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EFFLORESCENCE IN BUILDINGS AND A NEW METHOD OF CURE.

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Preliminary.

It is well known to all the Punjab Irrigation engineers that the water-table in the canal colonies before the introduction of canal irrigation was deep and although some of the pioneers of Punjab Irrigation did foresee a rise in the water-table, for they had instituted the observation of water levels as early as 1870, the idea of providing damp-proof courses to the buildings that were constructed then, did not strike anyone. The water-table, for example, in Lyallpur was 90 feet below the natural surface before canal irrigation commenced. At Sargodha it was 48 feet and at Montgomery it was 65 feet from the natural surface.

With the rise in water-table moisture and salts have travelled up the soil profile and have attacked the brickwork of many buildings to such an extent as to render them unfit for habitation. Those of us, who have had to tour in areas with high water-table, can well realize the unhealthy condition of the rest houses they have to occupy. In almost all cases the plaster falls down, the brickwork disintegrates, the floors burst and the whole rest house gives an offensive smell. The disintegrated wall affords an ideal place for mosquitoes and other small flies to breed. Vegetation round the rest house disappears. The most notable examples of this type of rest house are Ludewala, Beriwala, Satghara (before under-pinning) in the Lower Jhelum Colony and Manuana, Sukheke, Sangla and Chuharkana in the Lower Chenab Canal area. Besides irrigation rest houses, other Government and private buildings in localities where the water-table has risen, have similarly suffered. The towns of Akalgarh, Hafizabad, Sambrial, Chuharkana and Sukheke are examples. The water-table is still rising and in the next few years the buildings in Lyallpur, Gojra, Toba Tek Singh, Sangla, Montgomery, Okara, etc., are threatened with this "disease". If buildings in these big cities are to be saved from ruin and if the health of the people is any consideration it is of the greatest importance that a type of damp-proof course should be evolved which should be capable of application to existing buildings most of which are two-storied or even three-storied buildings.

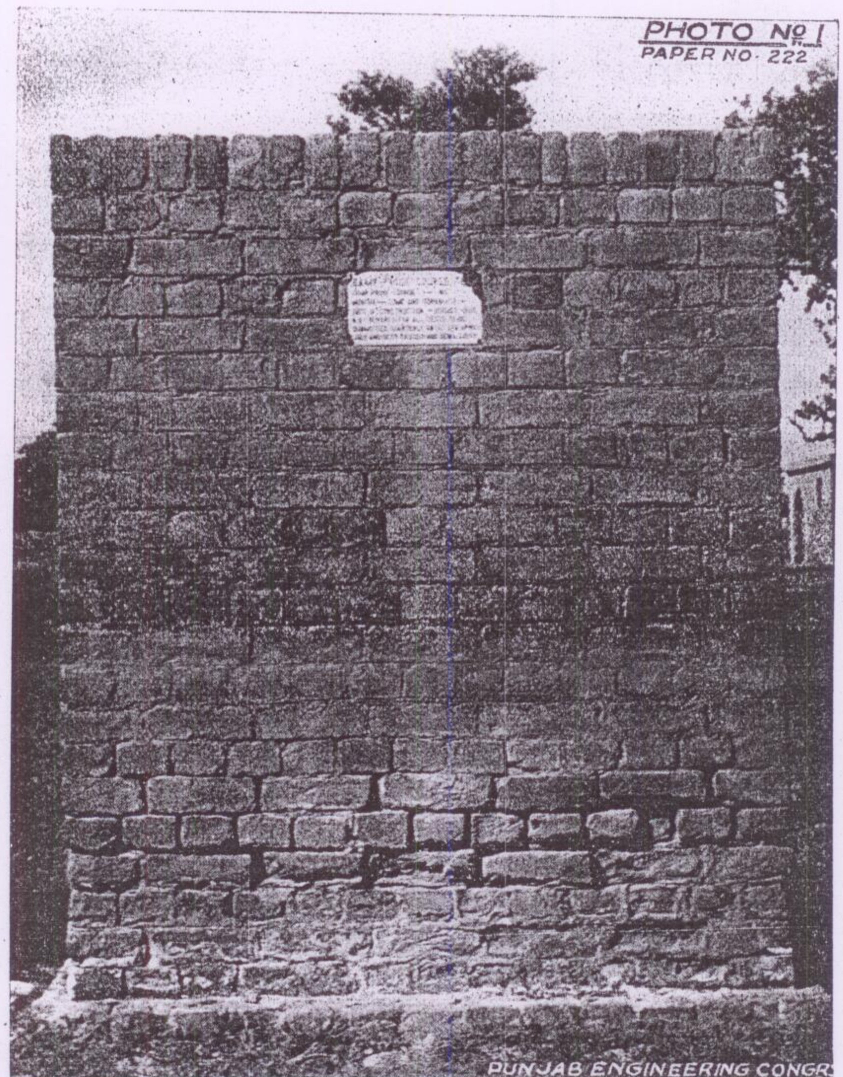
Phenomenon of Efflorescence.

