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from the EDITOR

The opening of Highways Research Station by our Chief Minister Sri K. Kamaraj under the presidentship of Sri Kakkan, Minister for P. W. D. Madras marks a very important land mark in the advancement of Road Research not only in this state but in the whole country as this Institution is the second of its type and the very first on a Regional basis, devoted to Road Research in India.

It has been recognised from last decade or two that Engineering Research plays a vital role in the economy of a country and indeed it can be classified as a primary need of man as any result that is obtained from thoughtful and devoted research affects the well being of man. In the context of present day advancements in technology not a few are the results of research work patiently perused.

As has been in other fields, so also in Road Engineering, fundamental studies and application of results of Research have opened out new vistas of knowledge. This new knowledge has not only thrown new light on old problems but also has enabled Road Engineer to design and construct structures consistent with economy and safety. Highway Structures make use of naturally obtained materials which vary in their properties. For example the properties of soil not only vary from place to place, but also from depth to depth and from season to season. It is clear Institutions devoted to Road Research will have to tackle problems arising out of the varied physical features of our country.

Hence it was, that proposals were put forward for the establishment of Highways Research Station in June, 1951 and Government of India agreed to the scheme in 1952. The cost of the building and equipment is Rs. 17 lakhs.

Primary aim of this Research Institution is to cheapen the cost of construction and maintenance of roads and bridges. The applied Research work of the station is divided into four sections

(1) Physical division which will deal with the Physical properties of road meterials, surface characteristics and safety problems of Roads (2) Concrete division which will deal with all problems of concrete road construction (3) Bituminous division which will deal with research on bituminous road construction and materials connected therewith (4) Soils division which will deal with properties of soil and problems connected with soil Engineering.

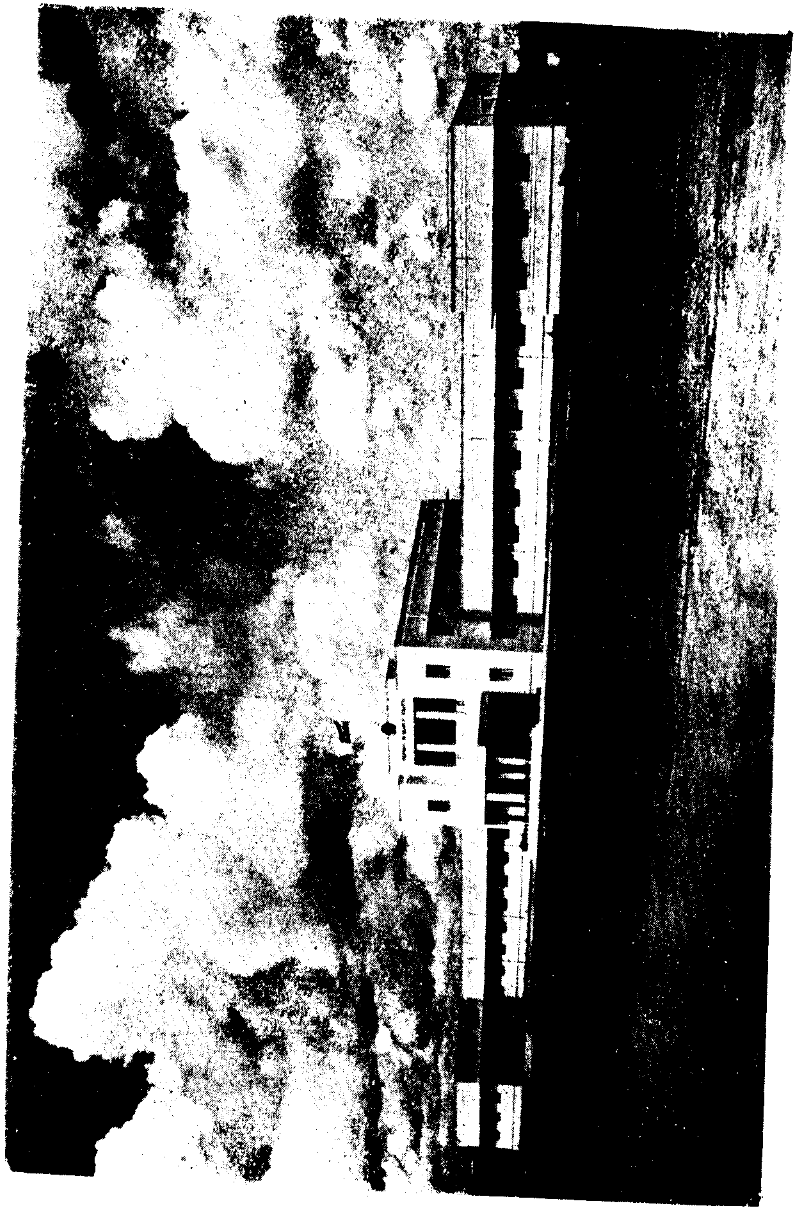
The Research Station is being equipped with a good Library. There is an indexing service to collect and discriminate technical data. It is also contemplated to start refresher courses and impart advanced training to the departmental officers in the institution.

The building of the Research Institution has been constructed keeping in view both the purposive and aesthetic considerations. Elsewhere in this issue is published an interesting article on the construction and equipment of the Research Station which gives complete details about the special features of the scheme.

It may not be out of place to mention that the success of any institution depends on the personnel who run the Institution. Research workers need moral qualities more than anything else. Sincerity of purpose, truth and abiding faith in himself and in others and love for the task are of very great importance.

Let us wish the young institution every success.

Sri Kamaraj, Chief Minister, Lighting Kuthuvilakku on the occasion of the opening of Highways Research Station



HIGHWAYS RESEARCH STATION

Design and Construction of H. R. S.

BY

Sri KALYANASUNDARAM, B.E.,

(*Junior Engineer, Highways Research Station*)

Introduction

1.1. With the construction completed, of a new building to accommodate the Highways Research Station, it appears timely to describe, in some detail the scope and activities of this growing branch of the Madras Highways Department.

1.2. In olden days when traffic consisted mostly of animal drawn, iron-tyred vehicles, roads were laid and maintained in passable conditions with little knowledge of the rudiments of Highway Engineering. Road-making, then, was not a special technique; Recourse had then to be made to trial and error methods, to determine the most suitable methods of construction, consistent with economy. These methods more or less relied solely on rule of thumb, personal opinions and observational powers of the individual. But with the enormous increase in traffic in recent years, both in relation to the intensity and weight carried, the conventional trial and error methods of construction have become obsolete and a radically new approach to the problem is called for. The Road Engineer today has to tackle manifold problems ranging from modernisation of the existing network of highways to suit the changing traffic pattern, to the designing of highways to cater for the future increase consistent with economy, and developing alternatives with the use of machines to traditional manual methods of construction.

1.3. The basic problems are essentially the same in all countries, although differences in climatic conditions may well throw the emphasis in different directions in different areas. For example the foundation problems in the Gangetic plains of U. P. and Bengal deficient in road stones, in Assam subject to heaviest rains are very different from those of Madhya Bharath with black cotton soils; areas with heavy rain falls will have skidding problems that hardly occur in areas of no or little rain-fall; areas deficient in good road stone will have special surfacing problems that may not arise in areas with good road stones as in our State. Naturally with such varying conditions, climatic, geological and traffic obtaining in India extending a vast area in globe, establishment of Road Research Stations to serve various Zones, charged with the task of Investigating problems of the respective area should be considered inevitable in the development of roads. In the Southern Zone this Research Station in a similar way was considered. Proposals for establishment of a Research Station were put before the Government of Madras on 11-6-51 and the Government of India agreed on 25-9-52 to the entire expenditure for building and equipping the Research Station, than roughly estimated to cost Rs. 10 lakhs, being charged from the Central Road Fund allocations to Madras and also agreed for giving a recurring grant from the Central Road Fund Research covering half the annual cost not exceeding Rs. 25,000/- a year to cover the works expenditure, to serve the Southern Zone in the matter of experimentation and testing.

1.4. The foundation stone of this building was laid by Shri Sri Prakasa, the then Governor of Madras, on 3rd February, 1956 and the work was commenced immediately after the sanction was communicated in April, 1956. The work has been getting prosecuted with that activity which was neither slow nor routine-like, and has been successfully completed in a record time despite adverse conditions of foundation soil etc. The rapidity of the construction has in no way injured its thoroughness.

1.5. In this article it is proposed to deal mainly with constructional features of this building.

2. Location and Lay Out

2.1.1. The site proposed for locating the Highways Research Station is about thirtyfive acres in extent and adjoins the Engineering College, Guindy on the western side. The site chosen is ideal for the activities of Highways Research Station surrounded by institutions such as the Alagappa Chettiar College

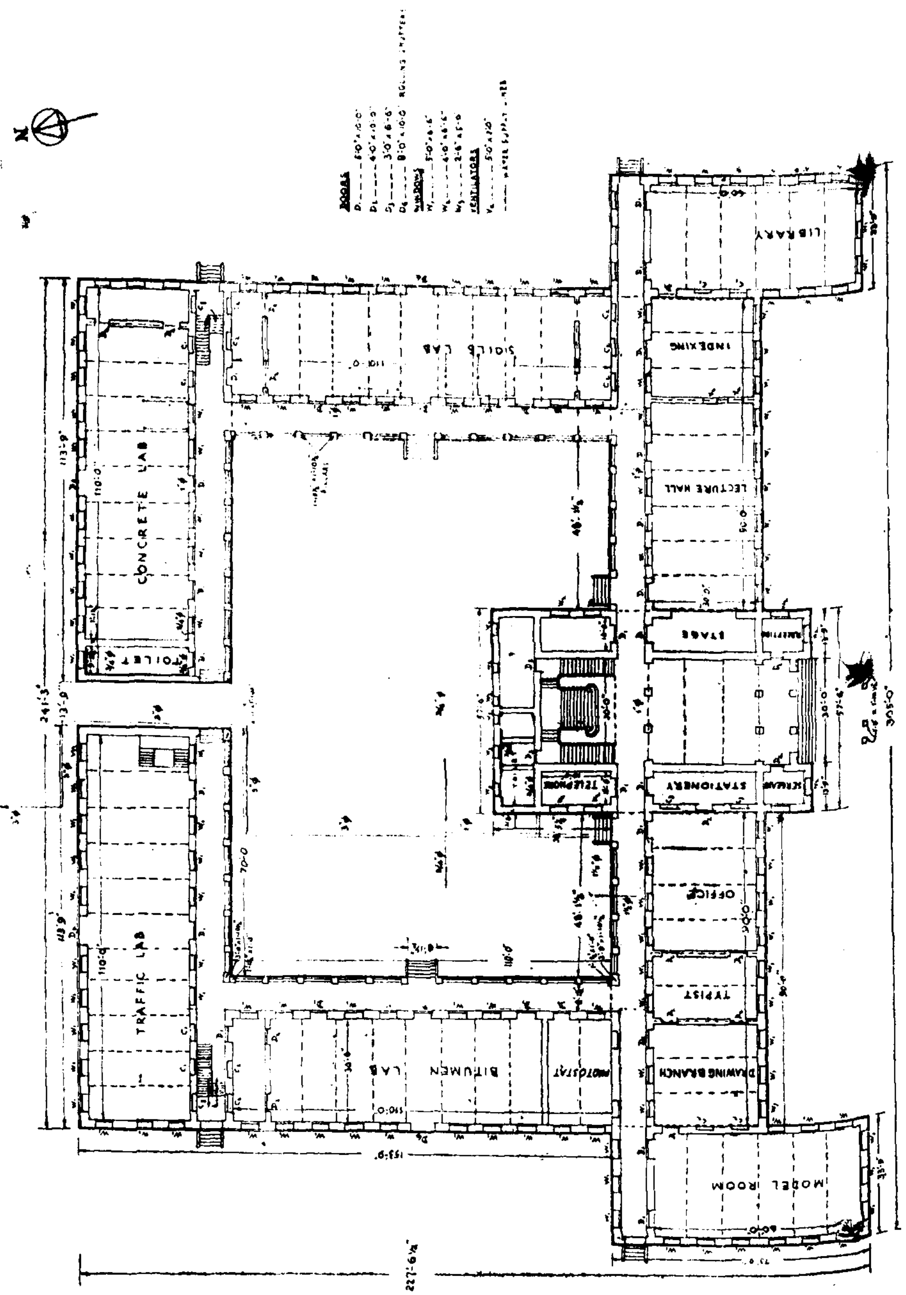
of Technology, the Central Leather Research Institute etc. engaged on similar research activities. 83

2.1.2. The plans of the building (Ground-floor and first floor) are given in figures 1 (*a*) and (*b*) showing the accommodation for the various sections of Highways Research Station. The open terraces in the first floor are intended for future developments to accommodate some of the city offices of the department. The foundations for the building have been designed providing for this additional load.

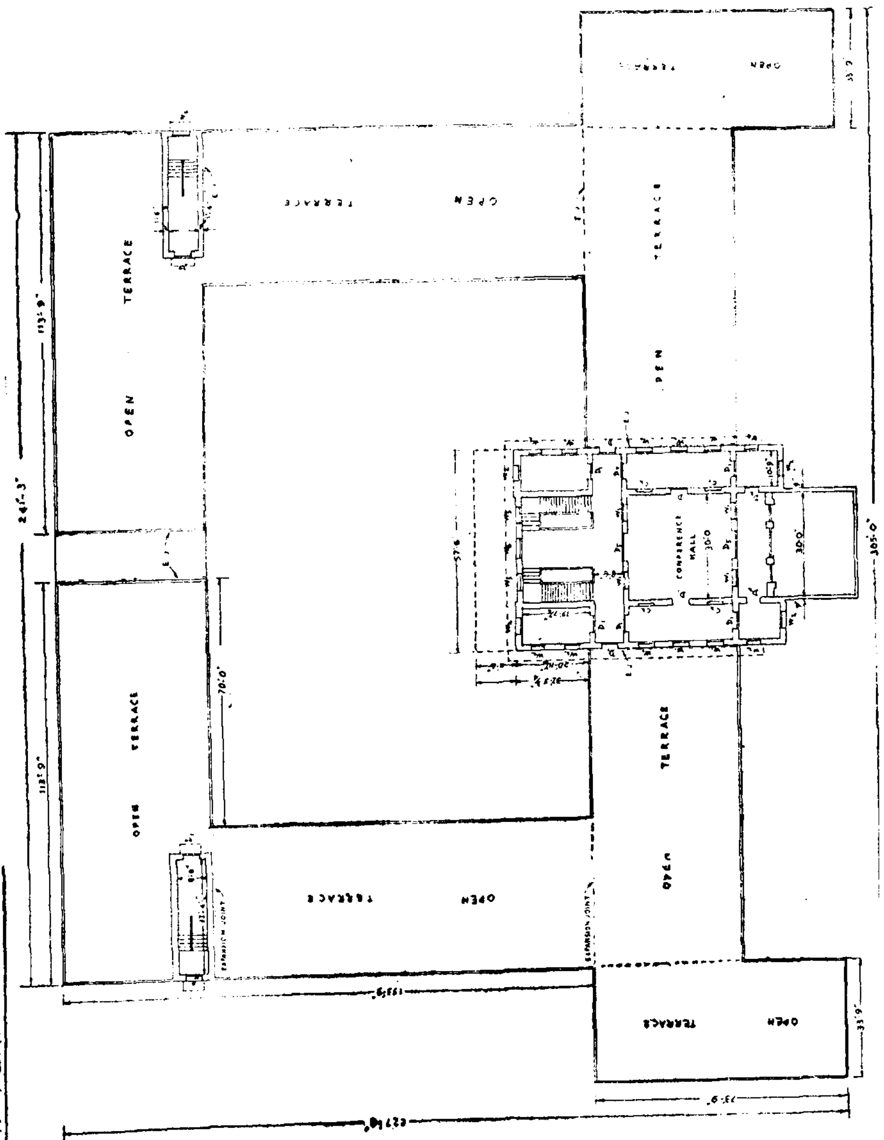
2.1.3. In general, the dimensions—length and breadth—of the various sections of the building should be worked out for the purpose, taking into consideration the furniture and other arrangements. In the administration section, three rows of tables and chairs are provided (with clear alleys in between them. The tables are 5′ 9″ long each and providing four alleys 3′ 0″ wide each, the width of the section worked out to 30′ 0″. Similarly this figure of 30′ 0″ was found to be quite suitable for the arrangement of equipment and other furniture in the different laboratories.

2.2. Foundations

2.2.1. Marking for foundations was taken up and the plan of the building was laid out by the contractor's maistry using steeltape and steel wire. On checking with theodolite by the Department it was found that the markings had been done remarkably well and that only a closing error of 1/8 inch could be detected in the same. It may perhaps be recorded that the maistry who was in charge of the lay-out was a very experienced man who had taken part in the construction of the old Engineering College Buildings nearby. Reference pedestals were constructed so as to be atleast 6′ 0″ away from the extreme edge of the excavation and having bearings, of centre-lines of all main and cross walls. The excavations had to be taken down to 7′ 0″ below ground level, and as the ground at site was sloping, it became necessary to fix the ground level, for reference. Site inspection revealed that the ground was sloping from East to West and from South to North. For Reference purposes, the level of ground at the southern front face of the building on the



HIGHWAYS RESEARCH STATION
GROUND FLOOR PLAN SCALE - 1" = 16'
FIG. 1 A.



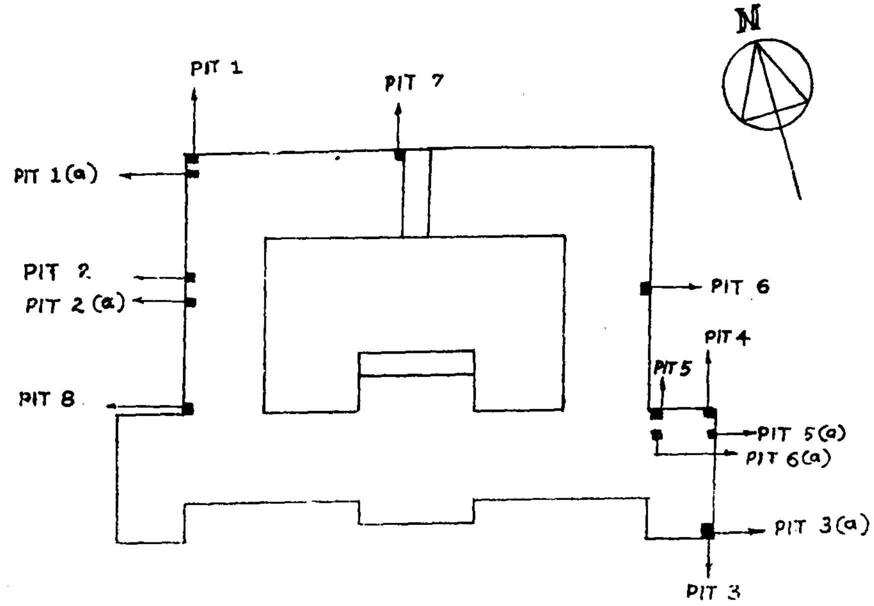
HIGHWAYS RESEARCH STATION
FLOOR PLAN SCALE - 1" = 16'
1 (b)

centre-line was taken as the ground level, and with reference to this, it was found that the ground at the south-eastern corner was 3″ higher; the south-west corner 3″ lower and the North-western corner was about a foot lower. This meant that the foundation would be shallowest at the North-Western corner and open to the objection, that the most exposed portion had the shallowest foundations. But, as a basement cellar room was proposed to be located in this corner actually the foundations had to be taken much deeper and so the adoption of the ground-level was found to be quite satisfactory.

2.2.2. The site is in a low lying area with high ground on all the three sides East, South and West, the soil being gravelly and sub-soil intermingled with granite rocks. At the time of preparing the estimates for the work, trial pits were made just on the Government lands surrounding the site, as proceedings for acquisition of site were not taken up then. Actually during execution, the soil met with was different from the results of the preliminary investigation. The soil is of a heavy clayey nature.

2.2.3. Detailed investigations were taken up by the soils—section of Highways Research Station for determining the soil at the foundation elevation and the safe bearing capacity of the same. Borings were made at corners and centres of each length of important main walls and undisturbed soil samples of 3″ and 1½″ sizes were secured. For determination of bearing capacity of soil it is important that samples obtained between the proposed elevation of the base of the footings and a depth below the base equal to twice the maximum width of the footing are to be tested as prescribed in Madras Highway Manual clause 1003-10. The borings were taken down to 16′ 0″ below ground-level. The location of the borings are indicated in Fig. No. 2. The soil samples were tested for mechanical properties, Atterburg limits and moisture content. Unconfined compression test and direct and triaxial shear strength tests were also conducted. The results of tests are shown in table I and II.

2.2.4. The tests on mechanical analysis and consistency limits revealed that the soil was stiff plastic clay with a shrinkage as high as 14%.



Fig, 2. Showing the Location of Bores taken.

2.2.5. The safe bearing capacity of the soil was computed from shear test values by using "Plummer and Dore" formula, as well as from unconfined compression test values. A factor of safety of 2 was adopted in the calculations for full load condition, and this was sufficient as the full live-load was to occur at a considerable time after the construction of the building and as the normal live-load will be considerably less. The safe bearing capacity of the soil was found to be 1·6 tons/sq. ft. on the average, as against the load of 1.33 T./sq. ft. coming under walls in the worst section, and the maximum load of 1.43 T. sq. ft. under wall in basement room including load from first floor proposed at a future stage. The soil was therefore safe to take the load of the structure, but another factor—and the most important, in clay soils—had to be considered, and this is, the minimum depth of foundation required with regard to seasonal variations of moisture content in the ground.

2.2.6. Clay soils are subject to volume change owing to swell and shrinkage alternatively under wet and dry seasons of

TABLE I

Showing the tests conducted and the test results of undisturbed soil samples taken from the foundation elevation of the proposed Highway Research Station, Madras-25

Serial No.	Location of the sample	Natural moisture content %	Natural wet density lbs./cft.	Natural dry density lbs./cft.	Sieve Analysis—% Passing						Liquid limit %	Plastic limit %	Plasticity Index	Shrinkage limit
					3/8	10	36	52	100	200				
1	Pit 1(a)	33·6	105	78	100	100	97·5	96·1	94·7	94·2	59·1	25·6	33·5	15·3
2	2(a)	34	108	81	100	99·4	94·2	92·4	90·7	90·0	55·0	22·5	32·5	...
3	3(a)	25	109	82	100	100	99·8	99·7	99·5	99·3	65·5	30·3	35·2	...
4	4(a)	37·6	108	79	100	96	81·2	75·8	69·0	64	48·6	16·9	31·7	12·9
5	5(a)	31·8	100	76	100	99·9	99·8	99·7	99·5	99·1	72·0	28·0	44	14·3
6	6	38·9	103	74·5	100	99·8	99·3	99·1	98·5	97·9	81·0	21·3	59·7	12·0
7	7	35·8	105	77·5	100	99·8	97·2	96·5	96·1	95·8	73·5	24·0	49·5	16·6
8	8	18·5	112	94	100	99·1	90·1	87·4	83·4	81·5	57·2	21·7	35·5	12·0

TABLE II

Showing the Bearing capacity of the undisturbed soil samples taken at the foundation elevation in different places of the proposed Highway Research Station Building, Madras-25

Serial No.	Pit No.	Unconfined compressive values as per triaxial shear test lbs./sq.in.	Direct Shear values		Triaxial Shear values		Bearing capacity as per Plummer & Dore with direct shear values (Tons/sq. ft.)		Bearing capacity as per Plummer & Dore with Triaxial shear values (Tons/sq.ft.)		Bearing capacity as per U.C.C. values (1½ times U.C.C.) Tons/sq. ft.		Average bearing capacity Tons/sft. F. S. 2
			C Tons/sft.	ϕ	C Tons/sft.	ϕ	Factor of safety-3	Factor of safety-2	Factor of safety-2	Factor of safety-3	Factor of safety-3	Factor of safety-2	
1	1(a)	17·3	·495	6°	·75	8°	·764	1·146	2·10	2·33	1·1	1·65	1·632
2	2(a)	16·8	·795	8°	·6	18°	1·45	2·175	2·295	1·53	1·62	2·43	2·3
3	3(a)	15·0	·465	10°	·65	8°	·93	1·395	1·8	1·2	1·44	2·16	1·78
4	4(a)	18·9	·57	10°	·51	8°	1·13	1·695	1·404	·936	1·22	1·83	1·64
5	5(a)	18·0	·465	10°	·45	16°	·93	1·395	1·74	1·16	1·15	1·725	1·62
6	6	17·7	·51	14°	·514	16°	1·2	1·8	1·98	1·32	1·13	1·645	1·81
7	7	22·6	·81	6°	·48	23°	1·33	1·995	2·745	1·83	2·17	3·25	2·66
8	8	21·5	·66	18°	·7	22°	1·83	2·745	3·45	2·3	2·05	3·07	3·08

the year. "When considering foundations in clay soils it is important to bear in mind that it is the drying rather than the wetting of clays which deserves greater consideration. Drying, although it increases bearing strength, also produces volumetric shrinkage. This in turn causes vertical subsidence as well as lateral cracks and movements. Subsequent wetting will expand the clay causing a heaving action on the foundations but this will become apparent only after re-wetting."

2.2.7. This volume change of clay soil was also evidenced, in our case, by the presence of large cracks on the surface. These cracks, caused by the drying shrinkage of clay in dry season were traced to about 5′ 0″ below ground level, thereby indicating the extent to which the soil-moisture variations were present.

2.2.8. In such expansive clays it is necessary to locate the foundations below the elevation of the lowest summer water-level, that is, in a zone of constant moisture-content, which is unaffected by seasonal variations of moisture; the clay soil in this region is not subjected to any volumetric change and no trouble should be expected with foundations.

2.2.9. The foundations proposed for the building consisted of spread footings 5′ 6″ wide at bottom for all walls taken down to 7′ 0″ below ground level except in the basement cellar section under the Traffic Laboratory where the depth of foundations was 12′ 0″. Free water was found to occur at six feet below groundlevel and so the proposal for founding the structure at 7′ 0″ below ground level was in order. But in order to provide for a contingency of long-drawn drought, in which case the drying of clay will penetrate deeper into the ground, it was proposed to carry the foundations to 8′ 6″ below ground level. A sand raft 1′ 6″ thick was laid at the bottom to provide a compact surface and to keep down the cost and the concrete footing 5′ 6″ wide and 1′ 6″ thick was laid as per sanctioned estimate over the sand-layer. The concrete footing in effect is thus located in the constant-moisture zone, obviating the problem of volumetric change of clay-soils.

2.2.10. In the case of verandah walls the intensity of pressure on soil was found to be only 0.45 tons/sq. ft. and therefore the width of foundation under the verandah walls was reduced from 5′ 6″ to 4′ 0″ but the depth was taken down to 8′ 6″ below ground level, as for the main walls. Incidentally the expenditure involved by the provision of sand-raft was nearly off set by the savings effected by this change in the design of footings for verandah-walls.

2.2.11. Earthwork excavations for the foundations upto the required depth were carried out, and it was generally observed that the soil was dry cracked clay for a depth of about 3′ to 4′, below which moist clay was present. The soil was sufficiently stiff to be able to withstand the vertical cuts made, but when allowed to stand overnight it was observed that about 4 to 6″ of free water collected at the bottom of the excavations. The clay soil at the sides rapidly gives up moisture and the resulting shrinkage and settling of the sides at the bottom causes loss of shape in the top-layers and failure of the sides. The time during which an excavation pit is left open has to be reduced to the minimum as otherwise the underlying clay might also swell, reducing the shearing strength of the soil. Therefore a mat of sand 1′ 6″ thick was spread on the bottom immediately after the excavations were complete and concreting for the foundations were taken up on the succeeding day. The rate of excavations and spreading of sand was regulated to keep pace with the concreting operations that followed the next day.

If there was any unavoidable delay in concreting, the excavations were kept braced with horizontal planks and walings. The concrete footing of 1′ 6″ thick were laid in three layers and when concreting operations had to be stopped at the end of the day, the ends of the concrete layers were kept stepped, each layer stretching beyond the one above by a length equal to the width of the footing.

