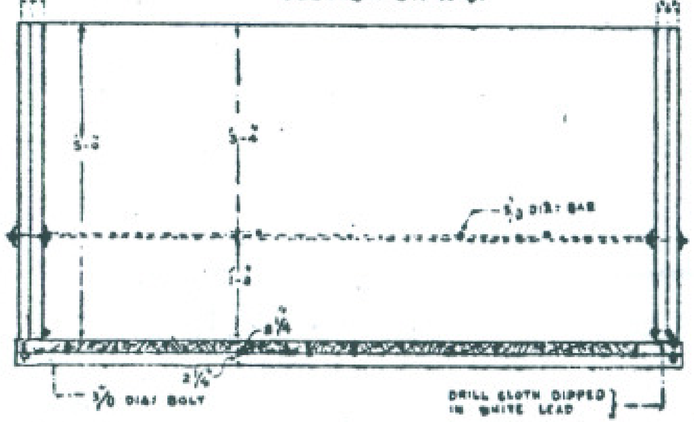
PAPER No. 270

DETAIL OF OVER HEAD WOODEN TANK

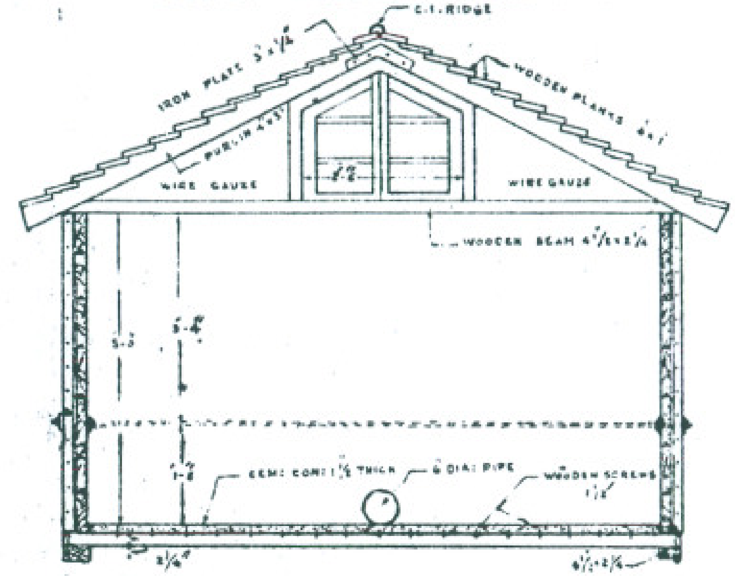
SCALE 3/8" = 1 FOOT



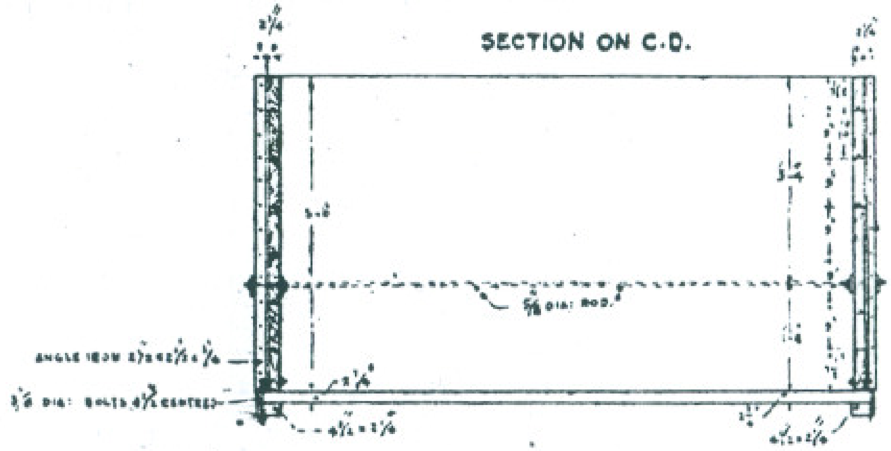
SECTION ON A.B.



SECTION THROUGH OVER HEAD TANK



SECTION ON C.D.