2.2.12. A cross section of the footing foundation adopted for the main walls is shown in figure 3. It will be seen that the width of concrete footing and the sand layer underneath have been kept the same, equal to the full width of the trench. In this

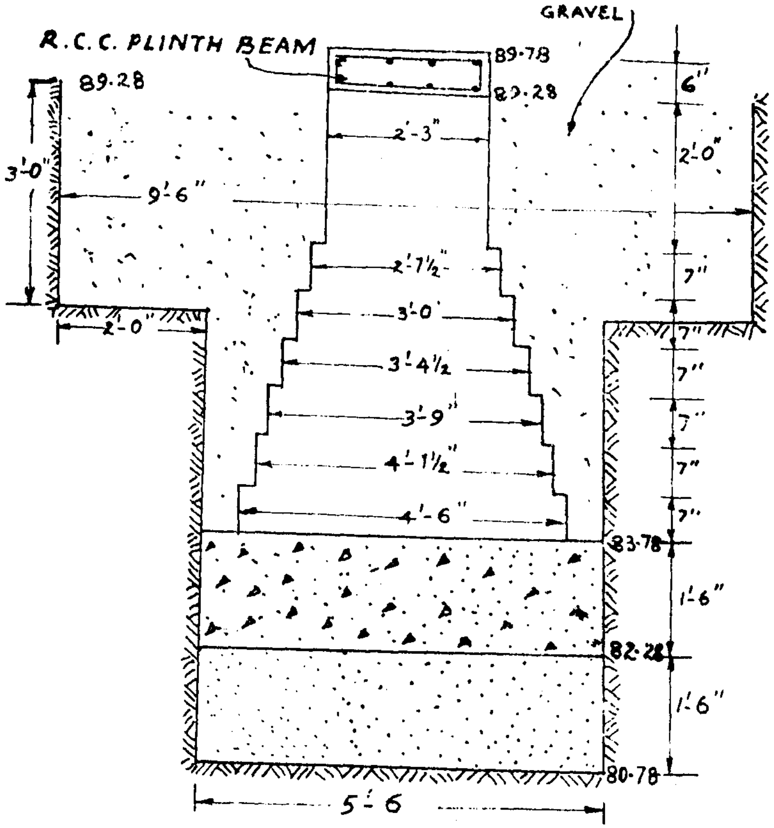


Fig. 3. Cross section of footing foundation with details of backfill

context the Bombay P. W. D. practice in founding structures on black cotton and shrinkable-clay soils provides an interesting point. The Bombay P. W. D. Handbook specifies that the trenches should extend on either side of the concrete footing and the same be filled with sand or some loose material, so as to prevent intimate contact of the foundation concrete with the clay soil. In effect this means that the concrete footing is not laid to the full width of the trench excavated, the space allround being filled with sand. Sections of foundations for main walls as per the Bombay specifications are shown in figures 3(a) and 3(b). But it should be noted that the practice, though correctly adopted with a view to prevent the contact of shrinkable clay soil with

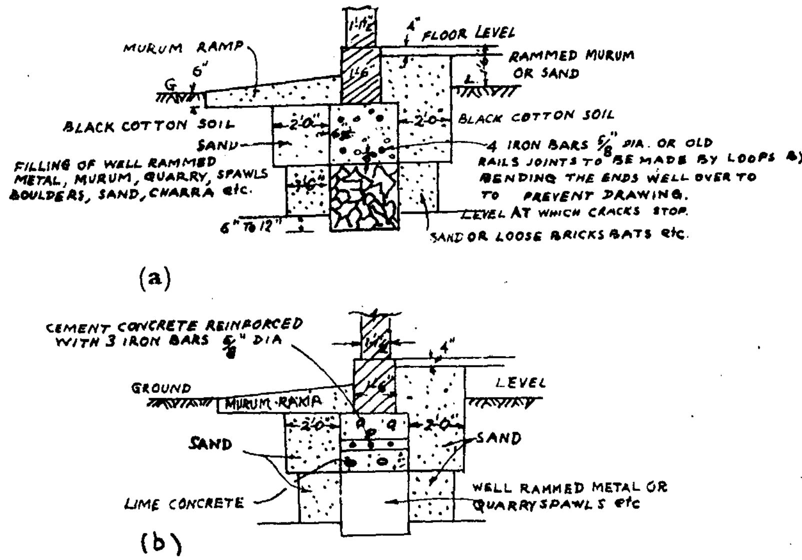


Fig. 3 (a) (b). Sections of foundation for main walls

concrete foundations, applies only to conditions in which the clay soil at foundation elevation is subject to seasonal variations of moisture. In our case, the foundations have been taken down to a zone of constant moisture-content and hence the adoption of the Bombay practice referred above does not serve any useful purpose in this particular case and also has some disadvantages as follows:

(1) The concrete footing is not laid to the full width of the trench and hence the use of shuttering etc. involving additional cost becomes necessary;

(2) The concrete footing when laid to the full width of the trench and rammed, adheres well to the sides of the trench, this adhesion providing additional frictional resistance which in effect aids the bearing capacity of the soil.

(3) In the case where the footing is not laid to the full width the sides of the concrete footing are open to the ingress of water from outside through the porous soil medium.

3. Brick Masonry

3.1. General

All brick work has been constructed in cement mortar 1 : 5 using first-class bricks and pillars in cement mortar 1 : 2, to the specifications of the M. D. S. S., yet a few of the existing clauses call for a review based on actual observation during construction.

3.2. Bricks-Specifications

3.2.1. Modern first class bricks are no doubt better baked but there seems to have been little achievement as regards the standardisation of their size.

3.2.2. The M. D. S. S. specifies that in brick-making operations, the necessary allowance for shrinkage in drying and burning shall be determined by actual experiment for each brick-yard and the moulds made larger than the finished bricks to that extent. In the absence of any quality control, however, the exact allowance for shrinkage is never obtained, as this depends on many factors involved in manual operations such as composition and tempering of clay, extent of watering, drying, burning and the like. In the result, the bricks turned out from one and the same kiln are not identical in dimensions, and differences of upto 1/4 inch are common and so the brick masonry could not actually be constructed exactly to the widths specified in the various sections, the actual width being generally more by 1 to 2 inches. Actual observations of sizes of bricks from three kilns are given in Table III.

TABLE III

Showing Differences in Dimensions of Bricks

S. No.	1	2	3
1	8 5/16"×4 5/16"×2¾"	9⅛" × 4⅜" × 3 1/16"	9" × 4 7/16" × 2⅞"
2	9"⅛ × 4⅜" × 2 15/16"	9" × 4⅜" × 3 1/16	9⅛" × 4½" × 2⅞"
3	8⅞" × 4⅜" × 2⅞"	8⅞" × 4⅜" × 2 15/16"	8¾" × 4¼" × 3"
4	9" × 4¼" × 3⅛"	8 13/16"×4 3/16"×3 1/16"	8 15/16"×4 5/16"×2 15/16"
5	9" × 4¼" × 2⅞"	9" × 4⅜" × 3"	9" × 4⅜" × 2 15/16"
6	8 13/16" × 4⅜" × 3"	8 15/16" × 4¼" × 3"	9 1/16" × 4¼" × 3"

3.3. Setting of Bricks in Mortar

3.3.1. This is a very important though simple, operation demanding close attention for securing strength in construction. The mortar joints should be tight without hollows or other cavities, as the strength is dependant mainly on such monolithic construction. This will be clear from the fact that the country brick taken individually is stronger in compression than the stock brick. The country brick being thinner in section is compressed better under the manual operation and takes a better baking. But the compressive strength of the brickwork with the use of country bricks is often less than the one constructed with stock bricks in cement mortar of similar proportions (*Vide* Table IV). As the country brick work contains more number of joints involving more number of hollows and cavities per unit than one with stock bricks-more often joints being of unequal shape and size-the compressive strength naturally is lowered.

TABLE IV

Results of Compressive strength tests on built up units of country and table moulded bricks in cement mortar 1 : 3

No.	Description and size		Compressive strength: Initial crack Tons/sq. ft.	Compressive strength: Final load Tons/sq. ft.
	Country Bricks :			
1	4½" × 4½" × 2"	...	2·84	60·66
2	4½" × 4½" × 4½"	...	13·85	25·13
3	4½" × 4½" × 7"	...	12·66	19·94
4	9" × 4½" × 2"	...	2·91	69·42
5	9" × 4½" × 4½"	...	4·38	27·87
6	9" × 4½" × 7"	...	5·48	21·06
7	9" × 9" × 2"	...	2·67	107·90
8	9" × 9" × 4½"	...	2·94	43·65
9	9" × 9" × 7"	...	2·49	22·49
	Table moulded Bricks :			
1	4½" × 4½" × 3"	...	14·23	50.08
2	4½" × 4½" × 3"	...	13·82	25·40
3	9" × 4½" × 3"	...	5·20	57.42
4	9" × 4½" × 7"	...	7·48	27·30
5	9" × 9" × 3"	...	7·46	64·00
6	9" × 6" × 7"	...	3·38	33.10

3.3.2. The M. D. S. S. specifies that the bricks shall be thoroughly bedded and flushed with mortar and grouted full at every course. This specification appears rather misleading as it does not indicate that the joints should be tightly filled with mortar. In general it is found that the usual practice is to lay brick in a thin bed of mortar, leaving the vertical joints to take care of themselves, throwing a little semi-dry mortar over the top of the bricks, and giving a sweep with the trowel while copious amounts of water are added to the mortar heap. In building thick walls the general method adopted is to lay up the outer stretcher courses between the header courses and then to throw mortar into the trough thus formed, making it semi-fluid by the addition of large doses of water, then throwing in the bricks, allowing them to find their own bearing. The top is finished by grouting as above and the next course laid repeating the operations. Mortar is made very thin for grouting. This interferes with the setting and adhesion of the mortar as the bricks will not absorb all the water. Watery mortar also contracts excessively in drying which causes undue settlement and cracks or distortion. Again, masons have a way, after bed mortar has been sufficiently applied to the top bed of brick, to draw the point of their trowel through it, making an open channel with only a sharp ridge of mortar on each side, so that, when the succeeding brick is taken up it shows a clear hollow free from mortar through the bed. Obviously these methods of the lay men adopted with a view to gain facility and celerity in executing the work, definitely tend to weaken the structure a great deal by denying the adhesion of mortar to the bricks.

3.3.3. It should therefore be specified that bricks should not be merely laid, but everyone should be rubbed and pressed down in such a manner as to force the mortar into the pores of the bricks and produce the maximum adhesion. With cement mortar this is still more important than with lime-mortar. For best work the bricks should be laid with a "shove joint" *i.e.* the brick shall first be laid so as to project over the one below and be pressed into the bed mortar and then be shoved into its final position. Each brick should be laid in full bed of mortar buttering ends and side-joints thoroughly in one continuous operation and the adjoining brick then laid tightly pressed against the mortar pad. This operation is very simple, and easy with skilful masons–if only they will do it. It should be emphasized that every joint shall be thoroughly packed with tight mortar reducing the chances of cavities occuring in brickwork. It requires lot of persistence on the part of the executive staff to get this accomplished.

3.3.4. The M. D. S. S. specifies that four courses of brick work when built with four joints for first class bricks should not exceed by more than $1\frac{1}{4}''$ the same bricks piled one over the other without mortar. With the variations in the dimensions of bricks and with the minimum amount of mortar necessary for solid bed-joints in construction this limit of $1\frac{1}{4}''$ appears to be too low; a limit of $1\frac{1}{2}''$ to $1\frac{3}{4}''$ being more practical has been followed in this work.

3.3.5. The quantity of mortar required will vary with the size of the brick and with the thickness of the joint. Owing to inequalities in the brick sizes and with the setting of such bricks in the manner advocated, the quantity of mortar prescribed in the Standard Data for Brickwork, is found to be quite insufficient. Thus for brickwork in cement mortar 1 : 5 it was observed that the quantity of mortar required for securing satisfactory joints all filled solid with mortar, was about $23\frac{1}{2}$ to 25 cft. as against 20 cft. prescribed in the Standard.

3.4. Mortars

3.4.1. It must be conceded, however that with all care and precautions it should really be very difficult to secure a construction with all the joints filled tight with mortar cent per cent. Even in our building, finished brickwork cut-outs when examined have revealed occurrence of a few imperfect vertical mortar joints here and there inspite of best efforts. In any brick construction, with the use of cement mortar particularly, it appears that some cracking or imperfect jointing is almost sure to be caused due to the shrinkage of the mortar that takes place as the work dries out. This feature naturally suggests that we examine the compositon of mortars.

3.4.2. A common idea is that mortar is used to bind bricks firmly together and it is therefore often concluded that the mortar having the highest tensile strength is the best. The mortars which exhibit the highest tensile strength are not necessarily those which adhere most strongly to all types of bricks. A high tensile strength in the mortar is valueless unless there is good adhesion to the bricks on each side. The true functions of mortar are to provide means of building up from single units, a mass of brickwork capable of withstanding a certain degree of compressive stress and exhibiting a reasonable resistance to the penetration of rain. To these requirements must be added that of durability. The characteristics of brickwork motar are dictated by these requirements.

3.4.3. For providing resistance to the penetration of rain preference is often given to the densest types of mortar. This is a mistake. Experience shows that penetration of rain almost always occurs not through the bricks or through the mortar, but through imperceptible hair cracks between the mortar and the bricks. Other channels through which penetration often occurs are poorly-filled vertical joints (at right angles to the wall face). The mortars which are in themselves are dense and impervious do not necessarily adhere best to all types of bricks. It follows that though a high tensile strength in mortar is not essential, a high degree of adhesion between brick and mortar is highly desirable. The ruling consideration in this connexion is not strength but weatherproofness.

3.4.4. Characteristics Desirable in Mortar

A good mortar for brickwork is one which:

(*a*) Is easily workable, standing up well on the trowel but spreading easily out on the bricks; good workability and plasticity are required to enable vertical joints to be thoroughly filled;

(*b*) Stiffens up quickly as the bricks are laid, enabling work to proceed without delay;

(*c*) Adheres strongly to the bricks;

(*d*) Develops a sufficient compressive strength in the masonry.

Evidently since the properties of the bricks are involved in (*b*) (*c*) and (*d*) above, the same mortar will not equally be suitable

for all kinds of bricks but a composition must be selected which will suit the particular bricks used. A plain cement mortar is very difficult to use with highly absorptive units, even if they are wetted first, for the water in the mortar may be abstracted so rapidly that the film of cements in contact with the unit, never sets properly and a channel is formed for penetration of rain. Mortars made from lime, or containing a high proportion of lime are better in such cases, for they lose water less readily and so help to ensure good adhesion.

3.4.5. A general principle of wide application which will usually lead to a wise choice of mortar is that mortar should be compounded so that its strength is similar to, but somewhat less than, that of the unit it binds: and so as to suit the characteristics of the bricks used. The combination of the plasticity of the lime with the hydraulicity of Portland Cement yields a mortar of excellent characteristics. As strength is not the prime consideration and from the point of view of weather proofness of having well-filled joints and good adhesion, the advantages of the composite mortar are apparent. There is in practice a wide latitude in mortar composition which can be used without materially affecting the strength of the wall

3.4.6. The Building Research Station, United Kingdom has suggested composition of suitable mortars for bricks of varying strength, and these are shown in Table V.

TABLE V.

Crushing strength of brick in lb /sq. in. 1	Composition of Mortar (Parts by volumes.) 2	Maximum permissible pressure (uniformly distributed in Tons/sq ft. of overall area of wall or pier) Model byelaws. 3
1500 — 3000	1 cement 3 lime 12 sand or 1 Hydraulic lime and 2½ sand.	5·5
3000 — 5000	1 cement, 1 lime 6 sand.	10
Over 5000	1 cement, 3 sand.	16

3.4.7. From considerations of all these factors, it was proposed during the course of construction, to adopt composite mortar of proportions 1 : 3 : 12 (one cement, three lime and twelve sand) for the superstructure, with the use of stock-bricks available round about Madras having crushing strength ranging from 1000-2000 lbs./sq. in. For the work in foundations mortar of 1 : 1 : 6 proportions was proposed to be used, as hardening and setting of mortar takes much longer duration below ground level continuously in damp conditions. Sanction was also obtained for this adoption as it accrues saving in cement which was a special consideration as cement is a controlled and scarce commodity. However the compo-mortar in its processing requires grinding mills and particularly when large quantities are involved, the usual country-mills worked with bulls are not suitable when speed of construction and targeted progress are aimed. Mechanically operated mortar mills were not then available all over the Indian markets, and importation would have meant delay and loss of time. So the idea of using composite mortars was not put into execution. But it is suggested that composite mortars, particulary in masonry, should have wide application in the interest of economy, and soundness of construction.

3.4.8. In the preparation of cement-mortars the M. D. S. S. do not make specific mention about the allowance for the bulking of sand. This factor is as important in the case of mortar as in concrete, in order to obtain nominal mixes. During execution, the percentage of bulk of sand was observed daily by careful tests in the field and the mixing of mortar done make due allowance to bulkage.

3.5. Footings

3.5.1. For the brick masonry in foundation the usual offset of $2\frac{1}{4}''$ has been given for every footing of two courses. Though the usual practice is to have each footing over two-brick-height, this method necessitates the use of brick-bats or closers to obtain break of joint in successive course, as explained in fig. 4(a). But on the other-hand if each course is set back $2\frac{1}{4}''$ from the face of the course below the off-sets automotically give quarter bond in the footing sections. But on the introduction of a closer in the next work (of walling) a straight joint occurs between the top course of footings and the first course of walling as shown in fig. 4 b.

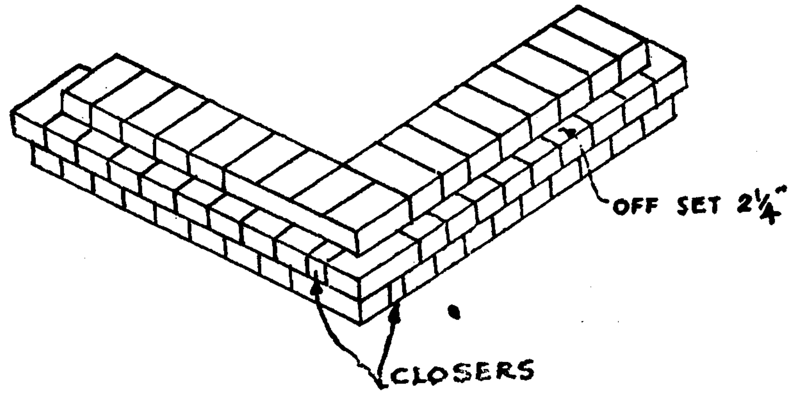


Fig. 4 (a)

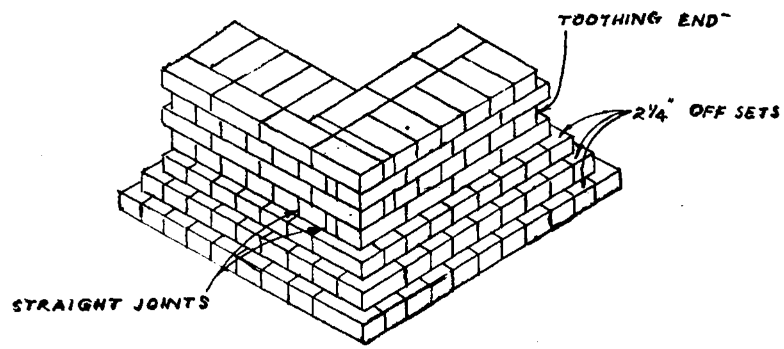


Fig. 4 (b)

3.5.2. The effect of this straight joint on the stability of the structure is negligible if the footings are properly constructed with all mortar joints solid. The introduction of a considerable number of brick-bats or closers in foundation-work may adversely affect the strength of the structure and can best be avoided by the latter method of setting back each course by $2\frac{1}{4}''$. Incidentally they will bring about economy in the foundation also, by the reduction in the sections.

3.5.3. In constructing long walls in brickwork masons usually lay up head-walls at random along the length of the wall, and then complete the intermediate spaces with brickwork. This method involves much adjustment with brickbats etc. because the gaps between the headwalls are not exact multiples of full bricks and as is more often the case, the thickness of mortar joints vary from place to place. To avoid this irregular construction, suitable templates were made to the exact lengths of brick-units of say four-brick lengths, making proper allowance for mortar joints. These templates were sealed over by the masons to exactly markout the gaps between the headwalls before constructing, into suitable multiples of full brickunits. Similarly templates were used to mark out the height of courses of brick-work so that the dimensions of each course were kept identical alround.

3.6. *Brick-on-Edge Course.*—The M. D. S. S. specification regarding the brick-on-edge course, built at the plinth-level for all walls calls for an objective review. This specification 31 cc.-29 requires that the bricks forming the corners of all such courses are properly radiated and keyed into position as shown in fig. 5.

Sketch for corners brick on edge courses in plinths and steps

Mortar System

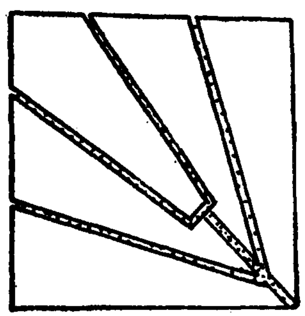


Fig. 5

The general trend here is to adopt broken bricks for obtaining the requirement of radiation and to fill up all interestices with mortar grout. But this is in contravention of Sp. 31 clause 6 of M. D. S. S. wherein is stated that no bats or cut-bricks shall be

used except where absolutely required for obtaining dimensions of different courses, or for obtaining the specified bond and where, in the opinion of the Executive Engineer the work is of too petty a nature to warrant the special moulding of bricks, of the shape required. The quantity of bricks required for the corners of brick on edge courses in a building is very little and special moulding to the shape required is not reasonable. Nor is it desirable to allow broken-bricks to be used in the construction of these corners, for the following reason :

(1) The brick-on-edge course is laid projecting 2¼″ outside for appearance.

(2) the bricks when cut invariably break in irregular shapes, and the brick bats are usually laid in place by trial and adjustment, thereby shattering the freshly finished structure adjacent. The only course to adopt in this case would be to grind each brick to the proper shape as required in the figure. Obviously this method consumes a lot of time and labour for a small work of this kind. A better alternative would be to lay the corners in cement concrete 1 : 3 : 6 which would also augment strength of the structure. In Research Station building all the outer walls are 2′ 3″ thick at the plinth level, the interior walls being allowing 2¼″ offset on either side from the floor to raft is 1′ 10½″ thick. While the brick-on-edge course can be laid for the former, the other walls being only two-and-a-half brick thick this cannot be laid without recourse to cut or broken bricks detrimental to the structure especially at this elevation. Hence all the crosswalls and interior walls at this elevation were constructed with bricks laid flat and the resulting difference in level 1½″ was made up with a levelling course in cement concrete 1 : 2 : 4 1½″ thick, thus providing one finished level alround for the superstructure walls.

In this case the provision of brick-on-edge corners at the junction of the interior and outer walls does not serve any purpose. Reference to fig. No. 6 shows that the provision of the corner at junction 'A' results in a straight joint between the corner and outer walls, there being no keying of the corner into inner and outer walls, which keying at corners, is insisted upon in all the structure, which keying at corners, is insisted upon in all specifications. On the other hand cement concrete corners, if

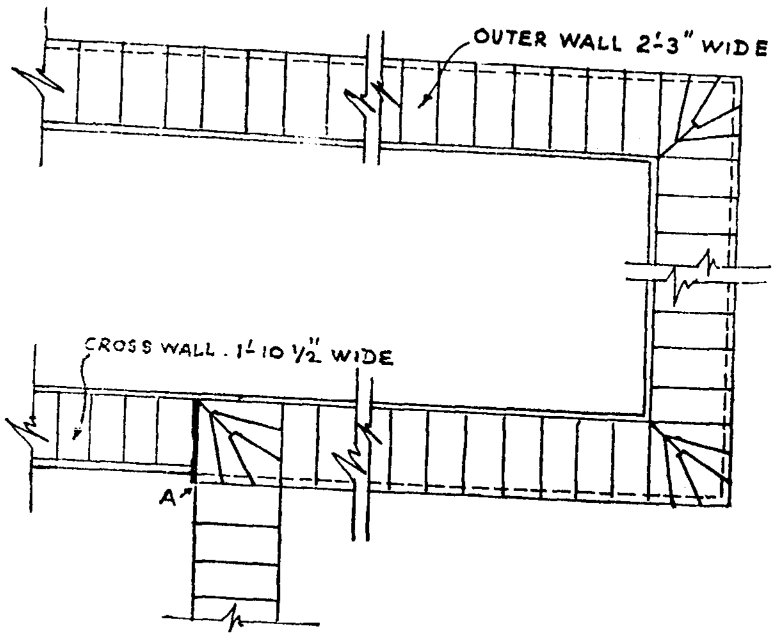


Fig. 6

adopted at junctions, can be laid along with the levelling course (1½" thick) of the cross wall thus bringing into play, the much-desired keying effect.

3.7. Finishing

The finishing of brick work has to be watched closely. All the face joints have to be kept well raked out for receiving the plaster later on. If this is not done at the proper time it becomes a very difficult job for the building contractor, and the tendency on the part of the latter would be to have the rendering without this very important but rather simple operation. Here care has been taken to take up this raking of joints within 24 hours of the construction of the section.

4. Backfilling (Foundations :)

4.1. Normally, backfilling of excavation trenches is done with the excavated earth. But in this case the excavated soil being treacherous clay, backfilling with this material was considered undesirable on the following factors :

(1) The backfill with lumps of clay-soil cannot be well compacted and settled in one season ;

(2) The backfill with clay soil will be subjected to the seasonal moisture variations from the surface downwards resulting in the development of loose cracked soil in the backfill portion allround the building. Lateral shrinkage arising out of this drying action of backfill and subsequent expansion in wet season will introduce lateral pressures over the footings detrimental to the structure.

4. 2. It was therefore proposed to fill in the foundation trenches with good gravel compacted at optimum moisture in layers. Besides, gravel filling was also done all round the walls for an additional 2'0" width and 3'0" depth so as to vitiate the effects of lateral movement of the clay soil. Incidentally this served as a good foundation for the concrete drains all round the building. Fig. 3 shows the details of backfilling foundation trenches with gravel.

5. Expansion Joints

Expansion joints are desirable in buildings over 200' in length, so as to separate the building into independent units with freedom from restraint at the ends, so that the stresses developed in one part are not transmitted on to the other causing cracks to the detriment of the utility or appearance of the structure. These generally take the form of continuous vertical joints provided at pre-determined spacing from foundation level, to correspond with the joints in the roof slab, so as to prevent possible cracks due to differential settlement (of the base of the structure or due to the expansion) of R. C. Roof slabs. In accordance with these principles the Research Station building was constructed into nine independent blocks, by providing vertical joints in brickwork along the contact faces of walls of adjoining blocks. The location of expansion joints in the structure are shown in figures 1 a & b. The joints, running from the top of the concrete footing in the foundation, up to roof-level, consisted of cardboards coated with bitumen shellmac RC 3 for the full width. The method of construction of the joints is briefly as follows. The end-face of one-section of the block was plastered with cement mortar ½" thick and painted with two coats of bitumen shellmac R C_3. The cardboards coated with bitumen were then placed on the section thus prepared and the other face of the wall pertaining to the adjoining block was then constructed butting against the bitumen-coated cardboards, thus maintaining the effective separation between the independent units. The bitumen-treated cardboards provide an effective barrier for excluding wind and rain from the joint.

6. Cross Walls

From the disposition of the various units formed after providing for the expansion-joints, it will be seen that the Soils and Traffic laboratories and the lecture hall and the administrative sections consist of two main walls only without any cross or lateral supporting walls. It is general practice in buildings to have the lengths of rooms not exceeding three times their width; unsupported lengths of walls greater than this limit are not desirable, from the point of view of stability of the structure and relative immunity from cracking. The main walls of each block in our building are 110′ long while the breadth of the halls 30′ 0″. So cross walls were introduced at 10′0″ from each end of the main walls, restricting the unsupported length of walls to 90′ 0″ (*i.e.* 3 times the breadth of halls). The cross walls were however not designed to take the roofload of the structure, but were built from the foundation level so as to bind the main walls effectively.

7. Plinth Beam and Continuous Lintel Beams

7. 1. Cracks generally occur near the openings, in buildings founded on clays, due to subsidence. For complete protection against damage due to subsidence, a building should be able to resist the effects of vertical and horizontal differential movements. Protection against damage by the differential horizontal movements is obtained by providing a lightly reinforced concrete beam tying the walls together. Usually one such beam is provided at the plinth or floor-level. Again, separate lintels are generally provided over door and window openings. Shrinkage cracks tend

to occur mostly where the section of brickwork is reduced, for instance, above corners of windows and door openings. Where these openings are numerous as in our case, a beam in continuation of the lintels *i.e.* a continuous lintel beam, has to be provided to obviate minor cracks resulting otherwise in the short-gaps of masonry. Incidentally this continuous lintel beam running allround the building will also ensure greater rigidity of the structure. Taking these into consideration, it was decided to provide an R. C. Plinth beam and an R. C. continuous lintel beam in the building as an additional precaution, against development of cracks due so settlement.

7. 2. Regarding the design of the plinth beam, there seem to be no hard and fast rules. As suggested by Rolt Hammond in his book on Foundation Engineering the design of the plinth-beam may be done similar to that of an R. C. base slab used on a granular base for protection against damage due to mining subsidence. The total tensile strength of the slab in the direction of either principal axis should be adequate to resist a force equal to the product of half the weight of the structure on the slab and the coefficient of friction between the slab and the granular material. This coefficient is usually assumed as 2/3. The permissible tensile stress in reinforcement may be assumed as 30,000 lbs./sq. in. and the permissible compressive stress in. 1 : 2 : 4 : concrete as 2000 lbs. per sq. inch. However the general practice followed in the buildings constructed by the Central Government is to provide plinth beams 4 to 6″ thick to the width of the walls in basement adopting nominal reinforcements both at top and bottom to provide for stiffness and for any reversal of stresses. Regarding the lintel beam it was found that generally a six-inch thick beam was required for spanning the main doors and windows and so a continuous lintel beam 6″ thick was proposed to be provided all round. The same thickness of 6″ was adopted for the plinth-beam also, as the effect of both the beams in imparting rigidity to the structure is more or less the same, especially when the beams, one at plinthlevel and another at lintel level divide the height into almost equal sections. The plinth beam was provided with nominal reinforcements (0·8%) corresponding to R. C. C. 1 : 2 : 4 mix ordinary grade stresses.

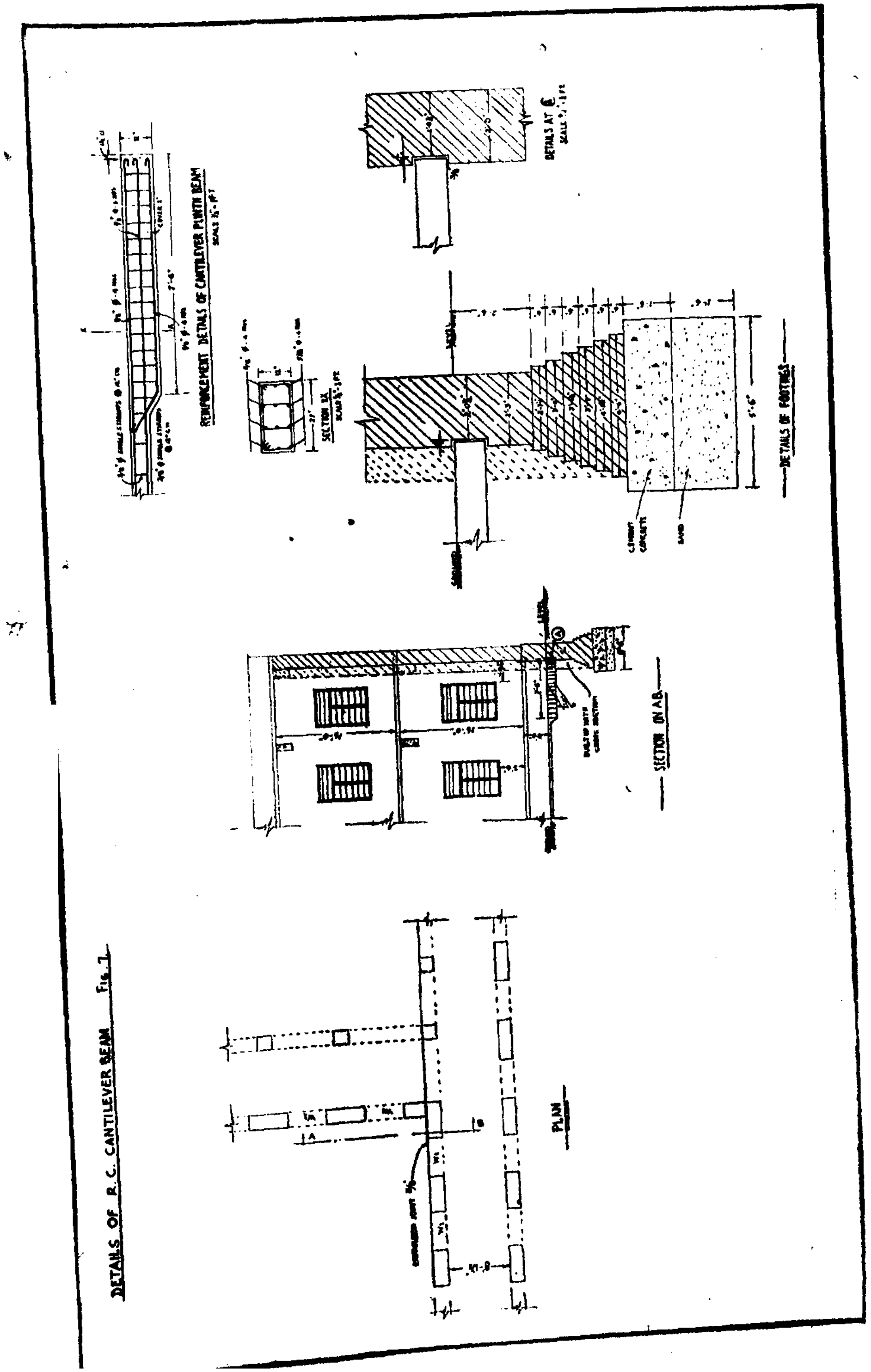
7. 3. In locating the plinth beam uniformly at the plinth-level allround the building, a practical difficulty arose while considering the disposition of ventilators in the basement cellar under the Traffic laboratory. These ventilators 5′ × 2′ size were provided at ground level for adequate ventilation and lighting of cellar room. The roof over the cellar functioning as the floor of the Traffic Laboratory consists of R. C. C. Tee Beams and slab. Hence a plinthbeam in this block at floor level or at any other level between the floor and the ground was out of question owing to the intervention of the Tee beam ribs and the presence of ventilators. The plinthbeam was hence located at ground level only, the top of the beam with 2″ brick courses forming the sill of the ventilator opening. As it was desirable to locate the plinth-beam in one level all round the building and as the continuous lintel beam was kept at one level only, the plinth beam in all the blocks were located at the same elevation as in basement cellar.

8. R. C. Cantilever Beams

8. 1. With the commencement of construction of the building in nine independent units from the bottom level of masonry footings, it became apparent that a cantilever beam at junction sections of the footings of contiguous blocks was necessary to maintain the expansion arrangements. The cantilever beam had to be provided at junction sections to prevent the load from one set of footings being carried into the adjoining section on the other side of the expansion joint. A typical joint with the cantilever arrangements in a junction-section is shown in Fig. 7. The portion of adjoining wall (in elevation) marked B is built up along with the wall shown in cross-section and the portion marked ‘ C ’ is the load coming on the cantilever for which the beam is designed. The position of the expansion joint is also clearly indicated. It will also be seen that the cantilever has been combined with the R. C. plinth-beam referred to above. The design of the cantilever beam is given in Appendix 1.

9. Doors and Windows

9. 1. The doors and windows should be so designed as to secure maximum natural lighting inside the room, at the same time serving the needs of security and ease of reach. It is generally



DETAILS OF R. C. CANTILEVER BEAM Fig. 7

accepted that in any case, the window area should equal at least 20 per cent of the floor area of any section.

9. 2. The main doors and windows in the building are of size 5′ × 10′ and 5′ × 6′ 6″ respectively with fixed ventilators at top provided with weldmesh. The doors were one-third panelled and two-third glazed while the windows were fully glazed and provided with iron-grills made of 3/4″ dia. bars running horizontally. Double ventilators 5′ × 2′ were provided in the cellar room, the inside ventilators being of the glazed type and the outer ones of mat-bar covered with fine wire-mesh.

9. 3. 1. The disposition of doors and windows in the walls is a controversial problem. Generally while preparing the plans, the doors and windows are marked centrally along the width of the opening and this causes confusion to the subordinate in charge of the execution, whether to fix them at the inner or outer face of the wall or centrally as per plans. At the outset, it may be conceded that when the doors and windows are fixed to open outside from the halls, least interference is caused with space inside the hall. Also, shutters exposed to weather should open outside to prevent entry of rain water inside.

9. 3. 2. Keeping these considerations in view, all the windows on the exterior walls exposed to weather were placed on the inside face with shutters to open out from the halls. This arrangement combined with the sunshade projecting out 2′ 6″ from the walls, provides the necessary setting back of the position of windows from the reach of normal rains falling at about 80°.

9. 3. 3. On the inside walls all doors and windows were kept at the outer-faces with shutters to open outside. This arrangement helps to keep the shutters in the open position, folded on the walls without any interference on the working space in the verandah. Incidentally it also provides better appearance, fully covering the face of the walls. On the other hand if they are provided on the inner face of the wall part of the shutters in open position will project into the verandah apart from showing out the series of openings of doors and windows on the wall face.

9. 4. All the windows and doors in the building were kept at 3′ 6″ above floor level following the general practice adopted in modern buildings. It is felt that this height of sill might perhaps have been lowered by 6″ to a foot so as to give better access to air flow at the level of the normal work-table which is about 2′ 9″ high. But then considerations of better light and immunity to rain, point in a contrary direction and a compromise between these opposing factors will have to be effected in the design of doors and windows in any building, taking into the bargain, considerations of locality, orientation of building, windiness, rainfall etc. For cutting off glare especially in summer, venetian blinds and can be used on the outside windows but these require considerable maintenance and subtle adjustments.

10. Continuous Sunshades

Along with the lintels continuous R. C. sunshades were laid 3″ thick at wall face and 2″ at free end and projecting 2′ 6″ from the wall-face. It was generally observed on inspection of buildings recently constructed, that temperature cracks developed in the sunshades at intervals of about fifteen feet. So cardboards 1/8″ thick and coated with Bitumen shellmac R. C., were introduced to the full width of the Sunshades at about fifteen feet intervals along the length, the lintel inside the wall being laid continuous.

11. Expansion Joints in R. C. Slab

11. 1. 1. Expansion joints are usually provided in the roof slab to take up the volume changes of the concrete structure due to variations of temperature and moisture content. The change due to the latter cause is mainly one of shrinkage, as the concrete usually dries out progressively, and rains do not ordinarily cause any appreciable gain in the moisture-content unless it be of a very long duration. The variations in temperature cause expansion and contraction and this may be a daily or seasonal feature. The size and location of expansion joints are usually decided on considerations of these causes of volume change and observations of buildings in service.

11. 1. 2. In general it is taken that the movement at the expansion joints in a building divided into 100 feet sections for a

50 degree range in temperature, will be about $\frac{3}{4}''$ and that due to shrinkage $\frac{1}{4}''$ to $\frac{1}{2}''$ per 100 ft.

11. 2. In the Research Station building expansion joints $\frac{3}{4}''$ wide have been provided in the R. C. roof in one unit without any intermediate joints to correspond with the joints in masonry carried from the foundation level. The expansion joints have been treated with copper sheet use and filled up with bituminous mastic to afford necessary water-sealing.

11. 3. 1. The expansion arrangements consist of copper strips 1/16″ thick (16 gauge) fabricated into bulb shape and placed in the joint between the slabs from adjacent blocks. These strips are secured in position by means of $\frac{1}{4}''$ dia. M. S. rods from the R. C. slab passing through slots made in the strips, at spacings of 2′-0″ centre to centre. The rods projecting from the copper sheets are tied together by longitudinal rods $\frac{1}{4}''$ dia. and the projections are bent down on the copper sheet. The bulb of the copper strip is then filled with poured-joint bituminous mastic filler made in the following manner. The materials required for the mastic are Bitumen 39/40 penetrations clean fine sand and coarse asbestos wool or fibre. Bitumen and sand are heated separately to a temperature of about 325° F. The required quantity of asbestos fibre is added to the sand while it is being heated, and is mixed well; The sand and fibre mixture is then poured into Bitumen and the mixture stirred well maintaining the temperature at about 325° F. The following proportions have been adopted for obtaining a good workable mastic. One pound of asbestos fibre to ten pounds of sand and eight pounds of bitumen. The mastic is then well packed into the bulb while hot, and finished smooth by means of suitable trowels kept hot. The joints are covered at the top by means of galvanised Iron sheets 18 gauge bent to shape and fixed to the floor and parapet as shown in Fig. 8.

11. 3. 2. In the above arrangement copper strips 1/16″ thick have been used as per directions given in the M. D. S. S. It is found in practice that these sheets are rather heavy and difficult to fabricate and a much lighter section should be quite sufficient for the purpose. Reference to general literature available on the subject reveal that mostly a 16 to 20 oz. copper sheet is used for

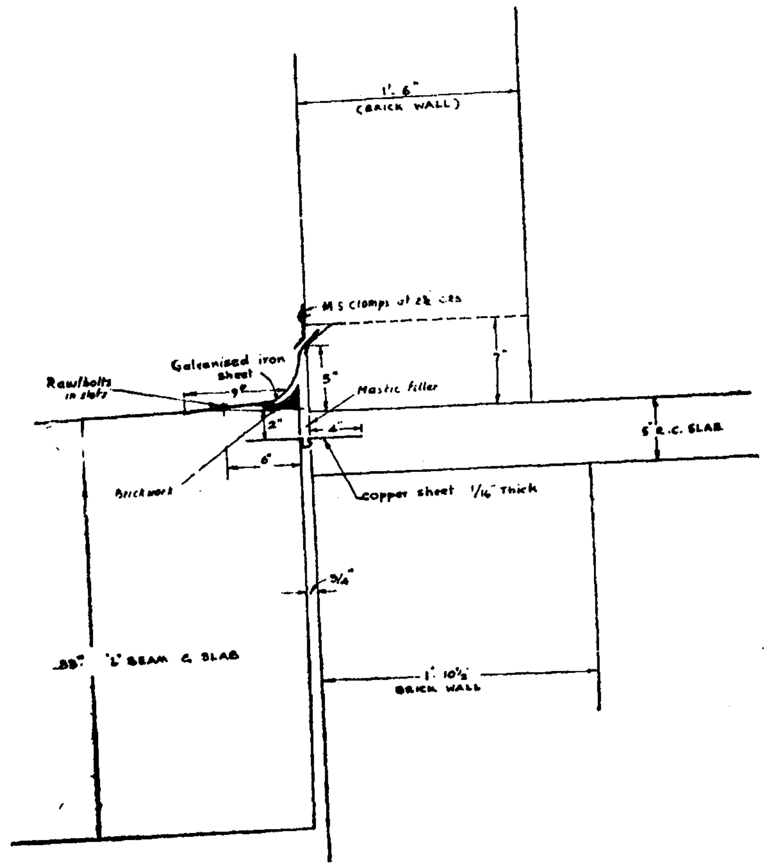


Fig. 8. Details of expansion joint

the purpose. The numerical coincidence indicates a likelihood that the 16 oz. sheets have been mistaken for 16 gauge sheets (1/16″ thick) specified in the M. D. S. S. This thickness give a 45 oz. sheet as against a 16 oz. or 20 oz. sheet that will suffice for the purpose. It seems desirable that, as 16 oz. sheets are quite easy to fabricate and will serve the purpose of expansion joints quite well, the M. D. S. S. may have to be suitably revised in this regard.

11. 4. The copper sheets are generally available in 4′ × 4′ sections and the required length of strip can be obtained either by

lapping and rivetting, or by lapping and soldering or welding. Both the types have been adopted For effecting waterseal, welded or soldered joint serve better.

12. Roof Slabs

12. 1. The ground floor and first floor roof consist of Tee beams and slabs. The spacing of Tee beams is 10′-0″ and the clear span 30′-0″. The clear span of R. C. slab over verandah is 8′-1½″. Originally the beams and slabs were designed for a live load of 100 lbs./sq. ft. But these were subsequently revised to suit the loads specified in the M.D.S.S. Thus live loads of 80 lbs./sq. ft. for ground floor and first floor and 50 lbs./sq. ft. for roof of first floor have been adopted in the design calculations. The R. C. slab is 5″ thick with main reinforcement 3/8″ dia. at 5″ spacings and distributors 3/8″ dia. rods at 15″ spacings. The Tee beam ribs measure 14″ width × 28″ depth excluding the slab. The reinforcements of Tee beam consist of M.S. rods 7 Nos. 1-1/8″ dia. each and shear stirrups ½″ dia. R.C.C. Bed block under the Tee beams were first laid and the brick masonry constructed upto level of bottom of slab leaving gaps for the Tee beam ribs. At the time of pouring concrete bituminised cardboards were introduced to permit the separation of the Tee beam concrete from the walls plastered with C.M. 1 : 3-1/2″ thick and to allow for minor movements of the R.C. work in the expansion. The structural roof was laid with the bearing surfaces of the walls laid with tar-lined kraft paper separating the roof structure from the masonry.

12. 2. It is usual practice to provide bearings for the Tee beams, for the full width of the wall sections. Then the end elevation of the support walls consists of both brick-masonry and cement-concrete faces and subsequent plastering leads to the appearance of patches forming to the pattern of the end-sections of the Tee ribs. To avoid this, the ends of Tee-beams were kept back 4½″ from the outer-faces of the support walls, and after the structural roof was laid, the recesses at the ends of the Tee-beams were built in with brick-masonry leaving a thickness of bituminised cardboard in between. This practice enables subsequent rendering to keep a uniform appearance.

12. 3. As the building has been divided into nine independent units it became necessary to provide Ell beams at the ends of blocks where expansion joints were located.

12. 4. 1. In the laying of the roof structure an interesting point was dealt with. The roof over the verandah portion of each block consisted of simply supported R.C. slabs. If the roof slabs on both the hall and the verandah were to be kept at one level, then the bearing provided by the common wall between the hall and the verandah had to be divided between the two structures as in fig. 9 (a) or alternatively, the roof over the verandah could be depressed so as to provide full bearing of the wall for both the structural slabs as in fig. 9 (b). In the first method as there will

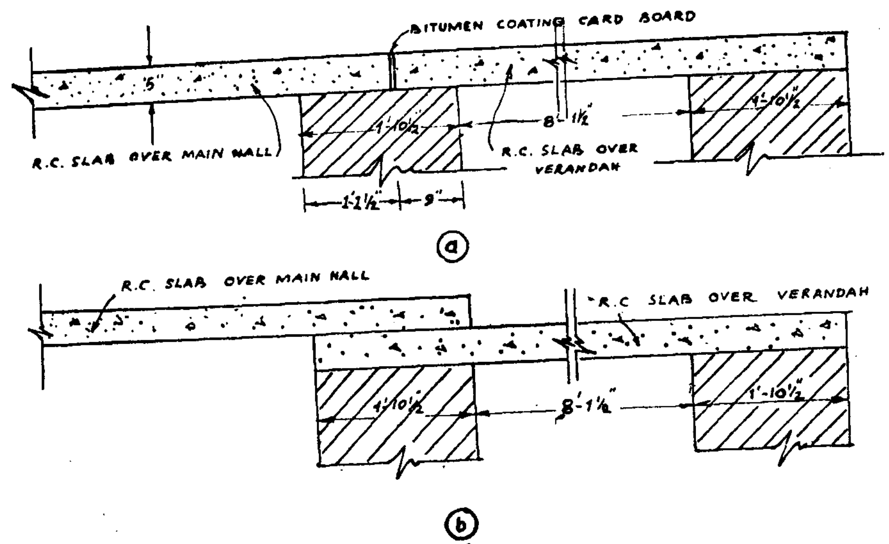


Fig. 9 (a) & (b). Alternative arrangements for roof slab

only be a butt joint between the slabs, some kind of blocking course over the wall covering the joint would be necessary to prevent rain water leaking through the joint. The latter course seems to be advantageous in this regard—though this involves additional length of slab under the overlapping section—as there will be a lap joint between the two slabs and rain water will not find its way through the same. This method will also effect savings in the provision of slopes for drainage as these can be provided with less material taking advantage of the depressions of the verandah roof-slab. On the other hand a filler course would be necessary to bring up the level of the depressed slab if the first floor has to be built on and this will mean additional dead-weight and additional cost. The roof slabs over hall and verandah were therefore laid in one level itself having bearings of 1–1½″ and 9″ respectively over the common intervening wall. First the roof over main hall was completed and the roof over the verandah was immediately laid allowing the slab portion to come over the Tee beam stem as shown in Fig. 10. A thin resilient bitumen-coated cardboard, introduced into the joint separates the two sections.

12. 4. 2. Over all such junctions of slabs, on the weathering course a bond wall is generally considered necessary to prevent the ingress of rain water. This arrangement introduces other complications to provide varied slopes for the flow of drainage. So in this case, the bond wall arrangement was omitted, taking advantage of the slabs spanning in opposite directions. However, as an additional precaution the R. C. slabs were kept continuously soaked with water and kept moist till the weathering course of brick jelly in lime was laid over the whole area and finished, so as to ensure that subsequent contraction of the slab with the loss of moisture will keep down the extent of expansion due to variations in temperature. By this arrangement no separating cracks, has been caused in the weathering course. Therefore all the roofslabs were finished with 3″ thick brick jelly in shell lime omitting the use of binding walls over the joints and two courses of flat tiles laid in and pointed with cement mortar 1 : 3 in slopes of 1 in 60.

12. 5. The roof over portico in the front was designed as an inverted Tee beam cum-slab so as to provide necessary appearance with a flat surface in continuation of the bottom face of the lintel over the main wall at the entrance.

12. 6. The roof over the rear passage consisting of a flat slab is suspended on to the main slabs in the roof of the adjoining blocks by necessary articulations in the slabs. The design details are given in Appendix 2.

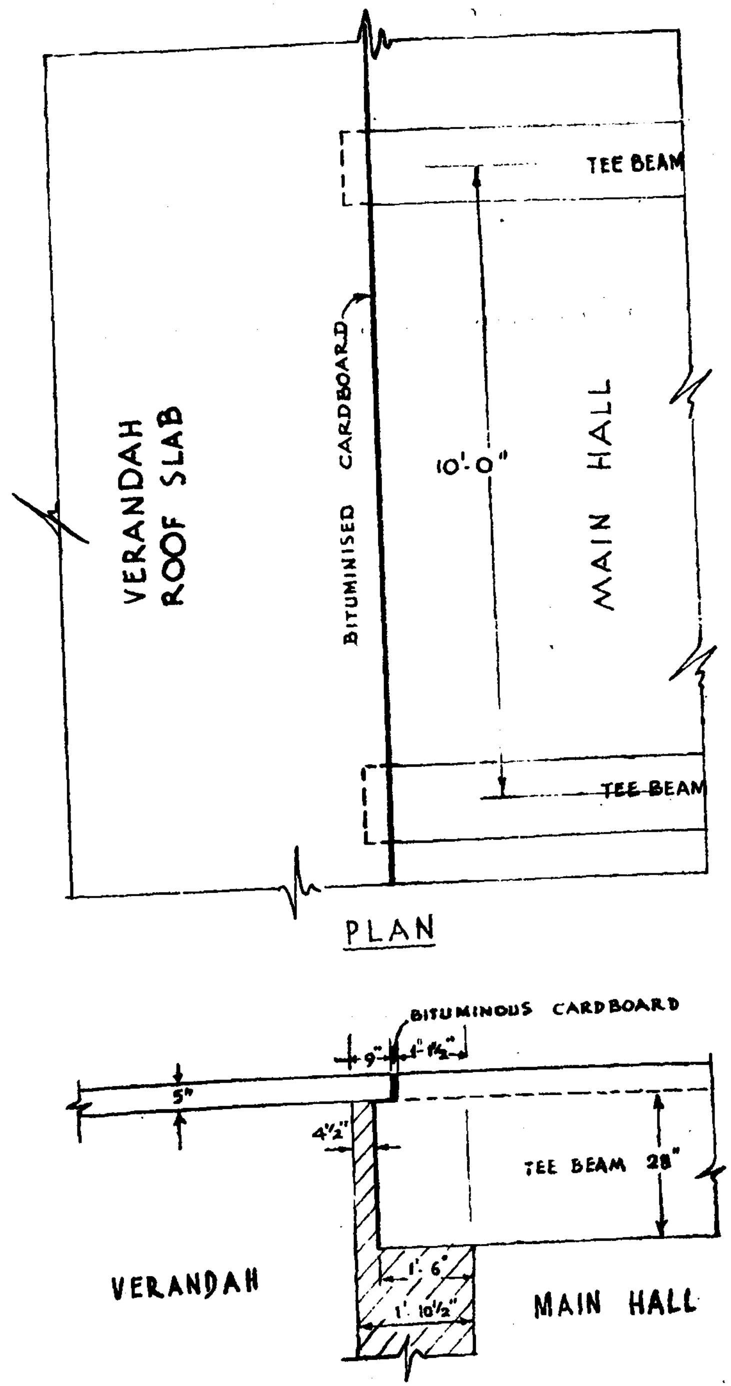


Fig. 10. Cross Section

12. 7. Mention may have to be made here of the special design features in the R. C. roof slab over the main staircase. The R. C. roof consists of a main Tee beam taking the roof over the verandah portion on one side and crossbeams on the other side with slab over the cross beams spanning parallel to the main beam. The design is given in Appendix 3.

13. Basement Room in Bitumen Laboratory

13. 1. The cellar room in the basement of the Bitumen Laboratory (Northwest block) is intended to store models of interest. The floor to floor height of this room is 10 feet and allowing for the Tee beam stem the free height available is 7′ 3″. The roof of the basement room acts as the floor of the bitumen laboratoιy and the steps and stair-case arrangements are made at the eastern end. The design feature of the Tee beam at this end carrying the staircase instead of the slab to serve as flange is explained in Appendix 4.

13. 2. Flooring of cellar room: The structural details of flooring adopted are given in Fig. 11 and 11(a) showing a cross section of the cellar room. Laying of the mastic asphalt course for the flooring is described in Appendix 5. A question may perhaps arise as to whether instead of such a heavy flooring as adopted, on R. C. raft foundation for the whole cellar portion including the walls, would not have been better and more economical. Tests conducted by the Soils section of the Research Station showed that the swell pressure of soil was about 0·5 Ton per sq. foot. This would mean in the worst condition, an upward thrust of about 18 Tons, on a strip one foot wide, of the structural raft. The upward reactions on the endwalls would then be about 9 Tons per foot run whereas the loads coming on the walls were about 5 to 6 tons only. This might therefore lead to an uplift of the walls to endanger the structure. The provision of a single raft was therefore not considered desirable. So the walls have been rested separately on spread-footings of adequate width and the flooring laid separatety to adequate depth to counter the hydrostatic uplift.