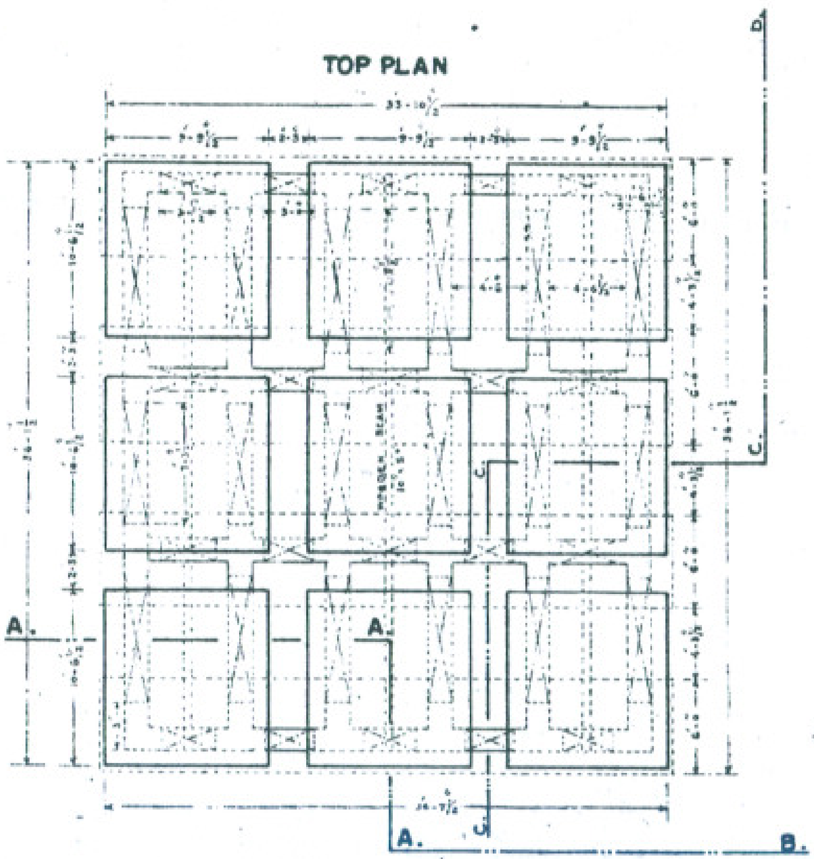


PUNJAB ENGINEERING CONGRESS'

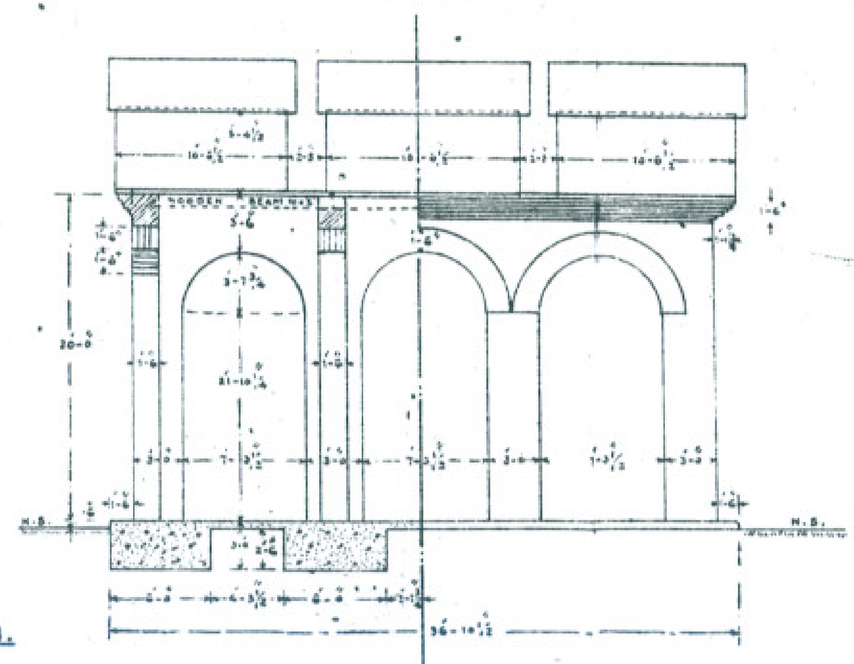
DESIGN OF WA
FOR
OVER HEAD WATER
SCALE 1/8"

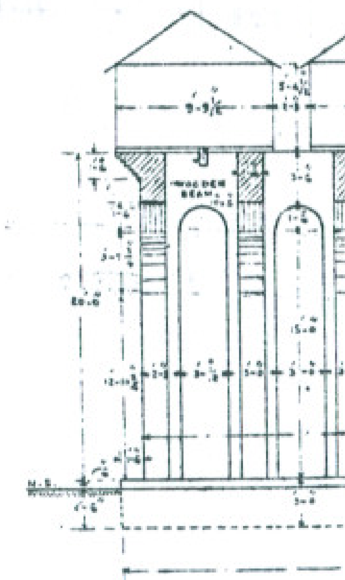
SECTIC

TOP PLAN



SECTION ON C.D.





DESIGN OF WATER TOWER FOR OVER HEAD WATER SUPPLY TANKS