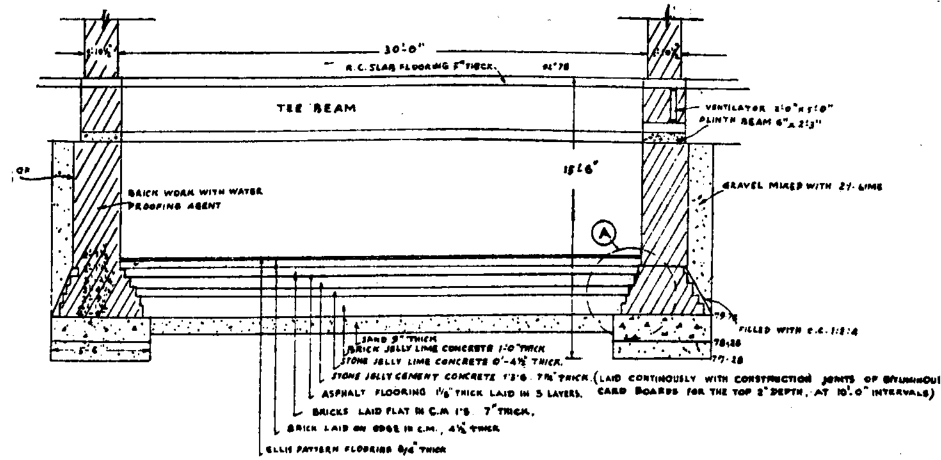


Fig. 11. Flooring proposals of the cellar room

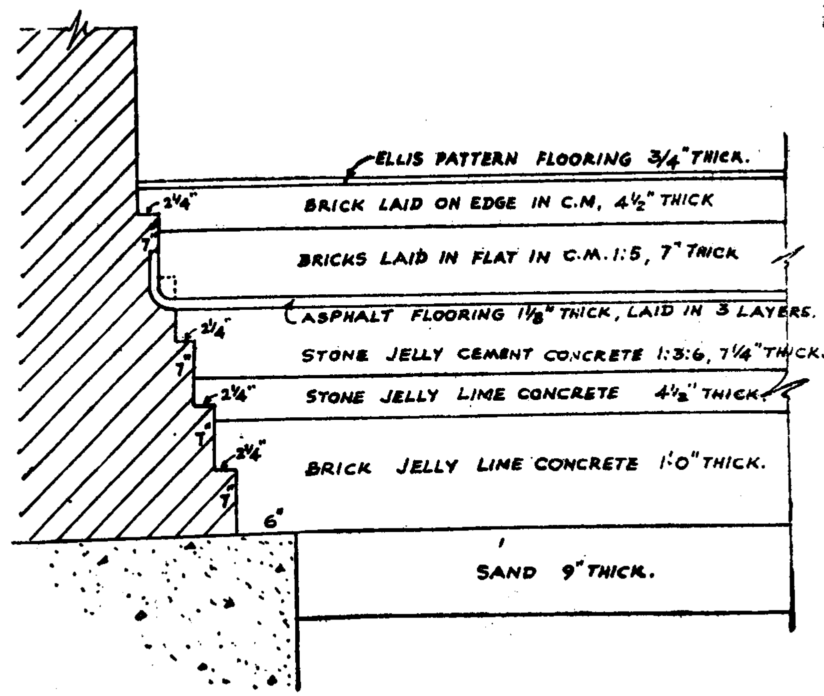


Fig. 11 (a). Details at A

13. 3. Waterproofing of Cellar Room

The walls allround in the basement room on the outside were treated for necessary waterproofing so as to exclude ingress of moisture penetrating inside through the wall section. The following were adopted for this purpose.

The outside faces were plastered from the top of the concrete footing in foundations of the main walls. For this purpose, the rectangular footings were filled with brick jelly concrete in cement mortar to provide a battered face. The plastering was done in cement mortar 1 : 3 proportions with a patent admixture compound, called "waterlock", manufactured by M/s. Paulson Paint Cellulose Works, Bombay, at the rate of one packet of 3½ lbs. per cwt. of cement. Tests also showed that the waterlock admixture had considerably improvided the waterproofing qualities. Details of tests on waterlock are given in Appendix 6. The dry plastered surface after necessary period of curing, was covered with three coats of Bituminous paint (RC$_3$ of Burmah Shell). In addition the gravel used in the backfilling of the foundations was also mixed up with 2% of shell lime. This percentage of addition of lime was arrived at after testing in the laboratory, *vide* details shown in Table VI. The addition of this percentage of lime markedly improved the water proofing qualities of the backfill. Due to these precaution taken, the basement room is quite dry and well ventilated, as any other section of the Research Station.

TABLE VI

Showing effect of Gravel Line Combination in Waterproofing

Serial No.	Particulars of mix	% moisture absorbed by capillary action — After 3 days capillary action
1	Gravel alone ...	15·9
2	Gravel + 2% lime ...	13·5
3	Gravel + 4% lime ...	16·5
4	Gravel + 6% lime ...	18·0
5	Gravel + 8% lime ...	18·0

14. Flooring

The flooring consists of 4″ thick concrete with granite broken stone in lime-mortar 1 : 2 using shell lime ; over which cement concrete 3/4″ thick Ellis pattern first sort was laid as per the M.D.S.S. Fine polish of the surfacing was obtained by grinding the surface with corborundum stones using neat cement cream. The additional cement consumed for the polishing works out to 75 lbs. per 100 sq. ft., over and above that provided for the flooring. Necessary recesses to accommodate the door-mats and entrance-grills have been provided in the flooring so that these will be flush with the floor surface. The central halls and toilet rooms were provided with mosaic tiles of pleasing colours, and bands.

14. 2. In flooring one point needs special mention. It was observed during execution that stone jelly in lime concrete does not work up well. Brick jelly in lime concrete, prrticularly for flooring, provides a smooth compact pavement to take up the Ellis Pattern surfacing. However owing to the longer lead involved, stone jelly was adopted here, being cheaper.

15. Plastering

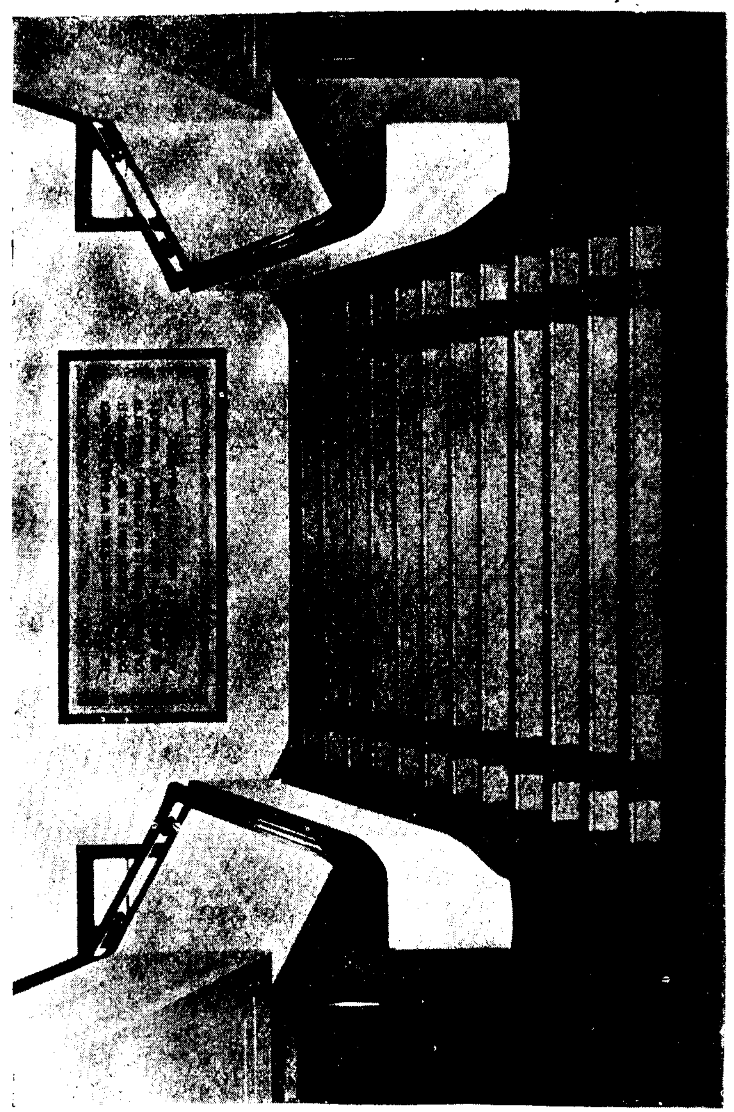
All walls were plastered with cement mortar 1 : 4–½″ thick. All the external faces were finished with a rough texture, and all the interior faces unexposed to rain were plastered smooth. Modern building are mostly finished with rough texture on the exposed faces though a certain prejudice against the rough finish still exists, because of the belief that rough finishes become dirty more quickly, than the smooth ones which do not afford any lodgement for dirt and may be washed clean by the normal process under rains. But actually rain water falling on a smooth non-absorptive surface does not distribute itself uniformly but runs down in streaks resulting in irregular discolouration and shabby look. On the contrary, rough surfaces break up and distribute the water films and so, although the total amount of deposited impurity may be greater, the disfigurement is less. This also provides good keying for the successive coatings of whitewash even under splashing rains.

16. Colour Scheme for the Building

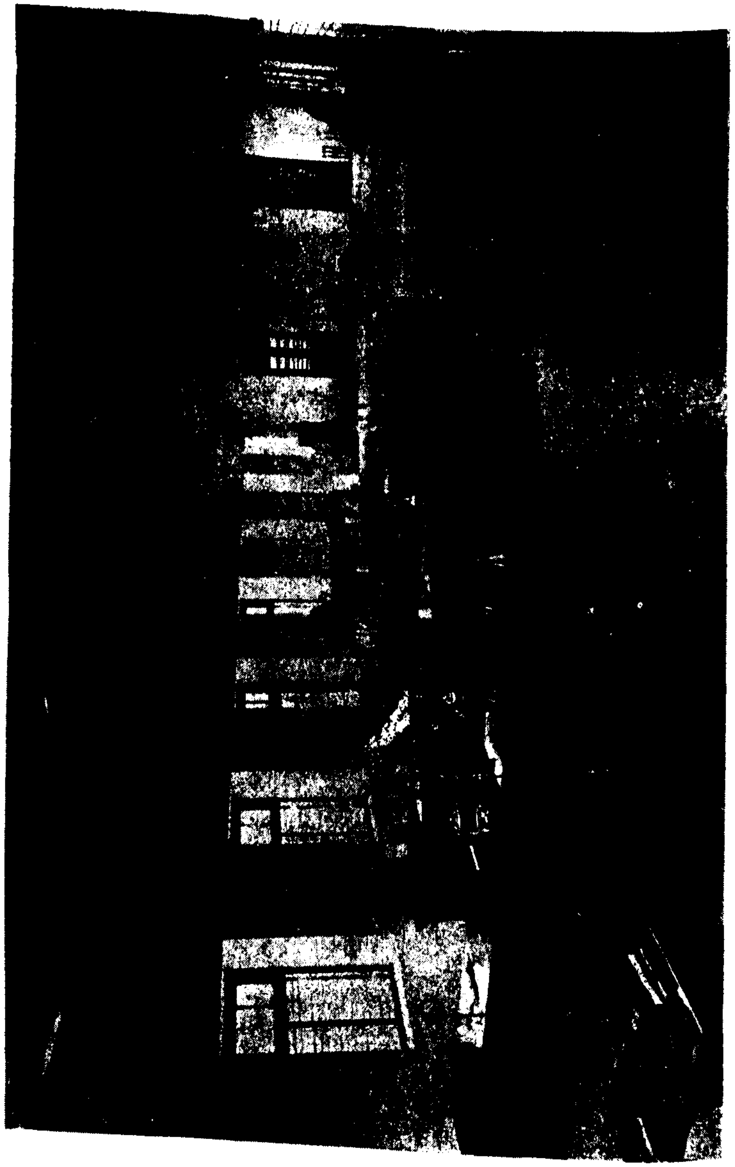
16. 1. Only by the skilful use of colour can the condition be established for a comfortable and pleasing visual environment. In selecting colours and paints, attention has to be given to the psycológical response to colour, to special uses to be made of the colours and to atmospheric conditions that might affect the paints. Light colours make rooms look larger while dark colours make them look smaller. Darker colours have a tendency to blot out while lighter colours emphasize. This knowledge could be made use of in making objects look large or small in subordinating undesirable details or in accentuating desirable details. Machines and equipment can be painted in colours, taking these points into account.

16. 2. There is a common tendancy to associate colours with ideas of warmth and coolness. Scientific evidence also points out that colours affect attitudes and the output of energy. Red and orange are regarded as warm and energising colours, and blue and green as cool and soothing. Colour has its chief value not in the use of specific hues for particular situations but in creating a general mood of acceptance and enjoyment in the situation of work. Colours can be so selected as to improve lighting and to substitute beauty for drabness.

16. 3. In general colours have a bearing on the problem of comfort in the building with respect to prevailing climates in the locality. In the summer we have to prevent the heat of the sun getting into our room and in the winter we have to conserve the heat produced inside the room against loss to the external air. It has been recognised that the absorption of summer sunshine by outside walls is reduced when they are colour-washed in yellow, and light-coloured inside walls pass heat less readily than dark coloured walls. From these considerations, the building has been colour-washed in yellow on the outside and left white-washed on the inside of walls. The painting of windows on the outside of the building has been done in colours complementary to the colour-washing adopted for the outside of the structure, without bringing in contrasts usually noticeable with green colours adopted for doors and windows under P. W. D. practice.



Main Stair Case



Soils Laboratory General View

17. Auxiliaries

Apart from the main laboratories certain auxiliaries such as the lecture-hall or auditorium, the library and recording sections, the photographic section etc. have been included in the building program and the points to be noted in the planning and design of these are dealt with below.

17. 1. Auditorium

The size of the auditorium should be so fixed as to cater for the assessed audience space, without providing much in excess. As the size increases it becomes more difficult for many types of activity to be carried on in as much as it is difficult for any person in the audience to project himself adequately in an auditorium which is too large. Seating in the auditorium should be so selected and arranged as to secure maximum safety, comfort, and sight-lines. Seat widths usually average 19 to 20 inches and an arrangement whereby a seat in one row is not directly back of a seat in the next-row, together with a sloping floor or gallery should secure ideal sight-lines. Aisles with seats on both sides should have a minimum width of 2'-3". Acoustical considerations need special attention involving the shape and dimensions of the auditorium wall and ceiling coverings, floor-materials and upholstery. This problems has to be solved with advice from acoustic experts.

17. 1. 2. Artificial lighting in the auditorium should be designed to give soft, even light, without glare. Some lights should be controlled from the rear of the auditorium and all lights should be controlled from the stage panel. Glaring colours should not be used on walls and the ornamentation scheme in the auditorium should be so designed as to focus attention on the stage. Usually scenic backgrounds are provided on the stage walls. In the stage walls at Highways Research Station exquisite ornamental patterns of Kuthuvilakku with bulbs—in line with our country's tradition and heritage—have been provided under a set of apt couplets from Tirukkural in brass letters in each wall. The Kuthuvillakku consists of rosewood body with the arms and the crown made of brass. A projector screen 12' $\times$ 8' made of hardboards of fine variety and sprayed three coats with aluminium paint has been built permanently in the rear wall of the stage and suitable screen

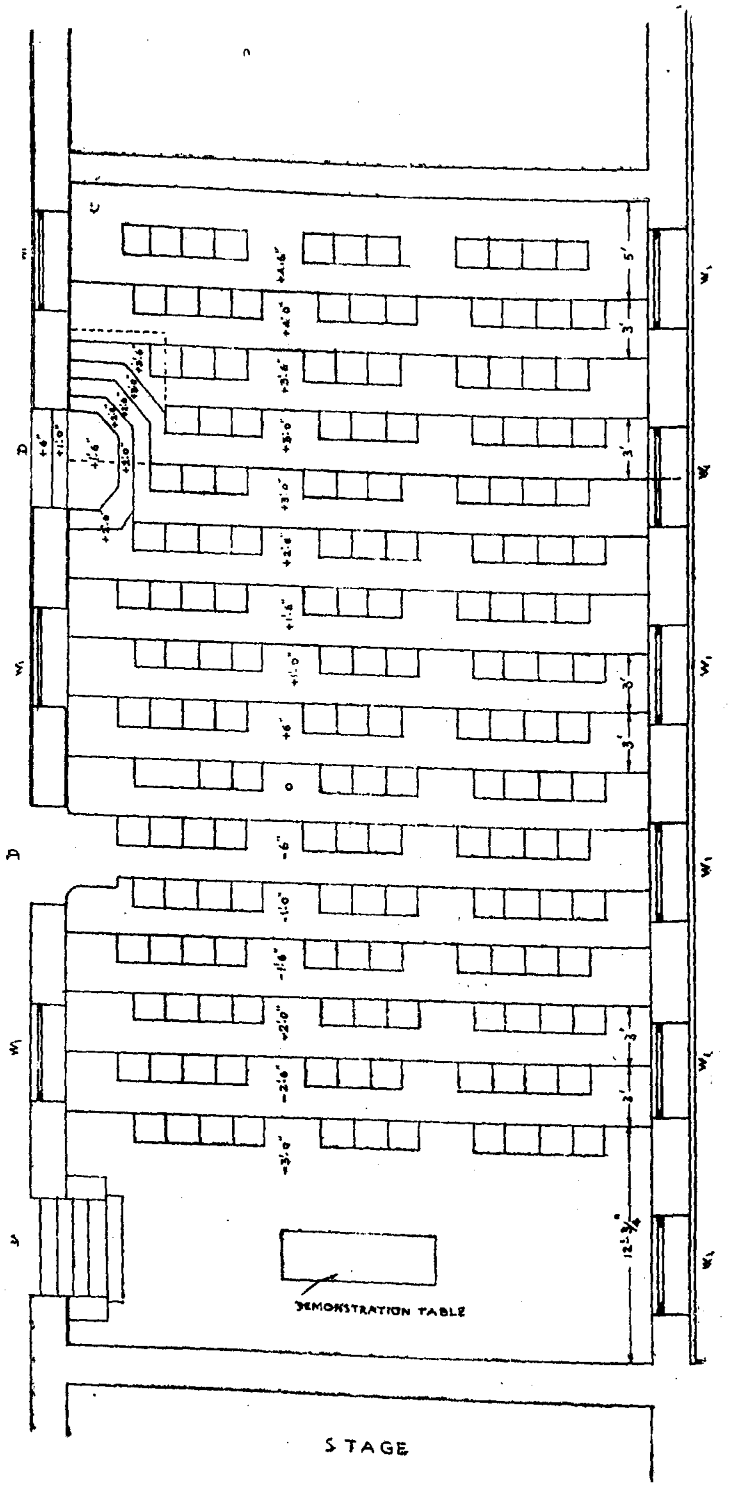


Fig. 12

LONGITUDINAL SECTION OF LECTURE HALL

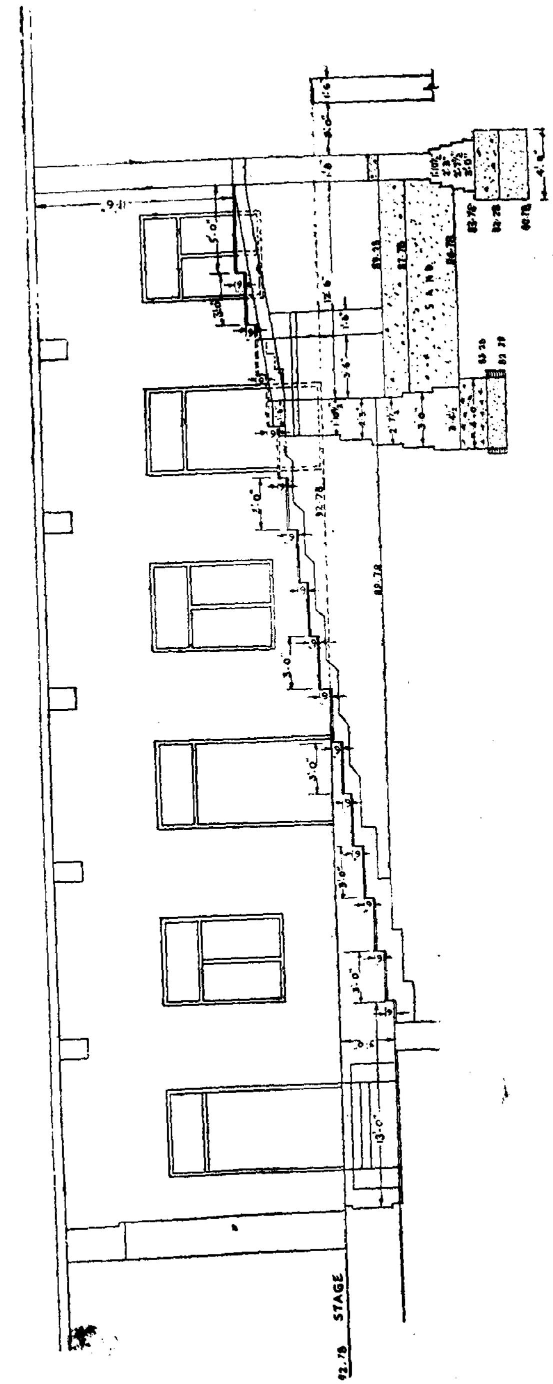


Fig. 12 (a)

curtains of the double folding type have been provided. The stage opening measures 18′-0″ long × 12′-0″.

17. 1. 3. As for flooring of the auditorium a cement floor properly sealed and hardened normally will do, though the aisles are preferably of a resilient materials such as linoleum cork or rubber tile. In the Research Station, only a cement floor for the whole of the lecture hall has been provided, with the aisles covered with red coloured jute-wool matting.

17. 2. Library

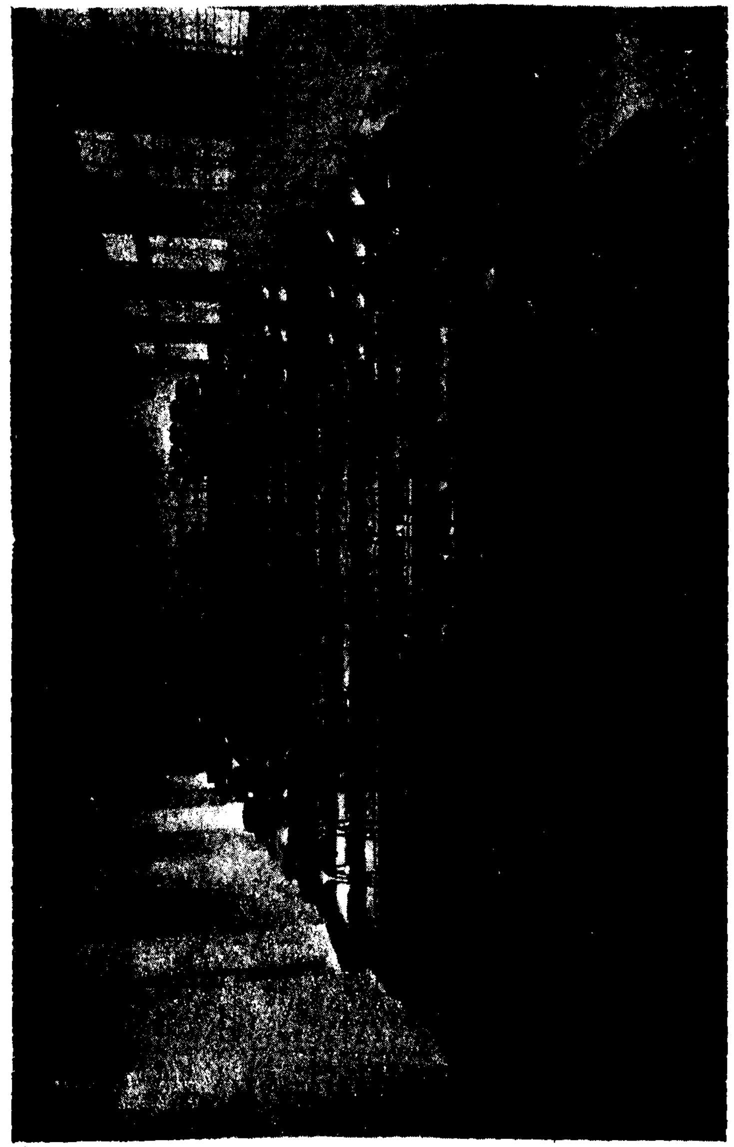
The library is an integral part of any modern Research Station. The library requires work-areas for reading and circulation, storage space, and office space for librarian and for indexing.

17. 2. 2. In the arrangement of library tables it is important that readers should not be forced to face windows or other unshielded sources of light. The library should include reading tables chairs, circulation desks, and magazine and journal racks. Book cases not exceeding 5′-6″ in height with the bottom shelf being 4 to 8 inches above the floor, are desirable. Special racks with slanting shelves should be designed for display of magazines and journals.

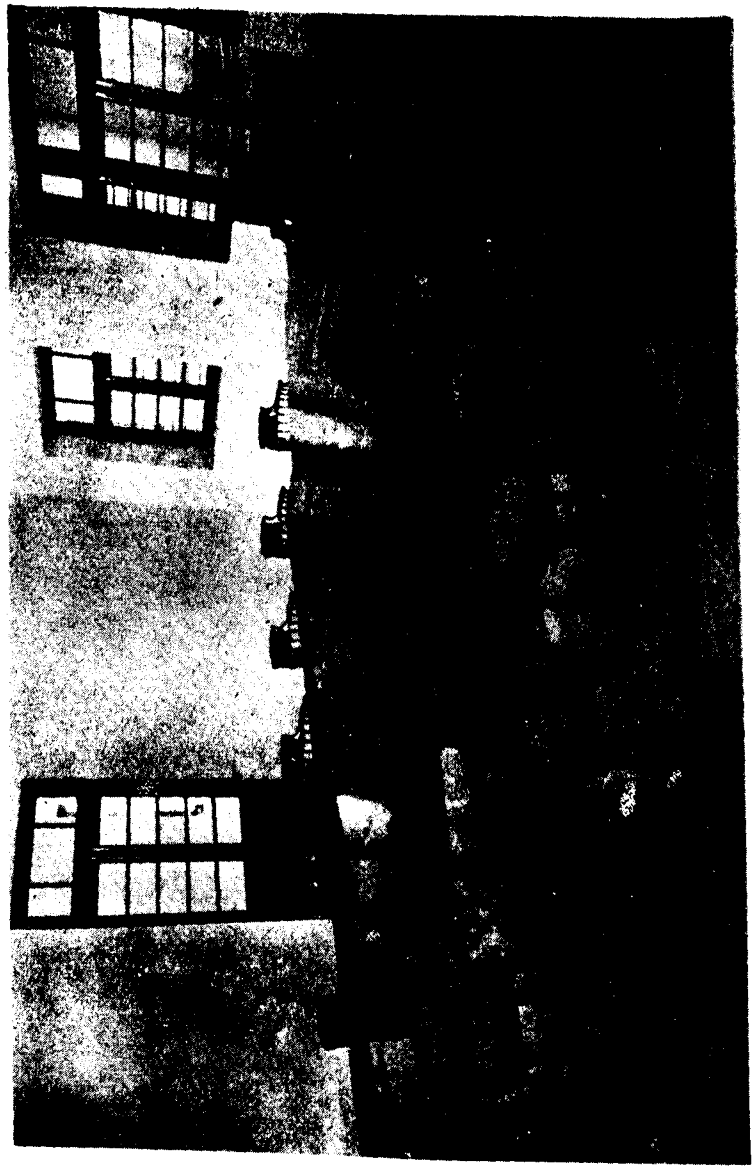
17. 2. 3. In addition to these arrangements a recording section has also been included in the library room as shown in fig. 13. These consist of two tiers of steel racks in six rows each with moving space of 2′-0″ between each row. A steel ladder in the central alley leads to the top-tier which is properly railed at the ends and sides of alleys for protection.

17. 3. Photographic Section

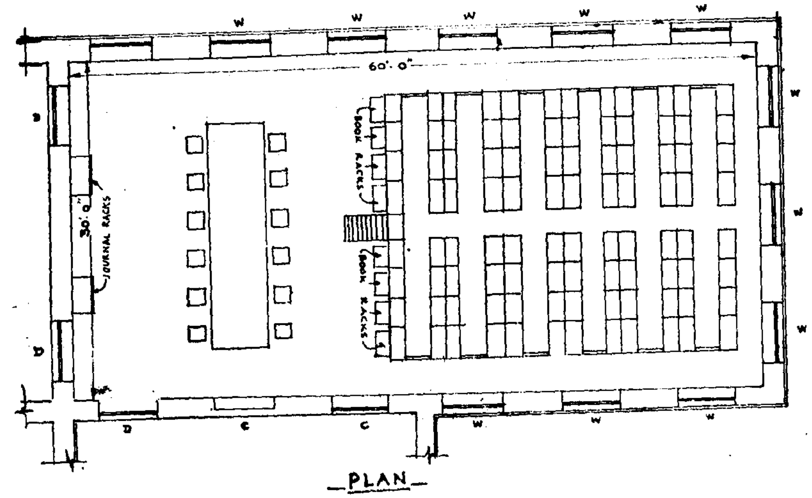
A photographic section has also been included in the Research Station. A Photostat Machine has been erected in this section for purposes of quick and easy duplication of all scientific literature direct from magazines when needed. This obviates the laborious work of comparing with originals and also the preparation of inked drawings from the originals. The necessary accessories such as wash basin, washing tank, water supply and



Lecture Hall



Committee Room



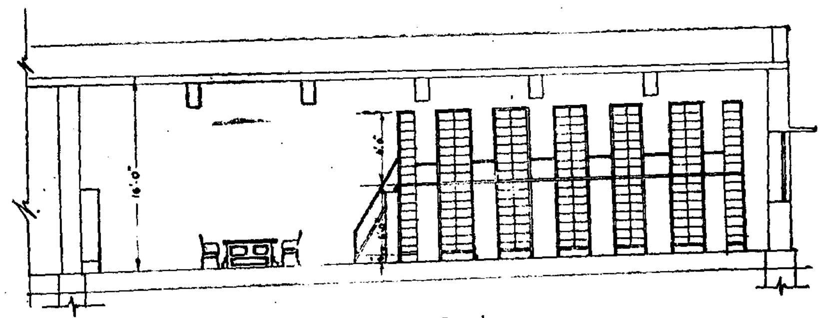


Fig. 13. Section

electric connections and work-tables and plan-filing cabinet have been provided in this section.

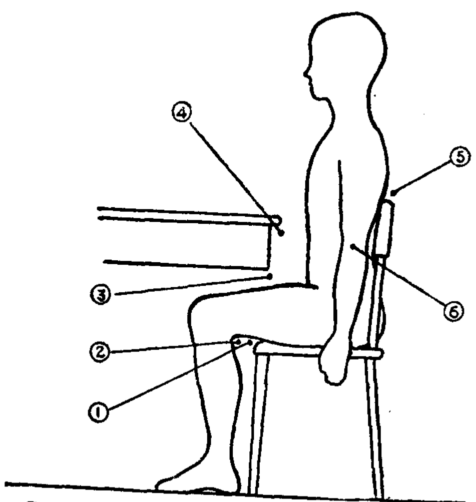
17. 4. Telephones

For large buildings such as the one constructed for the Research Station, some type of inter-communicating system or room telephone system is necessary for quick transaction of work. The Research Station is to be equipped shortly with an 'intercom' telephone system, in addition to the telephone installed by the Posts and Telegraphs Department for outside contacts. Wiring for the telephonic system should have its own special conduit and should be kept separate from other electrical connections.

17. 5. Furniture Requirements

17. 5. 1. Furniture requirements for various sections of the buildings as well as their arrangement should be careful planned to meet the specific purposes in each section. The furniture should be made of quality timber and should be strong, durable, have an elegant appearance, and should be finished in blonde or light honey colour with non-glass surfaces to minimise the effect of glare. Furniture required for the Research Station were made of Burma teak-wood. It is necessary that all the categories of furniture should be designed properly, keeping in view, the various needs and purposes that each is intended to serve, the habits limitations and characteristics of users, and ease of operation. Some important suggestions considered in the design of furniture are given below.

17. 5. 2 Seats: (1) Height: The person's feet should rest flat on the floor without dangling in the air and support sufficient weight so that there is no pressure on under side of thigh at front of seat; (*Vide* fig. 14).



① NO PRESSURE UNDER THE KNEES
② FREE SPACE BACK OF INSIDE ANGLE OF KNEE
③ ROOM ABOVE THE THIGHS
④ BACK EDGE OF TABLE OVERLAPS FRONT EDGE OF CHAIR
⑤ LOW CHAIR BACK, OPEN AT BOTTOM; SUPPORT FOR HOLLOW OF BACK ONLY
⑥ TABLE TOP HIGHER THAN ELBOW WHEN ARM IS STRAIGHT

Fig. 14

(2) When the person's back is properly supported by back rest, there should be three or four inches clearance between front edge of seat and inside angle of knee.

(3) The seat should slope slightly down toward the rear to overcome tendency to slide forward;

(4) The seat should be so shaped as to distribute the weight over a large area without undue pressure at specific points. It is better in situation such as seatings in the auditorium that there is no rail or ridge or other obstruction at the rear of the seat which prevent the extension of the buttocks boyond the back support.

(5) The back support should support only the lumbar region of hollow of the back between the hips and the shoulder blades.

(6) There should be a slight slope of the back support but this in most cases depends upon the total chair design.

17. 5. 3. Tables

It is usual practice to provide the administrative staff with an ordinary table with two drawers. This type of table is quite inadequate for the proper storage and handling of office files and other records. The general tendency will be to heap them on the table—top itself or keep them strewn all over, by keeping additional benches and make-shift racks a round the seat. In the Research Station à special Ell-shaped table with drawers and cupboards has been designed for the administrative section to provide adequate space for files both for storage and while handling. No record is left on the table-top at the close of the day so that the table serves as a compact unit for each member of the section. Plans of the various pieces of furniture adopted in the Research Station are furnished in figures 15 (a) to (k).

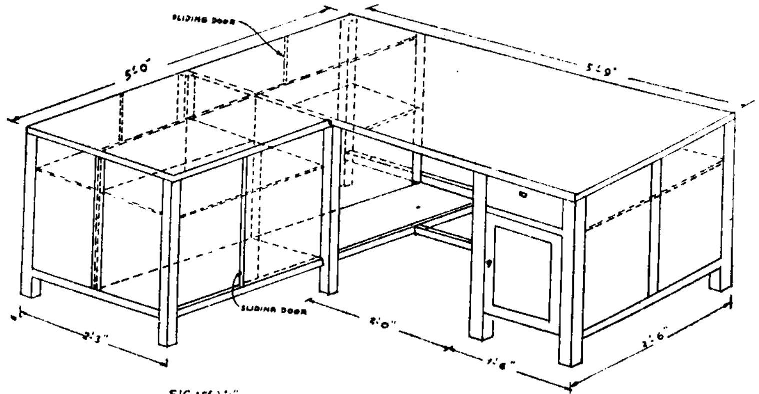


FIG.15(a) 'L' TABLE WITH SLIDING DOOR. FOR ADMINISTRATIVE SECTION

(for clerks)

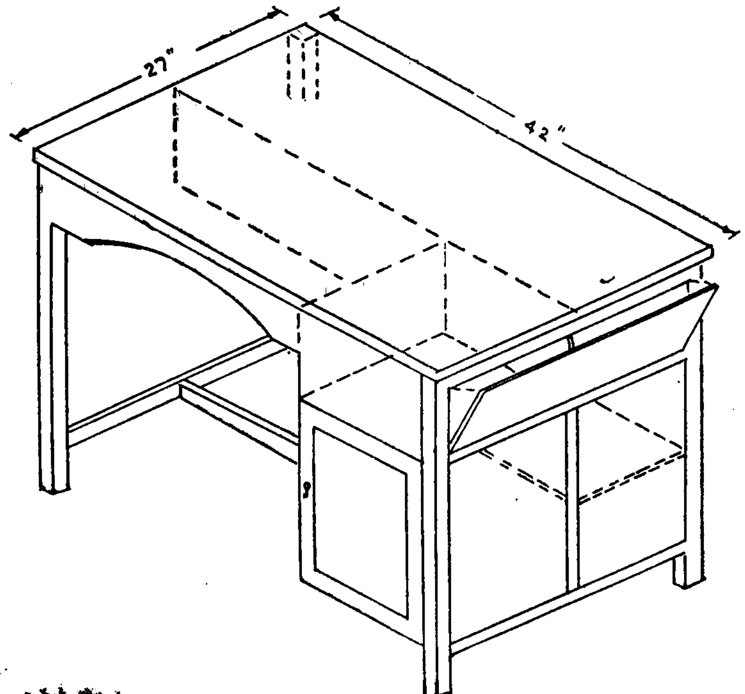


Fig. 15 (b). Drawing Table

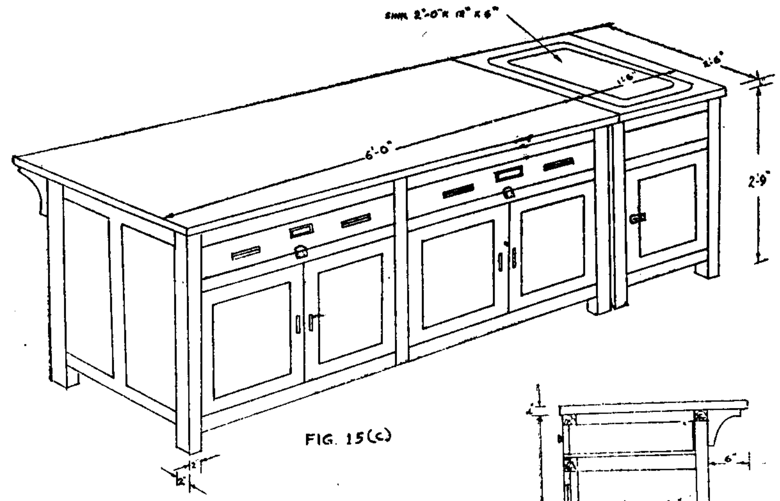
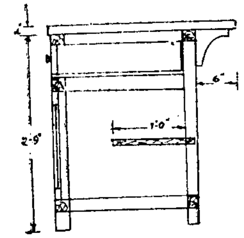


FIG. 15(c)

LAB. TABLE WITH SINK ATTACHED



SECTION

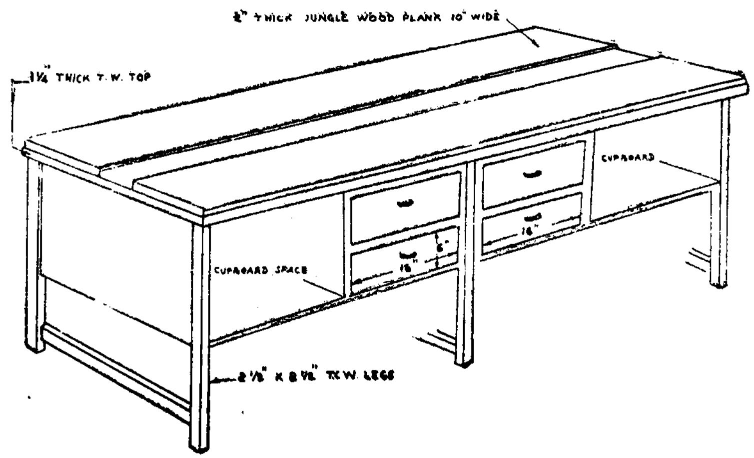


Fig. 15 (d). Work Table 10′ long, 3′ wide and 2′ - 9″ high

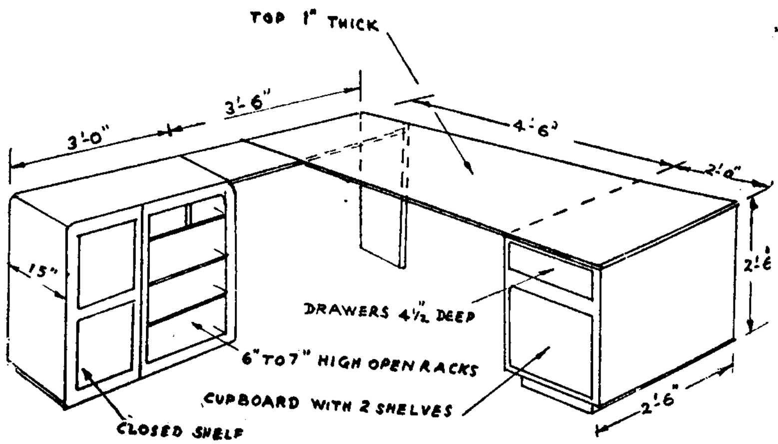


Fig. 15 (e). Table with side shelf (Librarian)

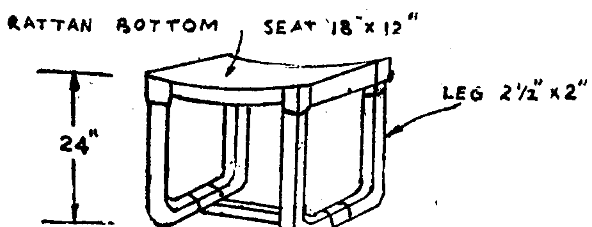


Fig. 15 (f). T. W. Stool for Drawing Section

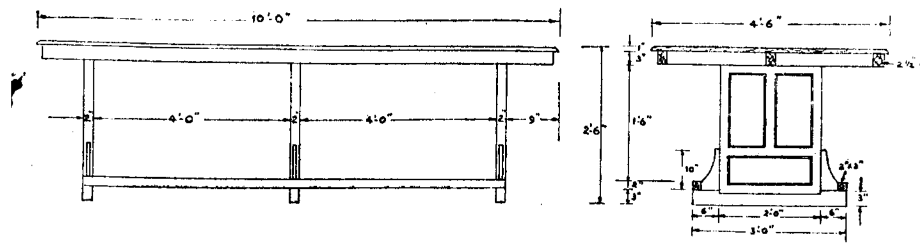


Fig. 15 (j), Front Elevation—Cross Section

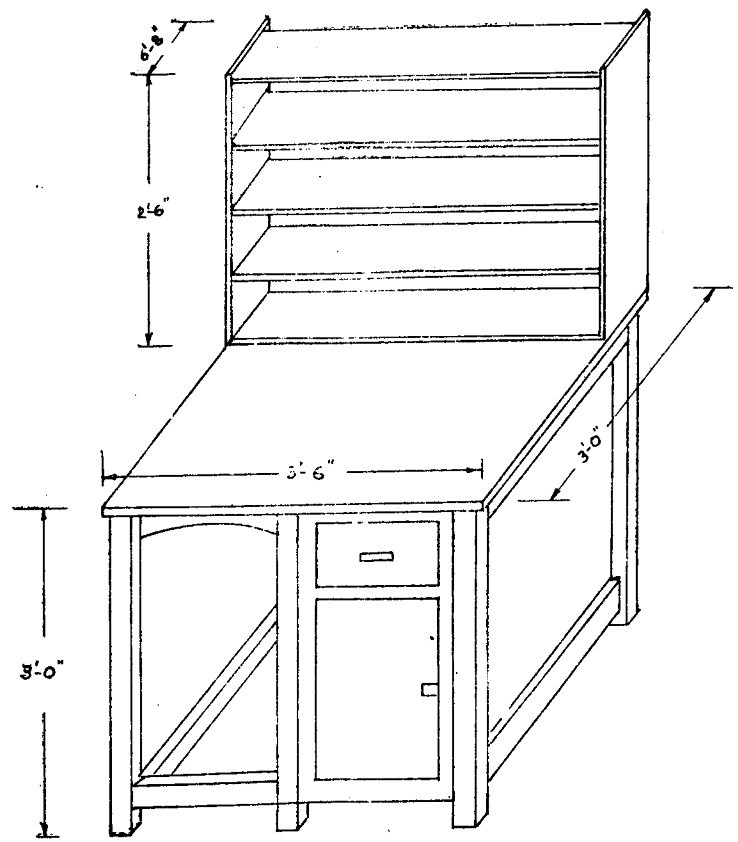


Fig. 15 (j). Chemical Table for Photastat

18. Electrification

18. 1. The Research Station building has been provided with necessary electrification. By electrification the common conception is to have few lights and fans hanging from the ceilings controlled by some protruding switches and a meter at the entrance indicating the energy consumed. In the days of planned development, every activity is planned to secure maximum comforts at reasonably low costs, and so also should be the scheme of electrification. The increasing use of electricity in the home and in industry and the progressive improvement in the types of generating machinery, and research in the manufacture of electric lamps have generally reduced the cost of lighting in the present days, when the tendency is to take the issue of lighting out of the realm of scientific standardisation into one of aesthetics modernization and changing style.

18. 2. It is common knowledge that eye-strain fatigue and head-ache can generally be traced to the effects of insufficient illumination. Improvements in seeing conditions and visual acuity, and the psychological effect of brightness and cheer that comes with improved lighting, all combine to improve the efficiency and out put of work.

18. 3. Optimum light intensities from the point of view of output have been derived from practical tests in industrial operations. The results show that improved lightings conduces to better and efficient output of work. It should be noted that for good quality of light and proper condition of seeing, what is needed is, as great a brightness contrast as possible on the visual task (*i.e.* black print on white paper as against black print on grey paper) but as small a brightness difference or ratio as possible within the surrounding and peripheral fields of vision (*e.g.* white paper on a light coloured desk-top, better for reading than white paper on a dark-desk top).

The American standard association have after careful consideration of all aspects of lighting, established a cope specifying recommended lights intensities varying with the types of activity and location. A summary of the recommendation is given below:

			Foot-candles recommended.
1.	Ailes, stairway	...	2-3
2.	Washrooms	...	3-5
3.	Carpentry benchwork	...	5-8
4.	Laundry, bakery	...	8-12
5.	Weaving	...	12-20
6.	Office, general, school	...	8-10
	Close work	...	10-15
	Typing	...	12-20
7.	Glass cutting	...	15-50
8.	Fine machine work inspection	...	25-100
9.	Jewellery work, drafting	...	25-100

18. 4. Distribution of Light in Rooms

A single point illumination gives rise to a sharp shadow. The light intensities from such an illumination vary from a maximum directly under the source to a minimum in the far corners of the room. The greater the number of light sources contributing to the illumination of the work-desk the less defined will be the shadows.

18. 5. In the design of lighting scheme for any particular room or hall, the following factors affecting utilisation of light have to be studied.

(1) The room index: This pertains to the geometrical layout of the hall. The larger the room the more effective is the utilisation of light. The size and shape of the room and the height of the light source above the plane of working are factors affecting the utilisation of light. These are formulated into what is called the room index as follows:

$$\text{Room Index} = \frac{2W + L}{6H}$$

Where, W, L and H are the width and Length of the room and the height of the light fixture above the work-desk respectively.

2. The Reflection Characteristics of the Room

Much of the light that contributes to the illumination of the work-table in a room is reflected light from surfaces such as walls and ceilings. When light strikes a surface, it is either reflected or absorbed. If the surface is rough and black, almost all the light incident on the surface is absorbed. But if the surface is smooth and light coloured, it reflects a large proportion of incident light. Of the light which strikes walls or ceiling a part is absorbed and the remaining is reflected to strike other surfaces to get reflected a number of times in every decreasing proportions till all the light is absorbed. Each of these reflections contributes to the illumination of the room over and above that of the lamp alone. It is therefore important that walls and ceilings of the right type of finish are chosen to aid the illumination of the room.

18. 6. The amount of reflected light in a room is therefore, affected by such variables as the colour of ceiling walls and floors, extent of non-reflecting surfaces such as doors, windows, black-boards, extent of obstructing surfaces such as beams, shafts, machines, etc. The reflection characteristics of a room are divided into three classes, as below;

Good: Clean white walls and ceiling, normal extent of door and window openings. No other interference.

Medium: Ordinary light walls moderately soiled. Moderate interference.

Poor: Dark or dirty walls, much interference.

18. 7. The utilisation factor of light is based on the room index and the reflection characteristics and typical utilisation factors for various ranges of room index and reflection characteristics are given in Table No. VII.

TABLE VII.

Typical Utilisation Factors.

Room Index.	*Reflection characteristics.* Good	Medium	Poor
1	... 0.42	0·38	0·35
2	... 0.52	0·49	0·45
3	... 0.62	0·58	0·55

18. 8. Artificial Lighting

Use of fluorescent lamps: The human eye is well adapted to the daylight and it is therefore desirable to have artificial lighting blended to such an extent as to produce the effect of daylight, for maximum comforts. The new fluorescent lamps adequately fulfil the requirements in this respect. The fluorescent lamp consists of a glass tube filled with mercury vapour and having an electrode sealed at each end. The current flowing through the mercury vapour produces an arc which generates invisible ultra-violet light. This acts upon a chemical coating on the inner surface of the tube, yielding a secondary lighting by fluorescence. This fluorescence in a wide range of colours can be obtained by choosing from different varieties of phosphoresent substance which fiuoresce under the influence of ultra-violet light. By suitably blending these substances, a resultant fluorescent light is obtained which stimulates daylight. Questions arise as to the relative merits of these fluorescent light tubes and the familiar incandescent light bulbs. Incandescent lamps and their fixtures are less expensive, easy to change, fit many types of fixtures and shades, start instantaneously without flickering, and burn without any sound. They have an average life of about 1000 hours which is not affected by the number of times the light is turned on and off. On the other hand they have excessively high spot-brightness resulting in glare, and give off considerable heat, which becomes a problem when high levels of illumination are to be maintained. Fluorescent lamps have numerous advantages over the gas-filled tungsten-filament incandescent lamps. The equipment using fluorescent lamps is much lower in brightness in the direct and reflected glare zones and provides a much larger and more uniformly illuminated area. Shadows will also be much softer and insignificant. Fluorescent lamps have comparatively verly high luminous efficiency yielding about 30-60 lumens per watt as against 8 lumens given by the incandescent lamp. "A 60 watt coil tungsten-filament lamp will emit 13·9 lumens per watt while a 40 watt white fluorescent lamp emits as much as 58 lumens per watt. These figures are for lamps which have been in use for 100 hours, and new lamps give of more light". Fluorescent lighting therefore is economical in use of electric current. The smaller use of current also reduces the heat generated by the lamp and the environments are therefore relatively cool.

18. 8. 2. But some persons experience discomfort and unpleasantness while working under fluorescent lighting. Complaints of eye-strain and ocular fatigue are common and these are mainly due to high intrinsic brightness and glare and partly due to what is called stroboscopic effect. The different phosphorescent substances that are blended in the tubecoating to emit white light, react at different speeds on exposure to ultra-violet rays and therefore an effect of rapid succession of colour changes is sometimes felt. These stroboscopic effects are greatly reduced in twin-tube installations provided with electric devices which throw the separate circuits out of phase. The life of the fluorescent lamps depends in large part on the number of times they are turned on and off; with an average burning time of three hours per start the average rated life is about 2500 hours; the fixtures for fluorescent lamps are more complicated and costly. Certain auxiliary equipment are incorporated within the fixtures such as a starter and ballast. These auxiliaries and the difficulty of cleaning complicate the maintenance problem. The ballasts in some fixtures radiate an almost inaudible sound. Even the fluorescent lamp is too bright to be used bare and the tube should be shielded so that it is not visible at any angle less than 45° from the horizontal. When costs of installation and of current are compared, fluorescent lighting costs more to install but less to operate than incandescent lighting. Many variables enter into figuring comparative costs, however, including the cost of installation the cost of current per unit, the member of hours burned per year, the frequency of turning the lights on and off, and the cost of maintenance and cleaning. It should be noted however that in places where cost of power supply is more, the increased cost of power have more effects on the total costs of the incandescent, than on the fluorescent, since cost of fixtures and maintenance are relatively higher for fluorescent than for the incandescent. Despite these short comings and the fact that incandescent lamps are still greatly in use the advantages of better visual acuity and coolness and their artistic possibilities have induced the use of fluorescent lamps in lighting.

18. 8. 3. A typical design of lighting for hall 90′ × 30′ size at Highways Research Station is given in Appendix No. 7. It will be seen from the design that quite a large number of Tungsten

filament lamps are necessary for given the total illumination required and these have to be provided at very close spacings. Fluorescent tube-lights are found to suit the situation much better, being only a few in number and giving more even or uniform light. The cost of wiring for one hall with tube lights compares favourably with that of lighting with Tungsten filament lamps involving greater number of points. 40 watt fluorescent twin tube lights have been proposed for the laboratories and halls, while 40 watt fluorescent single tube lights will serve the corridors. Mercury vapour street light lanterns are also provided at the corners of the building and at suitable situations on the approach roads to the building.

18. 9. *Wiring*: while in the subject of lighting, a brief note on wiring systems as related to architectural requirements of the building may not be out of place.

18. 9. 2. The architectural design of a modern building requires that the electrical installations which serve the building should be as unobstrusive as possible. Wires, cables, switches and other electrical equipment are indispensable necessities in any system of artificial illumination, and so convenient locations have to be found for the same in the interior of the building, without at the same time detracting from the decoration that goes into other aspects of the building such as walls, ceiling, lanterns, furniture etc. It is here that the case for concealed wiring comes into prominence-quite often an otherwise carefully planned and artistic appearance of a room is marred by ugly lines of rubber wiring around the surface of its walls.

18. 9. 3. At the very outset, it is conceded that concealed wiring does cost more than surface wiring, but this additional expenditure is considered by many as very necessary for promoting artistic outlook in structures of modern standards. In support of concealed wiring, it is emphasised that the extra expenditure can be cut down to a reasonable minimum by careful planning. The exact locations where the conduits of wiring have to be concealed have to be carefully pre-planned so that the channels for the conduits are provided at the exact places during the process of construction itself. If this is done, a large saving will be effected

in labour costs which would otherwise accure if ducts for electrical conduits have to be cut in finished works, not to speak of the possible structural damage caused to structures by such ministrations of hammers and chisels. Especially when the structure is of reinforced concrete it is quite possible that the locations of concealed wiring decided upon will interfere with the reinforcement rods in the concrete, which may have to be severed. If careful planning of the concealed wiring it undertaken before construction, the conduit can be made to run in conjunction with reinforcing bars or suitable clear-cut chases could be lift in the R. C. work by insertion of wooden battens where conduits for electrical wiring are to be located.

18.9.4. In concealed-wiring systems the light switches are also concealed in metal boxes and fixed flush with the wall and painted with the same colour as that of the walls, so that only the actuating toggle of the switch protrudes beyond the wall surface. Fan regulators are likewise fixed in walls such that the knob of the regulator alone is seen. Thus the electrical equipment can be made to fit in with the rest of the interior decoration of a building.

18.9.5. But the use of concealed wiring system involves essentially, considerable forethought and careful planning beforehand. Once the locations of wiring have been decided upon and installed, any alteration or modification of the system could be thought of only at great expense. Also, rough estimates show that the cost of concealed wiring if carefully planned beforehand, for new installations, is atleast 30 percent more than that of surface wiring, and the cost is more where chases have to be cut after construction is over. Concealed wiring is therefore generally not adopted in Government buildings, where unavoidable deviations and alterations during construction do occur and where the cost is a major consideration.

18.9.6. In the Research Station a semi-concealed system has been adopted by recessing the switch boards only into the walls instead of fixing them out on the walls. Concealed wiring in the ceiling has been adopted for lighting in the Entrance hall so as to maintain appearance. The main switchboard for power and light mains is located in the cupboard provided for this below the staircase

in the concrete laboratory verandah. Nine sub-main boards for the lights and six sub-main boards for power have been provided by dividing the circuit into independent units. One sub-main board has been fixed in cellar room for isolating the supply to this hall. Iron-clad cut-outs have been introduced in the various submains at the main switch board itself both for power and light, for facilitating introduction of submeters and carrying out repairs in any block without cutting off the supply to other blocks.

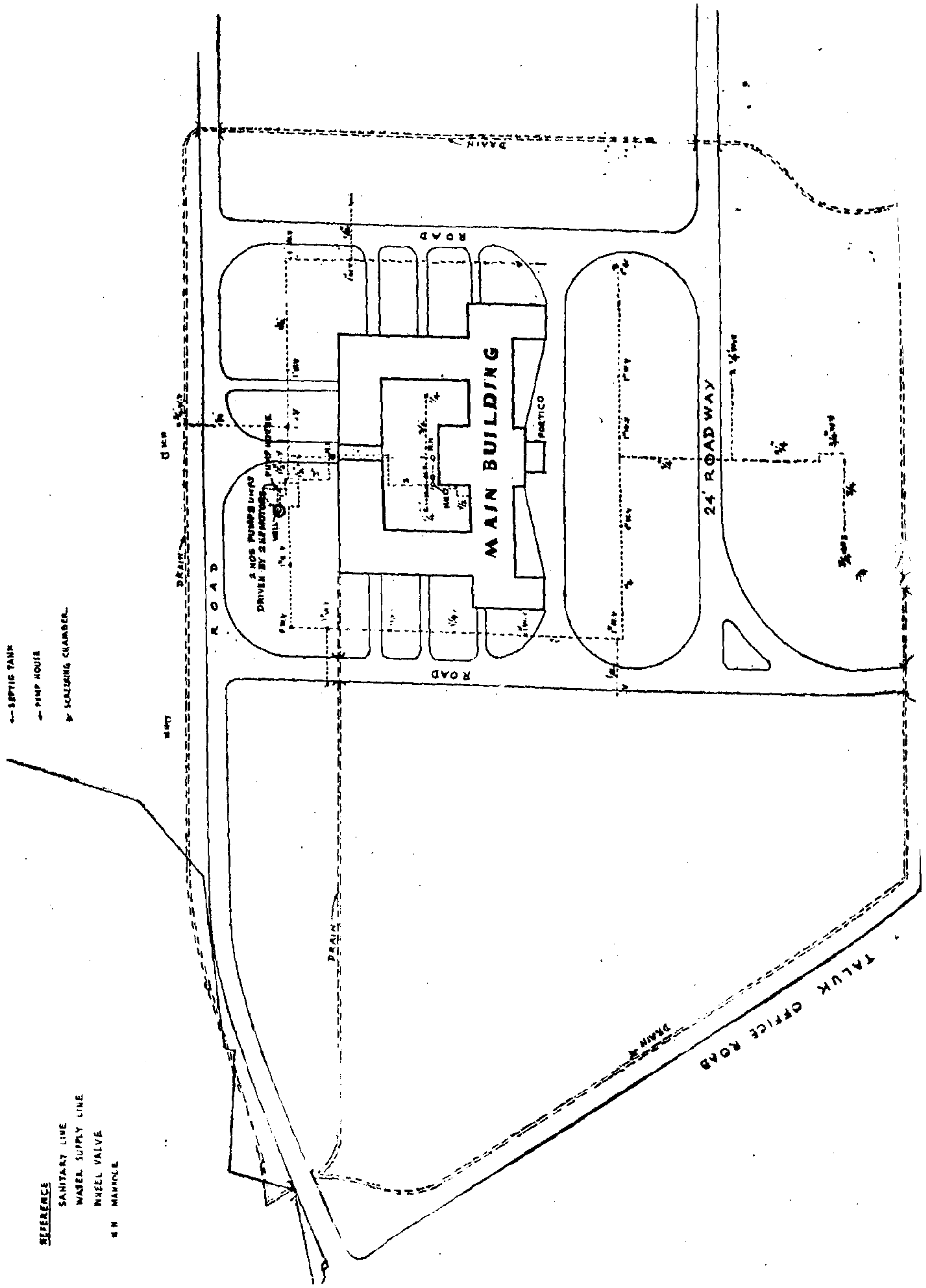
18. 10. Provision of Fans

To provide environmental comforts to secure better out-turn and improved efficiency, ceiling fans have been provided to serve the staff in the administrative section, and air-circulators in all the laboratories. In addition the electrification scheme includes provision of plugs in the different sections of the building for supply of power. The cost of electrification including M.E.S. charges is estimated at Rs. 84,000/-.

19. Sanitary Facilities

19. 1. Provisions should be made for properly designed, well located, easily controlled, and easily maintained sanitary facilities. The condition and sufficiency of these facilities affect the health of the inmates and hence the need for an efficient sanitary system cannot be emphasized too much. The lay out of the sanitary system installed in the Research Station is given in fig. 16.

19. 1. 2. Toilet rooms should have a minimum width of 10 ft. and entrances to Toilet rooms should be designed to prevent visibility from the corridor. Positive ventilation with segregated ducts is essential for toilet rooms. Natural light with glass area equal to about 12 per cent of the floor area, and ample artificial illumination are desirable. Mirrors with shelves below, should also be provided. Wash basins should be so placed that the users will pass them in leaving the toilet room, and should preferably be installed at a height of 3′ 0″ from floor. Drainage system should be in accordance with the best standard practice, with the collection and septic tanks being as far removed from the building as possible. The sewer drains should be correctly set out and laid to predetermined levels and jointed.



19. 1. 3. Manholes should be provided at the specified minimum intervals for the sizes of sewers and at every turn of the sewer lines. The system should be tested for leak-proofness. For this it is usual to start at the top of the system so that the water can be used again by flowing down from manhole to manhole. New drains should always be tested before the excavation trenches are filled in and the drains should not be passed unless they are perfectly water-tight. Before finishing the test, it would be desirable to look through the drains to see whether the drain layer has cleared all the cement from the inside of the pipes. This can easily be done by holding a small mirror in the manhole, and looking into it. If the length of the drain is long, an electric light placed in the man-hole next above the one in which the mirror is held is also useful to show whether the undersides of the joints in the drainpipes have been properly and carefully made and whether the invert of the drain has been laid true. It should also seen that the manholes are as water-tight as the drains themselves, and that manhole covers are properly bedded and sealed.

19. 2. Figures 16 and 1 (a) and 1 (b) show the arrangements of the water supply system adopted. A well has been opened out at the rear to serve as the source of supply and a storage R. C. tank measuring about 20′ × 10′ has been provided over the roof of the first floor of the Central Hall.

19. 2. 1. Construction of well :

Whether it be psychic or for scientific principle behind it, a water diviner was employed for selecting a good site for the well so as to ensure good supply of water. It was decided to locate the well at the rear of the building at a side selected by the water diviner. Borings were taken at the spot for ascertaining the depth of water and the soil profile at site. The boring chart is given in figure 17. Usually, in the construction of wells, dry brick masonry with open joints is employed for about two feet at the bottom and the remaining height is constructed solid with brick masonry in mortar. In such a case the water would have to be collected only through the bottom, even though the water-table might be considerably higher than the elevation of bottom of well. A different design has been adopted in our case, a special feature of which is the incorporation of " Windows " of dry

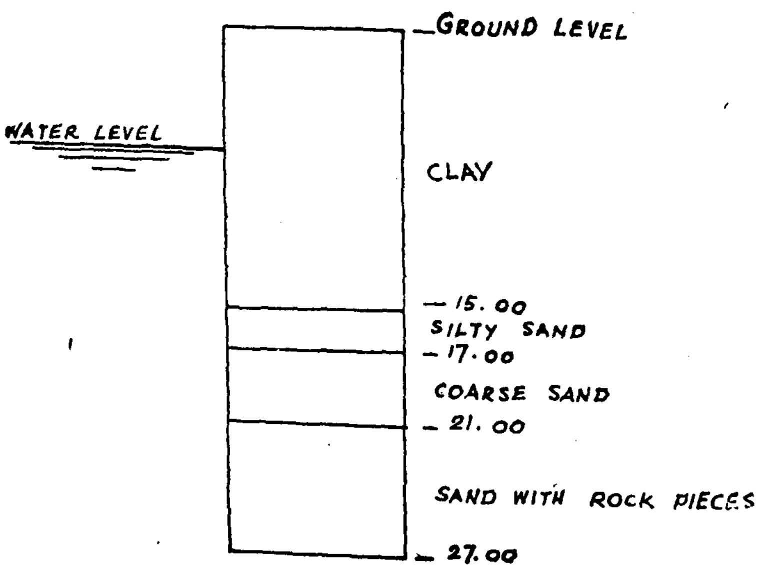


Fig. 17. Boring Chart for Well

brick masonry. The well structure consists of an R. C. curb at the bottom acting as the cutting edge, over which eight solid pillars of brick masonry in cement mortar spaced equally are erected along the circumference. Bond rods running through these pillars bind the structure to the R. C. curb below. Solid rings of brick masonry in cement mortar are provided along the height of the well at intervals of 1′-6″ thus forming window openings between the solid sections of masonry. These "windows" are constructed in dry brick masonry and are provided upto a height of feet from bottom of well. By this means, the subsoil water finds its way through the sides of the well allround, instead of having to enter the well from the bottom. This facilitates easy and ready recuperation of the well while pumping out water for use. The total height of the well is 21 feet and ~~its~~ internal diameter is 10′-0″; the well is plastered at the top on the outside faces, and is covered with precast R. C. slabs. Tests conducted showed a constant yield of 50 gallons per minute which is quite ample for our requirements.

19. 2. 2. A pumphouse with to centrifugal pumps, worked electrically, has been constructed adjacent to the well. The water

from the well is pumped into the storage tank and is treated by a "Surechlor" chlorination equipment at the delivery end of the pump.

19. 2. 3. Surechlor automatic water chlorinating Unit: The arrangement of the surechlor unit is given in Fig. 18.

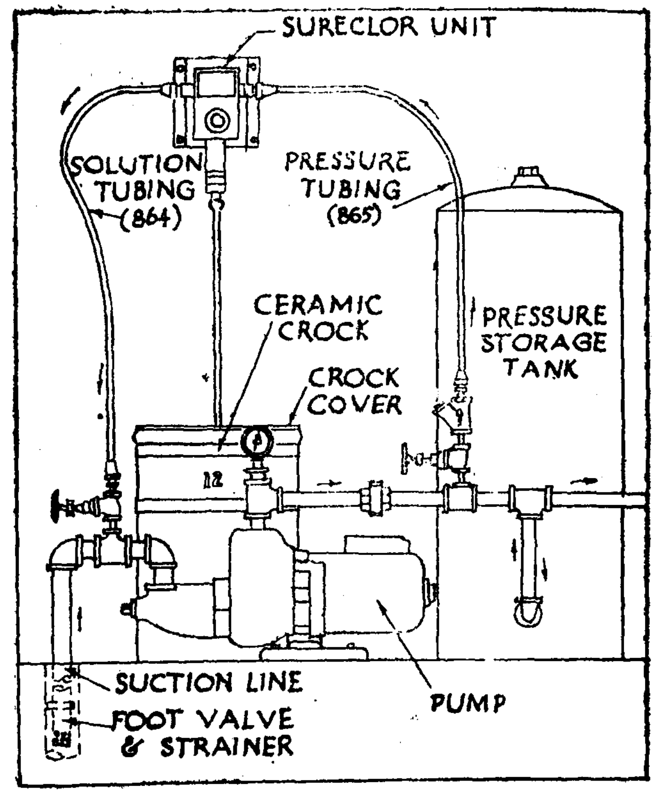


Fig. 18. Surechlor Unit

This unit is a chemical feeder designed to sterilize water in connection with domestic pressure water pump and small storage systems, by the automatic introduction of chlorine into the flow of water. It operates on a very simple hydraulic principle and employs a water-operated injector to produce a vacuum for raising the chlorine solution from the solution-container through a system of check and control valves to the head-block where it is mixed with water passing through the unit. A Flow indicator device is attached to the unit and by controlling the indicator valve, the desired rate of chlorination can be applied to the water-stream. The indicator is calibrated from 3 to 9 fluid ounces per minute. A solution feed rate of 3 fluid ounces would be normally sufficient for the treatment. A residual chlorine test-set is also attached to the unit, wherein colour standards for residual chlorine of 0·2 and 0·5 parts per millions are provided, for determining the correct setting of the control valve of the Flow indicator device. Depending upon the organic and chemical content of the water to be treated, the chlorine solution must be applied, until the residual found in the treated water ready for dirinking, is between a trace and 0·5 ppm. This is done by adding five drops of Orthotolodine solution to a test-tube containing two thirds full of the treated water and comparing the colour with the standards given in the test-set attached to the unit. Correctly chlorinated water will develop colour between the two shades of amber in the colour standards of the test-set.

19. 2. 4. Suitable water supply mains and distributors take the supply to the various sink and washbasins in the different laboratories and toilet rooms. Besides, outside hosefixtures have been provided on the outside of the building on all sides and in the inner quadrangle for serving the garden. Long range economy suggests the provision of non-corrosive piping selected not only according to immediate demands but also with a view to possible expansion of the services. Valves and fittings should be selected for ease of service and replacement. It is good practice to tag all valves for identification and in all cases a chart of the plumbing layout should be prepared and kept in safe custody.

20. Roads

20. 1. Approach roads form a necessary accessory to any building for providing the means of access to the same from the mian highways. A net work of approach roads has been provided all round the building, leading from the Taluk Office Road on the one side, and the Elliot Beach road on the other. The lay out of roads is shown in figure 16. The width of the roadway has been kept as 12′ 0″ between the metalled edges.

20. 2. One important point to be observed in the laying of estate roads is that these are to be so constructed as to merge with the general contour of the site. As far as possible, embanked roads are not desirable. The sub-base and road-crest are provided by trenching the sub-soil to the required level so that the finished level of the roads conform to the general contour of the adjoining areas, without being in embankment.

20. 3. The road structure consists of a base course of sand 6″ thick over which gravel soling is laid in two layers of 4″ thick each. Two courses of metalling of 3″ and 2″ thickness each are laid over the soling The wearing surface is of pre-coated chips using 9 cft. of granite broken stone chips ½″ size and 53 lbs. of Bitumen 90-100 penetrations per 100 sq. ft.

21. Gardening

A carefully planned gardening has been laid out, with extensive lawns, adjoining the building. The lawns are mainly intended more to maintain the sub-soil moisture for the stability of the structure, apart from its effect of general beautification. Site beautification, though a less utilitarian feature, is an essential accompaniment in the modern building program and gives opportunities for developing faculties of critical appreciation of planned nature.

22. Cost Particulars

Construction of the building commenced in April, 1956 and was completed in all respects in October, 1957. The details of cost of the work are given below :

1.	Land	...	Rs.	2,35,000
2.	Building	...	,,	9,31,000
3.	Services and Roads	...	,,	1,97,000
	Total	...	Rs.	13,63,000

The main building work was undertaken by M/s. K. S. Venkatraman & Co. (Private) Ltd. Electrical installations were carried out by M/s Philips (India) Private Ltd., while the water supply and sanitary installations were carried out by M/s. Joshi & Co., and furniture was supplied by M/s. Royal Cabinet Mart. The Research Station building was declared open by the State Chief Minister Shri K. Kamaraj on 14th November, 1957 by lighting a Kuthuvilakku.

23. Conclusion

23. 1. Generally the shape of the building has an effect on cost of construction. The greater the perimeter in relation to the area of the building the greater usually is the cost. Economy is achieved by avoiding undue ornamentation of building exteriors. Beauty in modern buildings is generally achieved through other means such as simplicity and proper massing of units.

23. 2. While economy is achieved by the elimination of waste space throughout the building, the same cannot be said of the practice of reducing ceiling heights, to this end. It is good practice to have the width of room not more than twice the height of ceilings. In our case, the width of various rooms were kept at 30′ 0″ and the heights of ceilings at 16′ 0″ (between floors). The savings in construction costs that can be made by reducing ceiling heights will not be proportional to the reduction of cubage, and in most cases, will be ruled out from considerations of ventilation and lighting.

23. 3. Where possible standards for selecting materials should be such, that later maintenance burden are not excessive. In all cases savings secured through the use of cheaper materials should be weighed against any values, or qualities, which may be sacrificed by such a selection. In the construction of buildings building codes should as far as possible be followed. There is no substitute for adequate competent and continued supervision at every stage of the construction if a good building is to be secured, but it should be stated that the so called codes and standards need continuing re-valuation in the light of new conditions and requirements, based on actual observations. We should hold fast what is good, but should rescind, modify, or improve, those whose validity cannot withstand the searchlight of critical scientific analysis.

Acknowledgements

The article is compiled with the help of Sri S. P. Krishnamoorthy, B.E., Assistant Engineer, Sri P. S. Srihari, B.E., and Sri K. A. Sivagnanam, B.E., Junior Engineers, in charge of construction, from the files pertaining to the Research Station work and is presented with the kind permission of the Director, Highways Research Station.

APPENDIX 1.

Design of R. C. Cantilever Beam (*Vide* fig. 7)

With 1st floor:

Cantilever arm $\frac{(4'-6'') - (2'-3'')}{2} = 1'\ 1\frac{1}{2}''$

Providing a recess of $2\frac{1}{4}''$
Cantilever arm $= 1' - 3\frac{3}{4}''$ or $1\ 5/16''$ $= 1{\cdot}31'$.

Load coming on ell beam and
Parapet : $5'\ 0'' \times 0'\ 9'' \times 3'\ 6'' \times 120$ — 1575 lbs.

Roof load : $5'\ 0'' \times \frac{30'\ 0''}{2} \times 140$ — 10500 lbs.

Brick work 1st floor:

$2'\ 9'' \times 1'\ 6'' \times 16 \times 120$	7920 lbs.
1st floor : $5'\ 0'' \times \frac{30'\ 0''}{2} \times 160$	12000
Masonry in ground floor $2'\ 9'' \times 1'\ 10\frac{1}{2}'' \times 16 \times 120$	9900
Basement $2'\ 9'' \times 2'\ 3'' \times 3'\ 0'' \times 120$	2222
	44117 lbs.
Load per foot run	16043 lbs.

Assume a thickness of 12″ for beam 2′ 3″ wide.
Self weight of beam $1 \times 9/4 \times 150$ — 338 lbs./ft.
Total load per foot $= 16043 + 338$ — 16381 lbs.

B. M. $16381 \times \frac{1{\cdot}31^2}{2}$ — 14100 ft. lbs.
$= 169200$ in lbs.

Depth of beam : 12″
Effective depth : $12 - 1{\cdot}312 = 10{\cdot}688$

$A_s\ \frac{169200}{18000 \times 0{\cdot}88 + 10{\cdot}69} = 1$ sq. in.

4 Nos. 5/8″ will do.

Check for shear:

End Shear $= 16431 \times 1{\cdot}31 = 21500$ lbs.
Providing 3/8″ double hoops at 6″ crs.

Shear taken by stirrups:

$$\frac{A_s\ f_s\ J_d}{p}$$

$$= \frac{1400 \times 0{\cdot}221 \times 10{\cdot}69 \times 2}{6} = 9596 \text{ lbs.}$$

Shear taken by concrete: $75 \times 27 \times 10{\cdot}69 = 188355$ lbs.

APPENDIX 2.

Design of Articulation

I—(a) *Design of Lintel Beam over the Rear Passage*

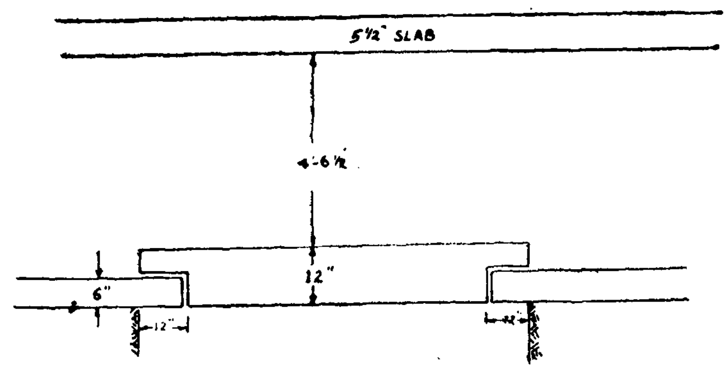


Fig. 19

Thickness of lintel assumed = 12″
Effective depth $= 12'' - (\frac{3}{4}''$ clear cover + 3/8″ stirrup $+ \frac{1}{2} \times 5/8$ assuming 5/8″ dia. bars)
$\frac{3}{4} = 10{\cdot}56''$
Effective span = clear span + effective depth $= 11'\ 9'' + 10{\cdot}56''$ $= 12{\cdot}63'$.

Loads:

Weight of brick $= 4'\ 6\frac{1}{2}'' \times 1'\ 10\frac{1}{2}'' \times 120$	= 1020	lbs./ft. run	(1)
Self weight beam $= 1'\ 10\frac{1}{2}'' \times 1'0'' \times 150$	= 281	,,	(2)
Weight of sunshade $= \frac{2{\cdot}5}{12} \times 1{\cdot}0 \times 2'\ 6'' \times 150$	= 78	,,	
Live load on sunshade $= 2{\cdot}5 \times 50 = 125$	= 125	,,	(3)
	1504		

or say 1,500 lbs./ft. run

$$\text{Max B. M.} = \frac{Wl^2}{8} = \frac{1500 \times 12{\cdot}63^2 \times 12}{8}$$

$$= 3{,}58{,}900 \text{ in lbs.} = 126 \text{ bd}^2$$

$$\text{d required} = \sqrt{\frac{3{,}58{,}900}{126 \times 22.5}} = 11{\cdot}26''$$

Actual effective depth available $= 10{\cdot}56''$

$$\text{Area of steel required} = \frac{3{,}58{,}900}{18{,}000 \times 0{\cdot}872 \times 10{\cdot}56} = 2{\cdot}166 \text{ sq.in.}$$

Adopting 5/8″ dia. bars, 8 Nos. giving 2.5 sq. in. are required.

Check for shear :

$$\text{Shear at support} : \frac{1500 \times 13{\cdot}7}{2} = 10{,}313 \text{ or } 10{,}320 \text{ lbs.}$$

The section of the beam at the support is 1′ 10½″ × 0′ 6″
Effective depth at this section $= 4{\cdot}56''$

$$\text{Shear stress} = \frac{10{\cdot}320}{22{\cdot}5 \times 0{\cdot}872 \times 4{\cdot}56} = 115{\cdot}2 \text{ lbs./sq. in.}$$

Adopting 3/8″ dia. 4 legged stirrups.
Spacing of stirrups

$$\text{required} = \frac{4 \times 0{\cdot}11' \times 18{,}000 \times 0{\cdot}812 \times 4{\cdot}56}{10{,}320}$$

$$= 3{\cdot}053''$$

Hence 3/8″ dia. stirrups may be provided at 3″ crs. at the support.

The shear stress for the lintel with 12″ thickness

$$= \frac{10{,}320 - 1500 \times 1}{22{\cdot}5 \times 0{\cdot}872 \times 10{\cdot}56} = \frac{8820}{22{\cdot}5 \times 0{\cdot}872 \times 10{\cdot}56}$$

$$= 42{\cdot}56 \text{ lbs./sq. in.}$$

Nominal stirrups of 3/8″ dia @ 10″ crs. may be provided.

I—(b) *Design of Articulation*

(Based on the Purnabhava bridge design published in I.R.S. Vol. X 1).

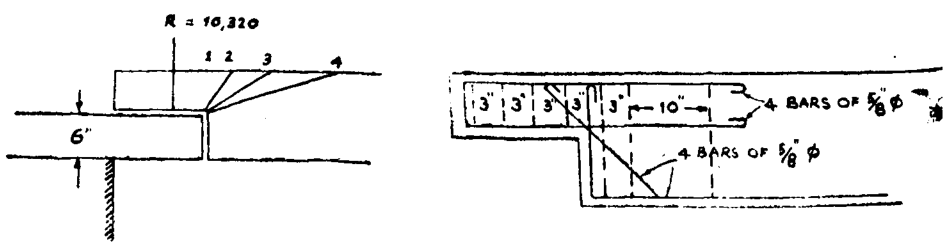


Fig. 20

Due to the sudden reduction in depth, the tensile stress due to bending across an inclined plane such as 2, 3, 4 etc. is often very heavy and the worst section is determined by trial as shown in the table.

The max tensile stress occurs across the section inclined at 16° to the vertical.

At this section b $= 22{\cdot}5''$ or $57{\cdot}2$ cms.

Effective depth d $= 4{\cdot}68''$ or 12 cms.
$bd^2 = 57{\cdot}2 \times 12^2 = 8236{\cdot}8 \text{ cm}^3$.

$$N = 2{,}843 \text{ lbs. or } \frac{2{,}843}{2{\cdot}2046} = 1289 \text{ kgms.}$$

$$M = 70{,}780 \text{ in lbs. or } \frac{70{,}780 \times 2{\cdot}54}{2{\cdot}2046} = 81530 \text{ cm. kgms.}$$

$$\text{eccentricity } C = \frac{M}{N}\ \frac{81530}{1289} = 63{\cdot}23 \text{ cms.}$$

The depth of the slab along this section $= 6''$ sec. 16°
$= 6{\cdot}24'' = t$

$e = t/2 - 1{\cdot}44 = 3{\cdot}12 - 1{\cdot}44 = 1{\cdot}68$ inches or $4{\cdot}27$ cms.

$C - e = 63{\cdot}23 - 4{\cdot}27 = 58{\cdot}96$ cms.

$$\frac{Me}{bd^2} = \frac{N(C\text{-}e)}{bd^2} = \frac{1289 \times 58{\cdot}96}{8{,}236.8} = 9{\cdot}23 \text{ kgm per sq. cm.}$$

$$\frac{N}{bd} = \frac{1289}{57{\cdot}2 \times 12} = 1{\cdot}878 \text{ kgm. per sq. cm.}$$

From the curve in Fig. 12 at p. 71 of I. R. C. Vol. X. 1 p the percentage of steel required.

$$= 0{\cdot}9\ 0/0 \text{ of bd} = \frac{0{\cdot}9 \times 22{\cdot}5 \times 4{\cdot}681}{100}$$

$$= 0{\cdot}95 \text{ sq. in. (normal to the section)}$$

As the rods will be placed at 45° to the vertical, area of steel

$$\text{required} = \frac{0{\cdot}95}{\text{Cos }(450 - 16°)} = 1 \text{ sq. in.}$$

Area of steel proposed to be provided $= 1{\cdot}228$ sq. in.
(4 bars of 5/8″ dia).

Vertical Section:

b = 22·5″ or 57·2 cms ; d = 4·56″ or 11·58 cms.

M = 61,920 in lbs. or 71,320 cms. kgms.

$$\frac{M}{bd^2} = \frac{71320}{57{\cdot}2 \times 11{\cdot}58^2} = 9{\cdot}3 \text{ kg. per sq. cm.}$$

$$\frac{N}{bd} = 0 =$$

From the curves μ = 0·78% of bd $= \frac{0{\cdot}78 \times 22{\cdot}5 \times 4{\cdot}56}{100}$

= 0·8 sq. in.

4 rods of 5/8″ dia (= 1·228 sq. in.) may be provided in the horizontal direction (*i.e.* normal Section).

The vertical portions of bars rigidly connect the bottom portion with the top and in addition resist the tension across the horizontal plane.

II. Design of Corbel Section Projecting from the Adjoining Blocks to carry the Passage Lintel Beam.

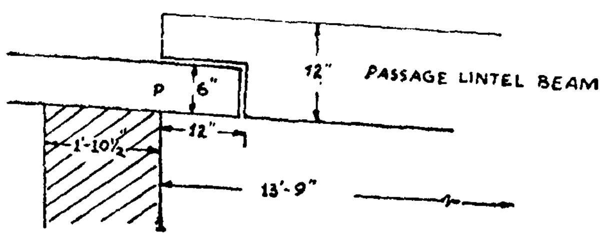


Fig. 21

The corbel in continuation of lintel beam will act as a cantilever with a clear span of 12″.

Loads:

Shear due to the lintel beam – 10,320 lbs. acting at 0′6″ from P

Max B. M. = 10 320 × 6 = 61,920 in lbs. = 126 bd²

$$\text{d required} = \sqrt{\frac{61{,}920}{126 \times 22{\cdot}5}} = 4{\cdot}673''$$

Effective depth available = 6″ – (¾″ clear cover plus 3/8″ stirrup plus ½ × 5/8″ assuming 5/8″ dia. bars for main reinforcements) = 4·56″

$$\text{Area of steel required } A_s = \frac{61{\cdot}920}{18{,}000 \times 0{\cdot}872 \times 4{\cdot}56} = 0{\cdot}865 \text{ sq.in.}$$

5-8″ dia bars 3 nos. giving an area of 0·9 sq. in. will be sufficient.

Check for Shear:

$$\text{Shear stress} = \frac{10\,320}{22{\cdot}5 \times 0{\cdot}872 \times 4{\cdot}56} = 115{\cdot}2 \text{ lbs./sq. in.}$$

3/8″ dia. 4 legged stirrups at 3″ crs. may be provided. II contd.

Check for Overturning:

The reaction of 10,320 lbs. acts at a distance 6″ from the support.

Overturning moment = 10320 × ½ = 5,160 ft. lbs.

The balancing moment required = 2 × 5,160 = 10,320 ft. lbs.

The weight of brick masonry and slab = 6 × 120 × 1′ 10½″
= 1350 lbs.

The length of fixity required to develop a balancing moment of 10,320 ft. lbs.

$$\sqrt{\frac{2 \times 10{\cdot}320}{1350}} = 3{\cdot}91 \text{ ft.}$$

which is within 4 times the span (therefore safe).

The section of the lintel assumed is safe for sheer to carry the length of the wall = 8 ft. of wall *i.e.* 8 × 1350 = 10800 lbs.

TABLE I

Section	Breadth in inches b	Effective depth. d	Area F in sq. in. = b × d	Modulus of section Z $\frac{bd^2}{6}$	X X in inches	£ in degree	M—RX (in lbs) R-10,320	N-Rsin (lbs)	£ Direct tensile stress N/F (lbs./sq. in.)	Bending stress M/Z (Lbs./sq. in.)	Total tensil stress	Total Com-pression stress
1	22·5	4·5" (4·5 Sec. X)	101·3	75·93	6" (6÷3)	0°	61,920	0	0	815·5	815·5	815·5
2	22·5	4·568	102·8	78·27	6·529	10	67,360	1791	17·42	860·6	878·0	843·2
3	22·5	4·637	104·3	80·65	6·748	14	69,630	2496	23·92	863·4	887·3	839·5
4	22·5	4·681	105·3	82·19	6·86	16	70,780	2843	26·99	861·2	888·2	834·2
5	22·5	4·732	106·4	83·95	6·975	18	71,960	3190	29·95	857·2	887·2	827·2
6	22·5	4·788	107·7	85·98	7·092	20	73,160	3529	32·75	850·9	883·2	818·1
7	22·5	4·966	111·8	92·47	7·399	25	76,330	4360	39·02	825·4	864·4	786·4

Design of Slab over Passage

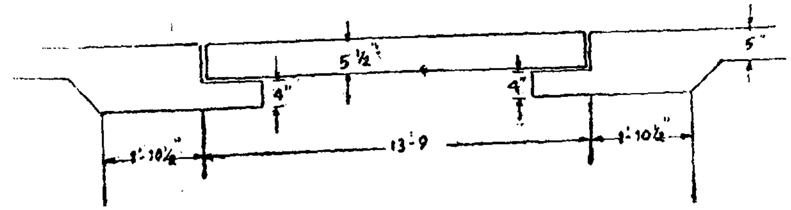


Fig. 22

Thickness of slab assumed = 5·5″

Effective depth available = 5·5″ — (1″ clear cover ½ × ½″ assuming ½″ dia main reinforcements) = 5·5″ — 1·25 = 4·25″

Clear span = 12′ 3″ Effective span = 12′3″ + 4·25″ = 12·6 ft.

Loads:

Weight of slab = $\frac{5{\cdot}5}{12} \times 150$ = 68·75 lbs./sq. ft.

Live load = 80 „

Finish = 12 „

160·75 or 161 lbs./sq. ft.

$$\text{Max. B. M.}\ \frac{Wl^2}{8} = \frac{161 \times 12{\cdot}6^2 \times 12}{8} = 38{,}340 \text{ in lbs.}$$

$$= 126\ \text{b.d}^2$$

d required = $\sqrt{\frac{38{\cdot}340}{126 \times 12}}$ = 5·05″ Effective depth available = 4·25″

A_s required = $\frac{38340}{18{,}000 \times 0{\cdot}872 \times 4{\cdot}25}$ = 0·5748 sq. in.

Adopt ½″ dia bars at 4″ crs. (= 0·589 sq. in.)

Area of distributors required = $\frac{A_s}{\sqrt{1}} \equiv \frac{0{\cdot}5748}{\sqrt{12{\cdot}6}}$ = 0·8619 sq. ft.

Adopt 3/8″ dia. bars at 8″ crs. (0·166 sq. in.)

Design of Cantilever Slab from the Adjacent (Corbel Section)

Clear span of cantilever — 9″

Assuming the depth of slab as 4″ and adopting 3/8″ dia. reinforcement.

Effective depth = 4″ — 3/16″ = 2·81″.

So effective span = 9″ plus 2·81″ = 11·81″

Load :

Total load due to Roof slab over passage $\frac{161 \times 13{\cdot}75}{2}$

= 1107 lbs.

Load due to self weight of slab = $\frac{9}{12} \times \frac{4}{12} \times 150 = 37{\cdot}5$ lbs.

So total load per foot width of slab 1144·5 or 1150 lbs.

Bending Moment = $\frac{1150 \times 11{\cdot}81}{2}$ 6792 in lbs.

'd' required = $\sqrt{\frac{6892}{126 \times 12}} = 2{\cdot}114$ as against 2.81″ provided.

'A_s' required — $\frac{6892}{18000 \times 0{\cdot}872 \times 2{\cdot}81} = 0{\cdot}154$ sq. in.

3/8″ dia. rods at 8½″ Crs. giving $A_s = 0{\cdot}156$ sq. in will be sufficient.

Check for Shear:

Shear per foot width = 1150 lbs.

Shear stress = $\frac{1150}{12 \times 2{\cdot}81} = 34{\cdot}72$ lbs./sq. in.

5½″ thickness adopted to facilitate bending of rods.

Check for overturning moment :

The reaction of 1150 lbs. acts at a distance of 4½″ from support.

Overturning moment = $\frac{1150 \times 4{\cdot}5}{12} = 430$ ft. lbs.

The balancing moment required — 2 × 430 = 860 ft. lbs.

The dead load of slab and weathering courses = 80 lbs./ sq. in. without live load on the main roof.

The balancing moment available = $\frac{80 \times 6{\cdot}875^2}{2} = 1891$ ft. lbs.

(Safe).

Design at Articulation

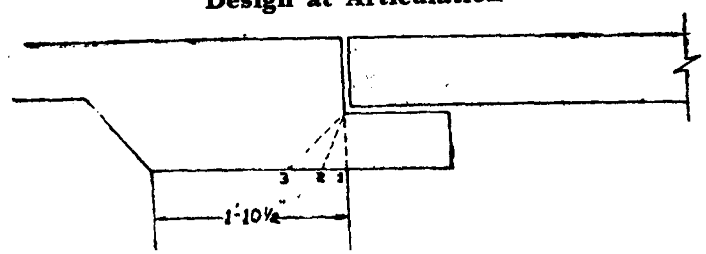


Fig. 23

On account of the sudden reduction in depth from 11″ over the support to 4″ in the cantilever portion the tensile stress due to bending across an inclined plane such as 2, 3 is heavy the worst section being determined by trial as worked out in the Table qelow.

The maximum tensile stress occurs at a section which is inclined at 20° to the vertical.

At this section b = 12 inches = 30·48 cms.

h = effective depth (with 1 clear — 2·99″ or 7·3 cms. cover)

N = 436·1 lbs. or $\frac{436.1}{2{\cdot}2046} = 197{\cdot}8$ kgms.

M = 6027 in lbs. or $\frac{6027 \times 2{\cdot}54}{2{\cdot}2046}$

= 6942 cm. kmgs.

Eccentricity $C = \frac{M}{N} = \frac{6942}{197 \cdot 8} = 35 \cdot 1$ cms.

$t = \sec. 20 = 4 \cdot 25 \qquad e = \frac{t}{2} - 1 \cdot 19 = 2 \cdot 13 \quad 1 \cdot 19 = \cdot 94''$

$= 2 \cdot 4$ cms.

$$\frac{Me}{bh^2} = \frac{N\,C-e)}{bh^2} - \frac{197 \cdot 8\ (35 \cdot 1 - 2 \cdot 4)}{30 \cdot 48 \times 7 \cdot 3^2} = 3 \cdot 98$$

$$\frac{N}{bh} = \frac{197 \cdot 8}{30 \cdot 48 \times 1 \cdot 3} = 0 \cdot 89$$

For the above values of $\frac{Mc}{bh^2}$ and $\frac{N}{bh}$ referring to curves in figure 12 page 71 of I. R. C. Vol. X — 1.

μ = percentage of steel required = 0·45%

So 'A_s' required $= \frac{0 \cdot 45 \times 12 \times 2 \cdot 99}{100} = 0 \cdot 164$ sq. in.

(Normal to the section)

As we are going to place the reinforcement at 45° to the vertical area required $\frac{0 \cdot 164}{\text{Cos}\ (45° - 24°)} = 0 \cdot 1781$ sq. in.

3/8″ dia. rods at 4½″ crs. giving $A_s = 0 \cdot 24$ sq. in. will be sufficient.

Section	Breadth of section b	Effective depth d	F b × d	Z 1/66 bd²	X in inches	X	M-Rx R. 1275	N sin X	Direct Tensile stress N/F	Bending stress M/Z	Total Tensile stress
1	12″	2 81	33·72	15·8	4″	0°	5100	...	...	322 8	322·8
		2·81 × sec. 10°			4″ 4 tan	10					
2	12″	2·853	34·24	16·28	4 353	10°	5550	221·4	6·468 or 6 47	341·0	347·47
3	12″	2·99	35·88	17·88	4·728	20	6027	436·1	12·15	337·0	349·15
4	12″	3·245	38 94	21·06	5·155	30	6572	637·5	16·37	312·1	346·83
5	12″	3·031	36·37	18 37	5·808	22	6130	477·6	13·13	333·7	343·55
6	12″	3·076	36·92	18·92	4·890	24	6234	518·6	14·05	329·5	339·49
7	12″	3·126	37·52	19·54	4·975	26	6343	558·9	14·89	324·6	328·47

APPENDIX 3

Design Features of Beams and Slab Over Stair-Case Hall:

The details of structural roof over the staircase hall are given in fig. 24.

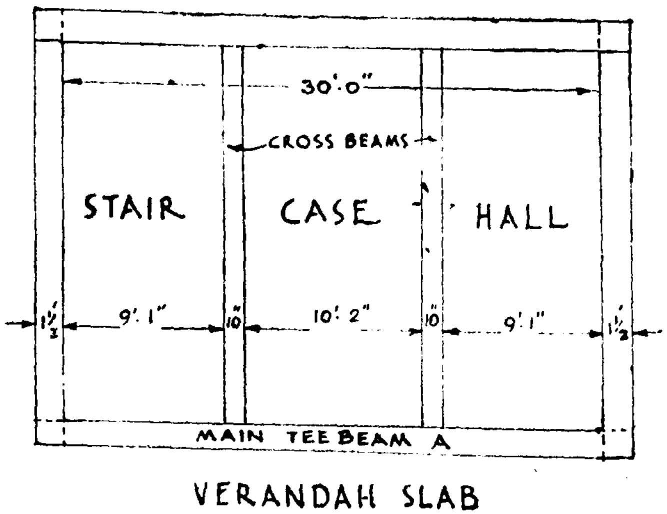


Fig. 24.

The Main the Beam 'A' supports the verandah slab on one side and cross beams 'B' on the other side with slab over the cross beams spanning parallel to the main beam (A).

The slab over the staircase hall is first designed as usual as a continuous slab over the cross beams. The main beams A is then designed as a Tee beam assuming that the verandah slab and the slab over the staircase act as the flanges of the Tee beam on either side. But since the slab over the staircase is spanning in a direction parallel to the main Tee beam. This assumption is not exactly correct. In such cases, the American Concrete Institute recommends that additional reinforcements transverse to the Tee Beam should be provided in the top of the slab; the amount of of reinforcement being designed to carry the load on the portion of the slab required for the flange of the Tee Beam, this flange being assumed to act as a cantilever. The design of the slab over stair-case for the flange portion of the main Tee beam 'A' is done based on this principle follows:

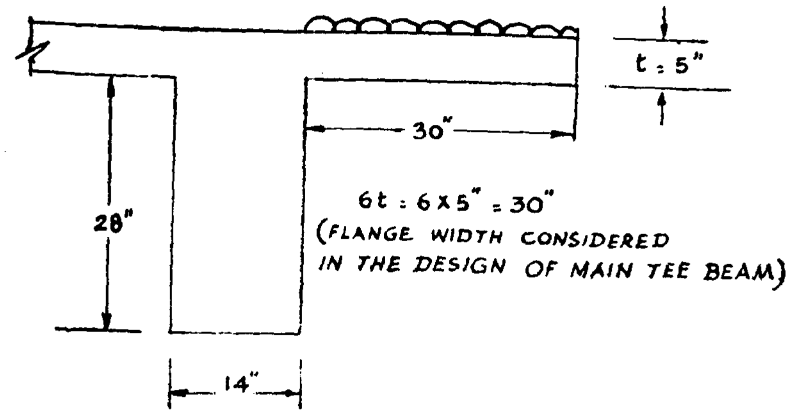


Fig. 25

Load:

Dead Load of slab 5" thick	= 62·5 lbs./sq. ft.
Live load	= 50 ,,
Finish	22 ,,
	134·5 lbs. or 140 lbs./sq. ft.

Clear span of cantilever = 2′ 6″

Effective depth of slab = 5″ − (1″ clear cover + $\frac{1}{2}$ × 3/8″ assuming 3/8″ dia bars for main reinforcement)

= 3·8″

Effective span = 2′ 5″ + 3·8″ = 2·8′.

$$\text{Bending Moment} = \frac{Wl^2}{2} = \frac{140 \times 2{\cdot}8^2 \times 12}{2}$$

= 6,595 in lbs.

$$\text{Area of stell required } A_s = \frac{6{\cdot}595}{18000 \times 0{\cdot}872 \times 3{\cdot}8}$$

= 0·1106 sq. in.

3/8″ dia bars at 12″ crs. shall be provide at the top of the slab, over the flange portion.

The verandah slab is designed as usual and the reinforcements from this slab are carried over the main Tee-beam and extended for a length of 6 t + 40 d from the Tee rib face (where t is the thickness of of slab and d the diameter of reinforcement rod).

The cross beams are fixed at one end to main Tee beam and simply supported over the wall at the other end. In addition to the maximum bending moment at the centre assuming simply supported end conditions, the beams should be designed for a negative Bending Moment of $\frac{Wl^2}{8}$ at the fixed end and $\frac{Wl^2}{16}$ at the free end.

APPENDIX 4

Design of end Tee Beam over Cellar Room, Carrying Stair-Case

The disposition of the Tee Beam and stairs leading to the cellar room are show in fig. 26.

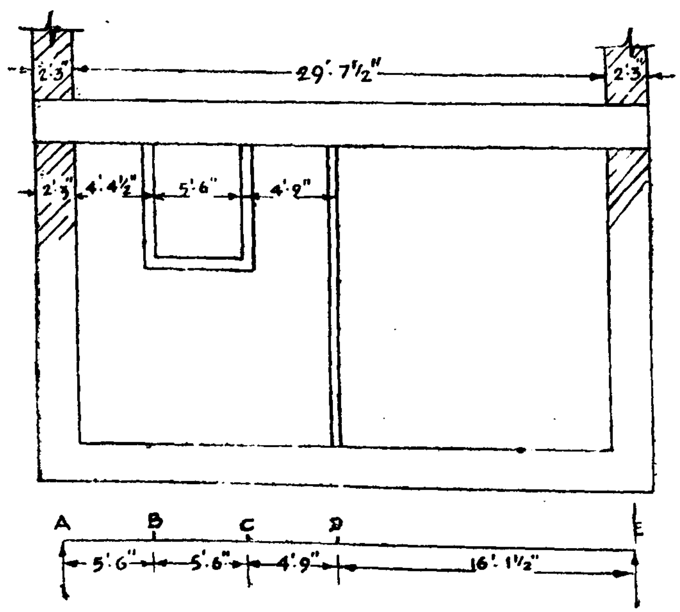


Fig. 26.

The main beam P is designed as a Tee Beam but over the stair-case portion, owing to the presence of slab on one side of the beam only the effective width of flange of the beam gets reduced and the compressive stresses in concrete is consequently increased. The compressive stress at the top of the Tee Beam in this portion therefore needs to be checked and compressive reinforcement provided if necessary.

The details of section arrived at for the beam P designed as a Tee beam for a maximum bending moment of 30,61,000 in lbs. is given in fig. 27.

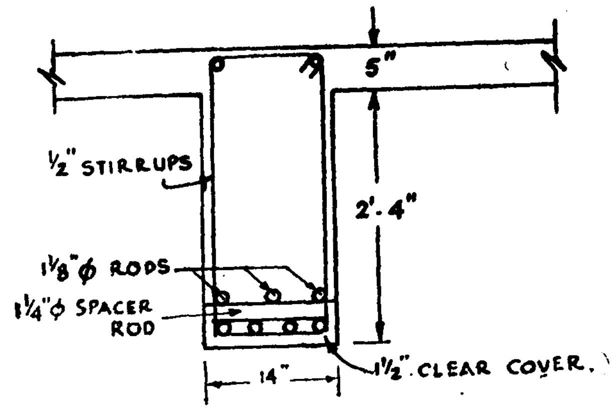


Fig. 27.

Check for Stress in the L-Beam Portion of the Tee Beam over the Cellar

Span :

Clear span	=	29'-7½"
Size of Rib assumed	=	14" × 28".
Effective span	=	29' 7½"+2' 3" = 31'-10½"

Load: 1 ft. run;

(*a*) in portion B (there will not be slab on one portion)

Weight of slab + live load + floor finish = 5' 7"

[(5/12 × 150) + 90 + 12]

= $5\frac{7}{12}$ × 154·5 lbs. = 863 lbs.

Weight of rib $1 \times 14/12 \times 28/12 \times 150$	408 lbs.
½ weight of staircase 1760/2	880 lbs.
	2151 lbs. or 2200 lbs.

(*b*) in portion BD (slab on one side only)

Weight of slab + live load + floor finish	863 lbs.
Weight of rib	408
Total	1271 or 1300 lbs.

(*c*) in portion DE:

Weight of slab on both sides + live load + floor finish $19' 9\frac{3}{4}'' \times 154{\cdot}5$	1531 lbs.
Weight or ribs	408 lbs.
	1939 lbs. or 2000 lbs.

Reaction E

$$= \frac{2200 \times \frac{5{\cdot}5^2}{2} + 1300 \times 10{\cdot}25 \times 10{\cdot}625 + 2000 \times 16{\cdot}125 \times 23{\cdot}81}{31{\cdot}875}$$

$$= \frac{33290 + 141600 + 768100}{31{\cdot}88} = \frac{9{,}42{,}990}{31{\cdot}88}$$

$= 29,580$ lbs.

Maximum Bending Moment occurs where shear force is 0

$$x = \frac{29580}{2000} = 14{\cdot}79'$$

$$\text{Maximum Bending Moment } \left(\frac{29580 \times 14{\cdot}79}{2}\right) 12$$

= 26,25,000 in lbs. occurring at a section where the beam has slabs on both sides for the flange. As the Tee Beam has been designed for a Maximum Bending Moment of 30,61,000 in lbs. the section adopted is safe.

We now have to find out the compressive stress in the portion of the beam where the flange width is reduced. Maximum compressive stress will occur at section D where the maximum Bending Moment for this portion occurs.

$$\text{Bending Moment at D} = 29580 \times 16{\cdot}125 - \frac{2000 \times 16{\cdot}125^2}{2}$$

$= (4{,}77{,}000 - 2{,}60{,}000)$ ft. lbs.

$= 217000 \times 12$

$= 2604000$ in lbs.

Area of steel provided $= 7 \times 0{\cdot}994 = 6.958$ sq. inches.

The C. G. of bars from the bottom of rib.

$$= \frac{4 \times 0{\cdot}994 \times 41/16 + 3 \times 0{\cdot}994 \times 79/16}{(4 + 3) \times 0{\cdot}994}$$

$= 3{\cdot}58''$

Therefore Effective depth $= d - 33{-}3{\cdot}58 = 29{\cdot}42''$

Kd = depth of neutral axis from top of slab

$$= \frac{2 \text{ nd } A_s + bt^2}{2 \text{ n } A_s + 2bt}$$

Where $n = 15$, $d = 29{\cdot}42''$ $As = 6{\cdot}958$ sq. in.

$t = 5$ b the least of

(1) 1/6 of effective span $= 12 \times 1/6 \times 31{\cdot}875 = 63{\cdot}75''$

(2) ½ clear span between ribs + rib width $= 67''$

(3) $4t + b_r = (4 \times 5) + 14'' = 34''$

$$Kd = \frac{2 \times 15 \times 29.42 \times 6{\cdot}958 + 34 \times 5^2}{2 \times 15 \times 6{\cdot}958 + 2 \times 34 \times 5}$$

$$= \frac{6141{\cdot}13 + 850}{208{\cdot}74 + 340} = 12{\cdot}73''$$

$$Z = \frac{(3kd - 2t)}{(2kd - t)} \times \frac{t}{3} = \frac{3 \times 12{\cdot}73 - 2 \times 5}{2 \times 12{\cdot}73 - 5} \times 5/3 = 2{\cdot}298''$$

Jd = lever arm $29{\cdot}42 - 2{\cdot}298 = 27{\cdot}122''$

$$\text{Stress at centre of gravity of steel } \frac{2604000}{6{\cdot}958 \times 27{\cdot}122}$$

$= 13800$ lbs./sq. in.

Hence within safe limits

$$\text{stress in concrete} = \frac{2604000 \times 12{\cdot}73}{34 \times 5\ (12{\cdot}73 - 2{\cdot}5)\ 27{\cdot}12}$$

$$= \frac{26040000 \times 12{\cdot}73}{170 \times 10{\cdot}23 \times 27{\cdot}12}$$

$= 703$ lbs. (safe)

Therefore no additional compressive reinforcement are necessary.

The stresses in other sections such as A, B and C will be lower but in the case where the tensile reinforcement rods are cut out progressively from the centre of beam towards the supports, the stresses at these sections also need checking which can be done on similar lines as above.

APPENDIX 5.

Preparation and Laying of Asphalt Flooring in Cellar Room:

The mastic asphalt for flooring in cellar room is prepared as follows:

The ingredients necessary are Bitumen 20-30 penetrations, clean sand and cement. One cubic foot of clean sieved sand is taken and mixed with 15 lbs. of cement. Bitumen 20-30 penetration is heated to about 350°C in a Heatmaster. The sand-cement mixture is poured into a drum-mixer and the mixer is heated from underneath. This is done so as to eliminate moisture completely from the sand-cement mixture. After sufficient heating, 25 lbs. of Bitumen 20-30 at 350°C from the Heatmaster is measured and poured into the heated mixture in the drum-mixer and the drum is rotated well so as to ensure thorough mixing of the Bitumen with the sand-cement mixture. About twenty five to thirty revolutions are generally sufficient for this purpose. The drum-mixer is then opened and the mastic is poured on to trays kept ready at the foot of the mixer. The trays are previously coated with oil, to prevent the mastic from adhering to them. The trays are then carried to the place of work, and the hot-mastic is then laid in place with suitable hot trowels, in layers of uniform thickness and is beaten down with rammers while still hot. The mastic is laid in three layers of 3/8″ thick each, each layer being laid so as to cover up the joints if any in the layer below, so that no hollows or loose joints are left in the mastic flooring.

APPENDIX 6.

Tests on Waterlock—Introduction:

Waterlock, a cement water proofing compound manufactured by Paulson Paint Cellulose Works, Bombay was recommended as a good water proofing agent which can stop leakage, dampness and seepage and which can be used on walls, floors, dams, etc. It was also suggested that the said-water-proofing agent had already been

approved and used by the Railways, Municipal Corporations and P. W. D. The Highways Research Station took up experiments to investigate its possible use in the brick masonry and plastering in the construction of cellar room of the Highways Research Station building. A free sample of 3½ lb. packet of the "Waterlock" was obtained from Best and Co., Private Ltd., Madras, for tests.

2. Type of materials used:

Bricks ...	G. P. R. Make
Cement ...	Dalmia Portland Cement.
Water proofing agent ...	Paulson's "Waterlock" obtained from Best & Co., Private Ltd., Madras.

3. Nature of tests conducted:

Built-up units with two bricks in each set were made with and without waterlock in the construction mortar and plaster. The particulars regarding the samples prepared for tests are as follows:

(Also *vide* Table No. 1)

Sample No. 1 and 2 ...	Construction mortar 1 : 5 Plaster 1 : 4 (½″ thick).
Sample No. 3 and 4 ...	Construction mortar 1 : 5 Plaster 1 : 4 (½″ thick) in waterlock.
Sample No. 5 and 6 ...	Construction mortar 1 : 5 with waterlock. Plaster 1 : 4 (½″ thick).
Sample No. 7 and 8 ...	Construction mortar 1 : 5 with waterlock. Plaster 1 : 4 (½″ thick) with waterlock.
Sample No. 9 ...	Plaster 1 : 4 (½″ thick) on all sides of on the single brick.
Sample No. 10 ...	Plaster 1 : 4 (½″ thick) with waterlock all sides of the single brick.
Sample No. 11 ...	Brick without plaster.

The water proofing compound was added at the rate of 3½ lbs. per 1 cwt. of dry cement. The cement and the compound were mixed well before adding sand and water.

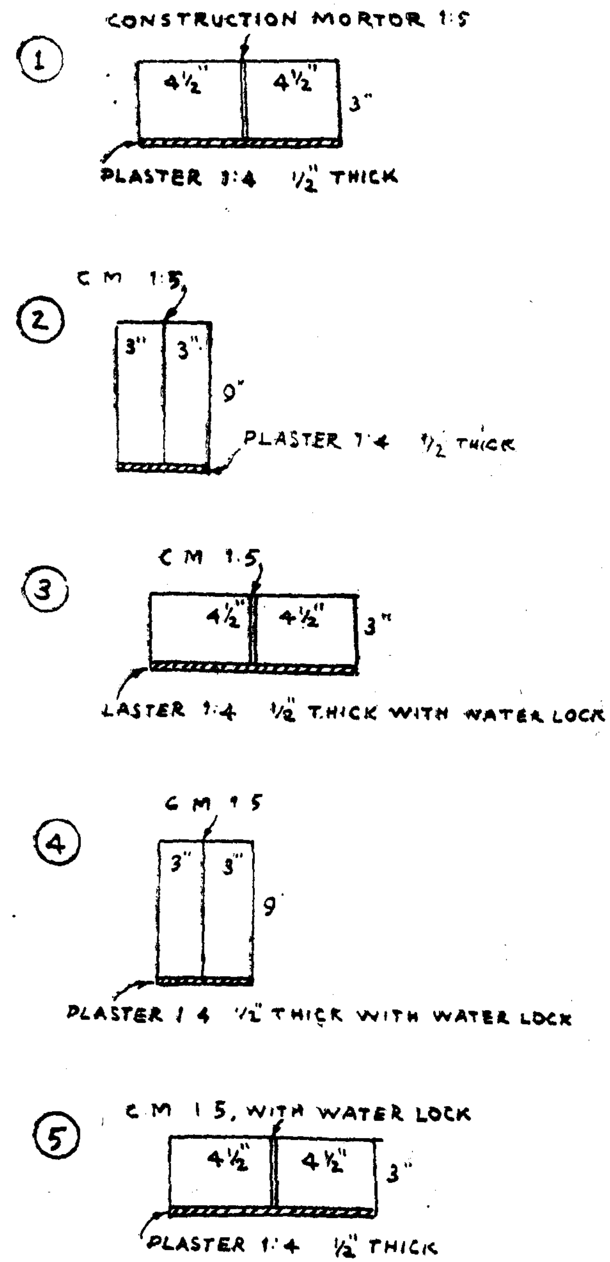
The samples were allowed for curing for 24 hours. Then samples No. 1 to 8 were placed on sand kept wet constantly with the plastered side touching the sand. They were allowed to stand in that position for 24 hours and then their weight were found. They were then dried to constant weight and then final dry weight were determined. The percentage moisture present in the samples was calculated as a percentage of dry weight.

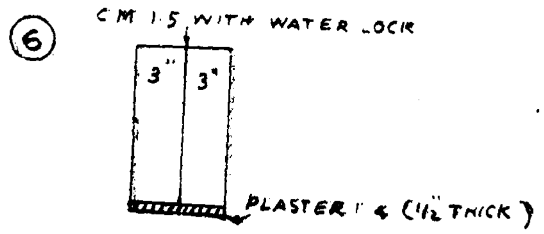
Samples No. 9, 10 and 11 after 24 hours curing were fully immersed in water for 24 hours and then the moisture absorbed was determined.

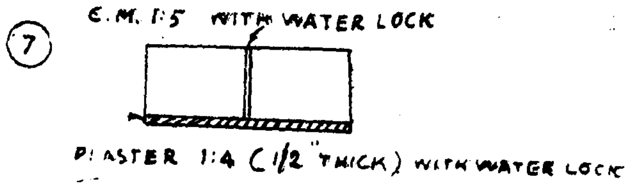
The results are given in Table No. 1.

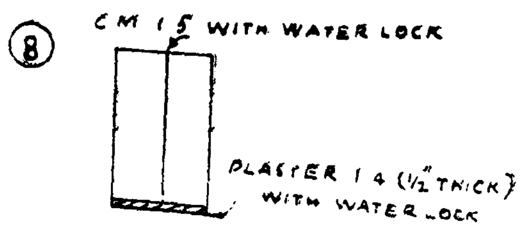
4. Conclusions

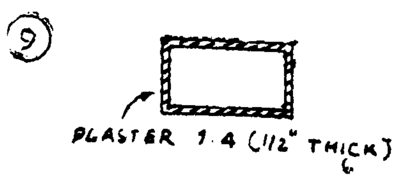
The 'Waterlock' has very good water-proofing properties and it has also been used in the brick masonry and plastering in the construction of cellar room of Highways Research Station and the results are very encouraging.

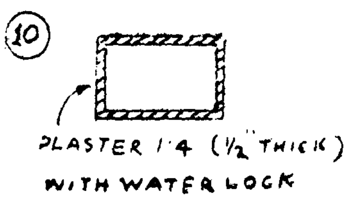












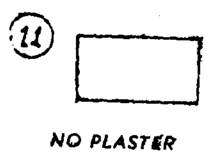


TABLE No. 1

Results of Tests Conducted to Determine the effect of Waterlock as a Waterproofing Agent

Sample No.	Particulars regarding the sample	% of total moisture absorbed (average)
1	Built up unit with two bricks construction mortar 1 : 5 ... Plaster 1 : 4 (½" thick)	10·7
2	Built up unit with two bricks construction mortar 1 : 5 ... Plaster 1 : 4 (½" thick)	9·1
3	Built up unit with two bricks construction mortar 1 : 5 ... Plaster 1 : 4 (½" thick) with waterlock	7·7
4	Built up unit with two bricks construction mortar 1 : 5 ... Plaster 1 : 4 (½" thick) with waterlock	5·1
5	Built up unit with two bricks construction mortar 1 : 5 with waterlock ... Plaster 1 : 4 (½" thick)	10·7
6	Built up unit with two bricks construction mortar 1 : 5 with waterlock ... Plaster 1 : 4 (½" thick) waterlock	9·0
7	Built up unit with two bricks construction mortar 1 : 5 with waterlock ... Plaster 1 : 4 (½" thick) with waterlock	4·4
8	Built up unit with two bricks constructions mortar 1 : 5 with waterlock ... Plaster 1 : 4 (½" thick) with waterlock	4·1
9	Single brick ... Plaster 1 : 4 (½" thick) on all sides of the brick	6·1
10	Single brick ... Plaster 1 : 4 (½" thick) with waterlock on all sides of the brick	3·1
11	Single brick, No plaster ...	12·8

APPENDIX 7.

Design of Number of Lights required for a Hall of Size

90′ - 0″ × 30′ - 0″

The lights are proposed to be hung from the T-ribs. As the height of the work table will be about 2½ ft. the distance between the source of light and table will be about 10′ - 0″.

The room index relates to the geometrical layout. The larger the room the more effective is the utilisation of the light. The shape of the room, as well as its size, and also the height of the lighting fixture above the working plane enter into the utilisation factor. The relations of these three variables are formulated as a room index as follows :

$$\text{Room index R. I.} = \frac{2\,W + L}{6\,H}$$

where W = 30′ ; L = 90 and H = 10′ = $\frac{2 \times 30 + 90}{6 \times 10} = 2{\cdot}5$

As per the table, the reflection characteristics for a value of 2·5 as room index is 0·5. As per the American Standards' Association Code (1932) 8 – 10 foot candles are to be provided for office-general school and close work and typing. Therefore the total requirement for the hall = $\frac{3 \times 90 \times 10}{0{\cdot}5}$ = 54,000 lumens (light unit) assuming 40 watts flourescent lamps, the luminous efficiency of which is 30 to 60 lumens per watt number of such lights required :

= $\frac{54{,}000}{40 \times 60}$ = 23 lights or 12 twin tube lights. On the other hand assuming 40 watts Tungsten filament lamps, the efficiency of which is only 8 lumens per watt, the number of such bulbs required = $\frac{54{,}000}{8 \times 40}$ = 170 against 4 lights proposed in the original estimate.

Using 240 watts filament lights cost for one hall :

27 points wiring 27 × 30	...	Rs.	810
Cost of bulbs and shades 27 × (3·00 for bulb and Rs. 10·00 for shade) and other necessary suspension arrangements	...	Rs.	351
Total	...	Rs.	1,161

Using 40 watts twin tube lights — 12 Nos. Cost for one hall :

12 Points wiring 12 × 30	...	Rs.	360
Cost of tube, fixtures and fixing charges (53 + 7) 12	...	Rs.	720
Total	...	Rs.	1,080

APPENDIX 8.

Tests on Materials used in Construction :

1. *Hard Granite Broken Stone:* Blue granite metal 1½″ size B. S. S. gauge obtained from Tattamkunni metal quarry was used for mass concrete work in foundation, while 3/4″ size B. S. S. gauge was used for reinforced cement concrete works. The grading of 3/4″ size coarse aggregate was tested for each item of reinforced concrete work before use. A typical grading curve obtained for 3/4″ size metal used on work is given in fig. No. 28.

2. *Sand:* Sand required for mortar was proposed to be secured from Nerkundram area. But it was observed that sand at this place was being quarried from the deep cuts in the Cooum river which was found to be not of a very good variety for concrete work. The sand for foundation concrete was obtained from Vellapanchavadi quarry which was about a mile upstream of the river and which was more easily accessible. The sand was found to be brownish in colour and of rounded variety. The sand was being collected from the deeply eroded faces of both the banks of the river, by burrowing out the sand lying underground beneaths 6 to 7′. This method o f extraction of sand was not desirable, a

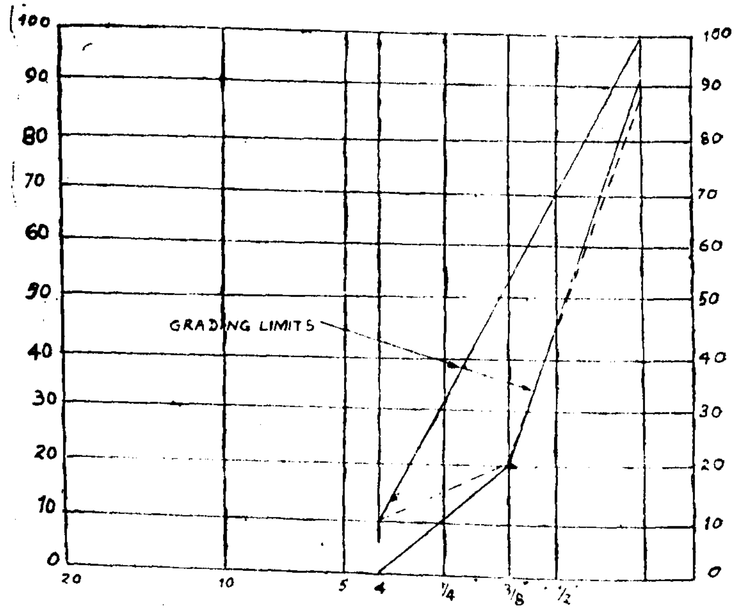


FIG 28 TYPICAL GRADING CURVE FOR 3/4" METAL

this allowed the soil overburden to fill up the depression in the sand excavated, thus making it difficult to obtain a uniform quality of sand. Admixture of clay and silt to varied extents was therefore possible. The sand was tested and was found to contain high silt percentage. A typical grading curve obtained for this sand is given in fig. 29.

Investigations were therefore taken up for alternative quarry sites in an effort to obtain sand of better quality. It was found that a quarry at Tiruvanmiyur offered very good material. The quarry consisted of fine brownish sand to a depth of 5 to 6′ from surface, below which layer, the sand changed to clean coarse white variety, owing to the presence of spring waters. The top fine sand had been removed to a large extent, exposing the bottom white layer for easy removal from underwater. The white sand from this quarry has been tested and was found to contain very little silt. The fine modulus of the sand was 3·2 which indicates the coarse grading of the sand suitable for concrete. The sand was clean, angular, coarse and free from deletious salts sulphates etc. The

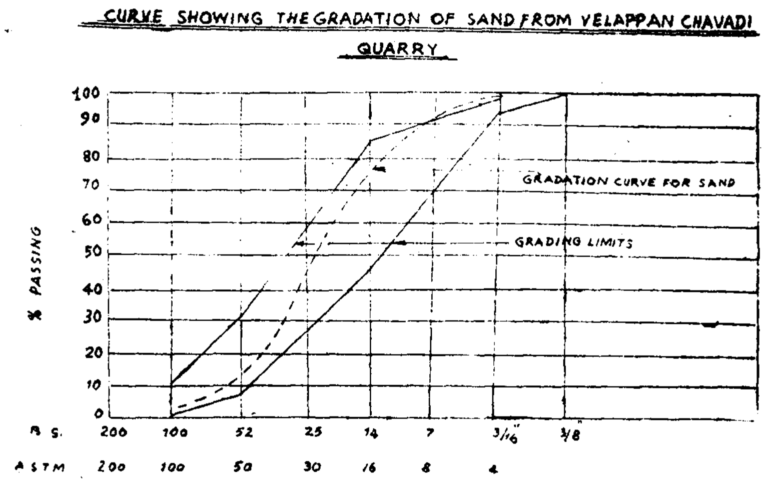


FIG 29 RECOMMENDED LIMITS OF GRADING OF FINE AGGREGATES FOR CONCRETE

MADRAS HIGHWAYS MANUAL 207-03

quarry was also much nearer the worksite with the lead being about five miles only as against the lead of 11 miles for the quarry at Nerkundram and Velappanchavadi. It was therefore proposed to use Tiruvanmiyur sand for all items of work above basement level. The top fine sand from Tiruvanmiyur was used for filling purposes, while the white coarse sand was used for concrete, and for mortar after suitably screening out the coarse content. The grading curve obtained for Tiruvanmiyur sand is given in fig. 30. The test findings for both Vellappanchavadi and Tiruvanmiyur sands are given in table No. VIII.

3. *Bricks*: First class bricks of various makes available in and around Madras were used after tesing the bricks for compressive strength and moisture absorption. Table No. IX shows the results of tests conducted on different varieties of bricks for finding their suitability for use in the construction.

4. *Gravel*: Gravel for the backfill was obtained from the quarry at Velachery. The gravel was tested and found to be of good quality. The results of tests on gravel is given in Table X.

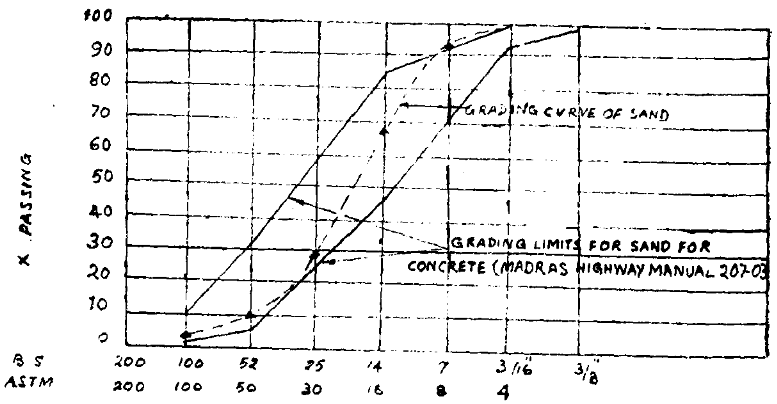


Fig. 30

5. *Lime*: The lime available from Kelambakkam near Madras was tested in the laboratory and was found to contain as much as 11.05% of insoluble matter. This sample was therefore found to be unsuitable for use in construction mortar. Good quality limestone was not available round about Madras for use in lime concrete in the flooring of cellar room. So lime was obtained from Vanur village in South Arcot District. This was tested for suitability of use as construction mortar. The tests conducted were (1) Visual examination (2) Unit weight of lime (3) Determination if Insoluble matter—Residue test (4) Fineness test. The test showed that the lime was of coarse variety. The percentage of insoluble matter in lime was 1·9% as against the specification No. 9 of M. D. S. S. which permits a limit upto 10%. The lime tested was therefore found to be suitable for use in the flooring.

Cement: Tested Portland Cement from Dalmiapuram was used for mortar and concrete works in the building.

7. *Steel*: Tested Imported Steel obtained by the department was used for the reinforcement rods in R.C. works in the building. Samples of various sizes of M. S. rods used were tested for tensile strength and was found to give satisfactory results. The results of these tests conducted on steel are given in Table No. XI.

TABLE VIII

Results of Tests on Sands

S. No.	Particulars of Tests	Test values	
		Thiruvanmiyur Sand	Velappan Chavadi Sand
1	% passing B.S. No. 100 sieve ...	1·7	2·4
2	% passing B.S. No. 200 sieve ...	0·9	1·2
3	Sulphate content ...	Nil	Nil
4	Chloride content ...	Nil	Nil
5	Organic impurities ...	Nil	Nil
6	Fineness modulus ...	3·0	2·7
7	P. H. Value ...	7·0	7
8	Visual identification ...	Coarse sand, angular in shape and white in colour.	Coarse sand, Brown in colour and rounded in shape.

TABLE IX

TESTS IN BRICKS

Particulars	1	2	3	4	5	6	7	8
Unit weight ...	110·4 lbs. cft.	...	...	118 lbs.	120·3	113·3	110·8	110·5
Moisture Absorption ...	12·8%	13·2%	...	9·5%	6·2%	12·6%	12%	12·6%
Compressive Strength ...	1151 PSI	1260 PSI	1665 PSI	1919 PSI	1403	1205	1814	1744
Average size ...	9 × 4¼ × 2⅞	9 × 4¼ × 3	9"×4"×3"	8½×4¼"×3	8⅘" × 4⅕" × 3"	9" × 4⅕" × 3"	8·7" × 4·1" × 2·9"	8·8" × 4·2" × 3"

TABLE X

RESULTS OF TESTS CONDUCTED ON GRAVEL

Particulars			Mechanical Analysis	
			Sieve size	Percentage Passing
Liquid limit 36%	...	...	½"	100%
Plastic limit 16%	...	...	¼"	93%
Plasticity Index 20%	...	...	B. S. S. No. 36	32%
Max. Proctor density 127 lbs./cft.	...	...	No. 100	27%
Optimum Moisture 104%	...	...	No. 200	24%

TABLE XI

REPORT ON TENSION TESTS FOR MILD STEEL RODS

Sl. No.	Particulars	1	2	3	4	5	6	7	8	9	10	11	12
1	Original dimension of cross section ...	1¼"	1¼"	1-1/8"	1-1/8"	1"	1"	¾"	¾"	½"	½"	¼"	¼"
2	Original area of cross section (sq. in.) ...	1·227	1·227	0·994	0·994	0·785	0·785	·44	·44	·194	·194	·049	·049
3	Yield Point: Total load (pounds) ...	54·000	52·500	46·000	46·000	33·000	33·000	19·000	19·000	5184	5184	·95 T	·95 T
4	do. Stress tons/sq. in. ...	19.8 T/sq-in.	19·25 T/sq.in.	20·8 T	20·8 T	18·7 T	18·7 T	19·3	19 3	19·8	19·8	19·3	19·3
5	Ultimate load (pounds) ...	82·000	81·000	67·000	67·000	51·500	51·500	31·500	31·000	13440	13500	1·3 T	1·3 T
6	Ultimate stress (tons/sq. in.) ...	29·2 T/sq.in.	29·4 T/sq.in.	30·0 T/sq.in	30·0 T/sq.in.	29·5	29 3	29·95	29·9	29·9	29 9	26·3	26·3
7	Total elongation ...	1·75"	1·75"	2·25"	2·25"	2·5"	2·6"	2·25"	2·25"	1·35"	1·35"	Nil	9/16"

The Tests were conducted in the Engineering College Laboratory.

ITEMS of interest

Monthly Review of Engineering Developments in the U. S. S. R.

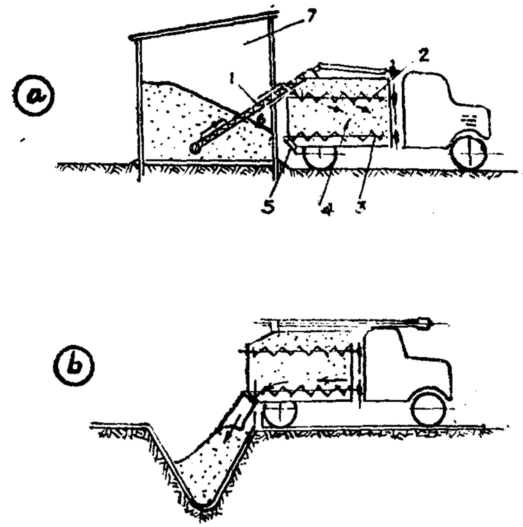


Fig. 2. The Bulk Cement Lorry.
(a) Loading Cement (b) Discharging Cement.

(1) Loading Apparatus. (4) A Tank.
(2) Spreading Apparatus. (5) Discharging Chute.
(3) Discharging Apparatus. (6) Feeding Chute.
(7) A Cement Store.

A Self-Loading and Discharging Bulk Cement Lorry

An interesting note describing a bulk cement lorry which was designed in the transport division of a Russian civil engineering contracting organisation, appears in the Stroitelnaya Promishlenmost for January, 1957. Since the existing types of bulk cements lorries require special mechanical loading arrangements, their use is restricted to the sites were such loading arrangements can be economically operated.

The new Russian bulk cement transporter is a $3\frac{1}{4}$ yd.^{3} ($2\frac{1}{2}$ m^3) tanker, is self-loading and self-discharging, and can also be used for transportation of lime and grain. The loading apparatus (Fig. 2a) consists of an elastic tube which is mounted on top of the tanker. A broken flight elastic screw conveyar is fixed inside the tube and is driven from the engine countershaft. The cement is spread inside the tank by a screw feed spreader. The discharging apparatus consists of a screw feed discharge which is located at the bottom of tank and is connected to a discharge chute. The screw feed spreader, and the screw feed discharge are both driven from the engine countershaft.

It can be seen from Figs. 2a and b that loading and discharging operations can be performed in all weather conditions with no loss of cement. The tests showed that when the loading apparatus is set up at an angle of 45 deg. and the elastic screw conveyor is operated at a minimum speed of 200-250 r.p.m. the pitch of the screw being $2\frac{1}{2}$ in. (64 mm.) three tons of cement can be loaded in five minutes. Discharging operations, under similar conditions require about four minutes. The experimental bulk cement lorry transported about 1000 tons of cement without a breakdown.

—Extract from Civil Engineering and Public Works Review, date June, 1957.

From other Journals

Some thoughts on concrete pavement problems

By A. T. GOLDBECK,

Engineering Consultant, National Crushed Stone Association, Washington, D. C.

The following random thoughts have occurred as the results of a recent exceedingly interesting field inspection of concrete pavements made in company with a number of members of the Committee on Rigid Pavement Design of the Highway Research Board. Actually, the thoughts which follow were not raised during the inspection but have since occurred as the result of further thinking of the problem of concrete pavement design and of concrete pavement behaviour.

Plastic Cracking

For the sake of adhering to some semblance of continuity, let's start at the beginning of construction of the pavement slab. The concrete is placed on the subgrade or, in more recent construction, on a granular sub-base and almost immediately there is a tendency for the mixing water to disappear, either by evaporation or by absorption. Hot weather, low humidity, wind, porous subgrade, and porous absorbent aggregates are the active agents which make the concrete dry out rapidly, and when this happens, crazing or fine hair checking of the surface due to shrinkage appears or, in severe cases, large shrinkage cracks are formed, sometimes parallel to one another and at an angle with the sides of the pavement. (Figure 1) A porous subgrade with local roughnesses will accentuate this from of cracking because when the concrete shrinks it tends to move over the subgrade and this motion is resisted by the subgrade friction. Fresh concrete has practically no strength and of course even the slight tension generated by these friction forces will exceed the tensile strength of the concrete and a crack forms. The cure for this difficulty consists of making the subgrade as smooth as possible, sometimes by the use of a layer of damp sand and sometimes even waterproof paper is advisable. Also, and of even more importance, protection from the wind and sun should be given and the use of a water spray as soon as possible is a good precaution. Thus the disappearing mixing water will be resupplied and the shrinkage will be minimized.

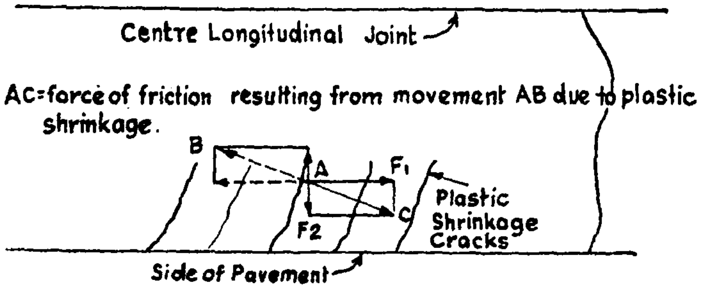


Fig. 1. One type of Plastic Shrinkage Cracks.

Thermal cracking of freshly placed concrete

Sometimes concrete placed near the end of the day will develop transverse cracking which will show up the next day rather close to the construction joint. This is due to the temperature falling at night; thus the slightly hardened concrete is caused to contract and this contraction is resisted by the subgrade friction and since the concrete has gained very little strength it is unable to resist the " drag " of the subgrade and enough tension is produced to crack the still very weak slab. When this becomes a troublesome problem, the surface of the concrete placed near the end of the day should be covered with an insulating layer of straw or other heat insulating material so as to avoid an excessive decrease in temperature during the night.

Thermal Warping Stresses

When the slab hardens it begins to develop high stresses due not only to the wheel loads of traffic but also to the fact that every day there occurs a cycle of temperature changes—warming up under the hot sun and cooling at night. These cycles are

rather rapid and since concrete is not a good conductor there is always a differential in temperature between the top and bottom of the slab of considerable magnitude. During the heat of the day the top surface becomes heated while the bottom changes in length a relatively small amount. The slab humps up at the center and its weight tends to bend it down. Hence the top of the slab is compressed and the bottom is stretched or subjected to tensile bending stresses. At night the reverse is true. The top is cooler than the bottom and hence the ends, sides, and corners rise, sometimes under a sudden severe drop in temperature. They tend to be bent down under their own weight and thus tension is produced at the top and compression at the bottom. The thicker the slab the more severe is this temperature differential and hence the greater is this so-called warping stress. Traffic loads tend to accentuate the effect of the warping stresses. Largely because of these temperature effects transverse cracks are formed. When no steel reinforcement is used, these cracks can become wide enough to admit water to the subgrade and if they are to be avoided it is good practice to build transverse joints into the pavement.

Influence of coarse aggregate on warping of pavement

The aggregate producer will be interested to know that the thermal coefficient of expansion of concrete differs widely and the coarse aggregate largely controls this expansion or contraction. Coarse aggregates have a wide range in thermal expansion varying from 0·000003 to 0·0000075. Limestones and traps generally have a low thermal coefficient and siliceous aggregates such as quartz and chert have vary a lot in their surface smoothness and the character of their fracture. Some fracture with a smooth, concoidal surface, others with a rough precipitous surface which furnishes an excellent mechanical bond with mortar. As a consequence, it is not impossible to find the transverse cracks in low thermal coefficient concrete very widely spaced up to 100 or 200 ft. apart; others with a high thermal coefficient as low as 15 ft. apart. Probably the bond between coarse aggregate and mortar and perhaps other little understood phenomena also control the frequency of cracking.

Spacing of contraction joints in plain concrete slabs

When building unreinforced pavements it is usual to space contraction joints from 15 to 25 ft. apart to prevent objectionable intermediate cracks from forming, but when previous experience is favourable, even wider spacing is acceptable. The friction effect of the subgrade, although important, is minor compared with the warping effect of temperature differential between the top and bottom of the slab. Limestones, traps, and granites have an exceptionally good service behaviour due to their low thermal effects and their favourable bond with the mortar.

When joints are used in plain unreinforced slabs there should not be expansion joints but rather contraction joints formed by installing planes of weakness which will cause the slab to crack at the desired locations. This plane may be a groove built into the slab or a transverse saw cut is made in the top surface to a depth of a few inches. When the slab cracks it will do so at these weakened planes and the cracks in the lower part of the slab will be irregular generally following the surfaces of the aggregates.

Aggregate Interlock

Obviously, as long as the crack remains tightly closed, the aggregates form projections which fit into the adjoining slab and there is created a condition known as "aggregate interlock" one slab is prevented form moving vertically with respect to its neighbour, and thereby the slabs are prevented from "faulting". Such a joint remains effective for transferring wheel loads from one slab to the other only as long as it remains tightly closed. A slight separation may destroy the aggregate interlock and due to heavy wheel loads the slabs might fault at the joint. Such a condition is readily detected by travelling public by the severe bumping as the wheels travel over the joint. This faulting in severe cases results in a lowering of the "far" side of the joint by as much as 3/8 to 1/2 in. The joint becomes a weak spot in the pavement and failure, especially on a poor subgrade, is imminent.

Strong Sub-base Beneficial

A pavement built in this manner required an extra strong sub-base and no expansion joints should be used, for these permit the slabs to separate and lose their aggregate interlock. Under automobile traffic alone, plain slabs built on a strong sub-base, with contraction joints but without expansion joints, can be successful but it seems inadvisable to resort to this construction when heavy trucks are to be carried, for faulting at the joints has occurred too frequently. A well graded stone sub-base makes an excellent support built either as a graded aggregate or a macadam base in which case care must be taken to provide on top a smooth thin course of sand or screenings so as to reduce the subgrade friction.

Reinforced Slabs

When reinforcing steel is used its purpose is not to prevent cracking, for this is impossible, but rather to hold the cracks tightly closed and thus prevent the infiltration of water. This construction involves the use of widely spaced transverse joints, either contraction or expansion joints and at such joints a means of carrying the load from one side of the joint to the other is provided. Steel, dowels are most widely employed for this purpose, generally located at the center of the slab in a line across the pavement.

Another matter worth noting is that the joint between the side of the slab and the waterproofed shoulder should be kept sealed in the same manner as a transverse expansion joint is sealed for it is just important to keep the water out of this joint as from the expansion or contraction joint. More attention to improving the shoulder is needed using a substantial load supporting and waterproof surface, for this is a relatively inexpensive way to increase the load carrying capacity of the pavement and it further gives extra traffic capacity to the pavement, it is an excellent safety measure.

To the stone producer it should be evident that he has an opportunity to be of real service in improving the life, the load carrying capacity and the safety of highways, not only of concrete, but of the bituminous concrete type also. It is urged that there be greater use of stone in—

(*a*) The building of a really substantial sub-base under pavements.

(*b*) Concrete pavement, which as a whole should result in reducing temperature warping stresses and the frequency of transverse cracking;

(*c*) The building of substantial, waterproof shoulders which by actual test have shown their benefit in increasing the load carrying capacity of the pavement.

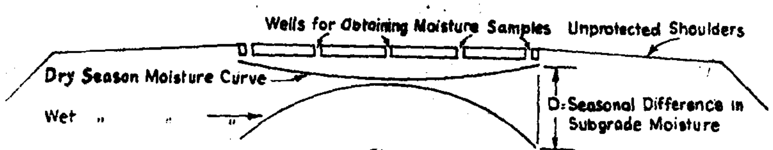


Fig. 2

SEASONAL VARIATION OF MOISTURE CONTENT IN SUBGRADE

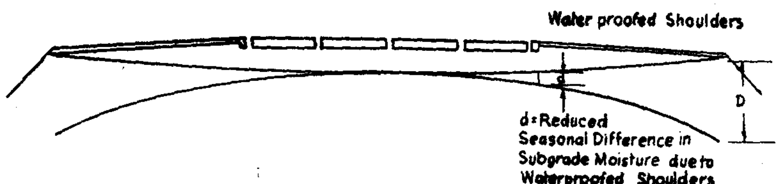


Fig. 3

IMPROVEMENT IN UNIFORMITY IN SUBGRADE MOISTURE DUE TO WATER PROOFING OF SHOULDERS.

—From the Crushed Stone Journal Washington, D.C. date June 1957.

Association NEWS

The Annual Session of the Association, which was proposed to be held in January, 1958 is postponed as certain important gatherings like Indian Roads Congress, ECAFE Session on low cost Roads and the Indian Science Congress are to be held during the month of January, 1958. The change in date will be intimated to members in due course.

MEMBERS ARE REMINDED THAT

SUBSCRIPTIONS

are

Due on 1st January

in each year

Early payment saves much time and money Those who have overlooked payment are earnestly requested to send a remittance

Without Delay

to the Secretary

THREE PRECIOUS THINGS

*   *   *

*   *   *

But I holdfast to three precious things which also I cherish.

The first is gentleness;
The second is economy;
The Third is humility.

With such gentleness I can be daring;
With such economy I can be generous;
With such humility I can be great in service as vessal of honour.

But in these days men forsake gentleness and become only abstrusive;
They abandon economy and become only excessive;
They relinquish humility and strive for precedence and thus for death.

Gentleness is ever victorious in attack and secure in defence. Therefore when heaven would preserve a man it enfolds him with gentleness.

From—The Simple way (LAOTZE)

By

WALTER GORN OLD, M. R. A. S.

IMPORTANT

Members are requested to notify the Secretary

AT ONCE

any change of address or of designation

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