Before we actually describe the new damp-proof course it seems necessary to explain the mechanism of the movements of salts and water in the soil profile and the way salts attack brickwork and damage it. The research work carried out in the Irrigation Research Institute has shown that at certain depths of the water-table the movement of the water from the surface of fields is downwards, and that this movement takes place in the form of unsaturated flow. Under these conditions there is neither any deterioration in soil nor any disintegration of the buildings. When the water from the water-table reaches a certain distance (which is characteristic of each type of soil) from the natural surface, the direction of moisture and salt movement tends to be reversed. With the reversal of movement, salts and water begin to travel upwards and attack everything that they come across. Vegetation is killed, soil becomes '*thur*' and building materials begin to disintegrate. For a more detailed description of the movement of salts and moisture in Punjab soils members are referred to the Annual Reports of the Irrigation Research Institute for the years 1937 and 1938. Four tables from these reports are reproduced in this Paper as Appendix I. In Tables 1 and 2 are given the moisture, salt and clay percentage of an unirrigated and an adjoining irrigated profile near Montgomery which is in the Lower Bari Doab Colony; Tables 3 and 4 show similar data for a profile near Samundri in the Lyallpur area. The conclusions arrived at from an examination of the results in Tables 1 to 4 are:—

1. That in the Montgomery area the soils have a higher clay content in the profile than in the Lyallpur area.

2. That under pre-irrigation conditions the salts are accumulated in the surface horizons and downwards distributed throughout the length of the profiles.

3. That in soils which have never been irrigated, the profile is dry to a depth of 19 feet in the Montgomery area, *i.e.*, a distance of approximately 18 feet from the water-table and to a depth of 22 feet in the Lyallpur area which means a height of approximately 8 feet from the spring level. The conclusion arrived at from this is that water from the water-table is lifted to a height of approximately 18 feet in the Montgomery area and 9 feet in the Lyallpur area. As the clay content of the Montgomery soils is high it may be concluded that the reverse movement of moisture and salts would take place when the spring level rises to within 20 feet from the natural surface. In the Lyallpur area the clay content of the profile is high to a depth of about 6 feet from the natural surface, below which it is practically all sand. In this case the water from the water-table is lifted to a height of 8 feet and when it touches the soil crust (the portion near the surface containing clay) it begins to affect the moisture content of the portion of the profile above it. In this area therefore disintegration of buildings is not likely to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start till the spring level rises to within about 14 feet from the natural surface. When the water-table rises to within the depths mentioned above the moisture and salts in the soil begin to travel upwards and are carried into buildings through the mortar and the pores of the bricks. At the surface of the bricks, evaporation takes place and the salts become concentrated. The salt which is mainly present in the Punjab soils is sodium sulphate. During winter, it crystallizes at the surface of the brick and the outer portion of the brick gets disintegrated. During summer, the salt is diffused again but in the following winter it crystallizes once more and causes a further disintegration of the bricks.

Method of cure experimented on.

It will be seem from the above that if a method could be evolved by which the upward movement of moisture in the brickwork of buildings is retarded, the salts will not be able to travel in solution. There is, firstly, the universal method of providing a damp-proof course. This consists of a cement concrete slab $1\frac{1}{4}''$ thick, placed just above the plinth level of the building and under the walls. This method is being adopted in all Government and private buildings which are being constructed now. There are other forms of damp-proof courses such as cement in pudlo, slate or stone slabs, mica in layers, patent bricks manufactured abroad and imported but the application of any of these to existing buildings is difficult and expensive. The exact process of laying such damp-proof courses to existing buildings has been described by Mr. Sharma in the Paper which he presented to the Congress in 1931. From the description given by him it can be understood that, apart from expense, the method advocated can be followed only under expert supervision. Underpinning two or three storied buildings by this method is simply out of question. Since 1931, when underpinning was done to Satghara (one of the Irrigation Branch rest houses in the Lower Jhelum Colony) very few Government buildings and no private ones have been treated in this way. Calculations show that, for about the cost at which underpinning to a single storied building could be done, the old building could probably be dismantled and a new one constructed. One of the authors who was in close touch with Mr. Sharma when he undertook the underpinning of Satghara rest house, felt that this was not a cure which would find widespread application. Experiments were started at the Irrigation Research Institute as it was considered that if bricks could be made water-proof it would be much easier to replace the existing layer of bricks near the plinth level with water-proof bricks than to attempt underpinning.

Bitumen is known to be a water-proof material. After making several trials with coating bricks with bitumen it was ultimately decided to impregnate the whole of the brick with bitumen so that all the pores were filled with this material. This was done with the help of a drying and a vacuum oven, the description of which is given later on.

The bricks that were treated in this manner were tested for their capacity to absorb water. The bricks were carefully weighed and then dipped in water. Each day they were taken out, surface dried and weighed. The results are given below :—

	Initial weight 27-5-38	WEIGHT ON DIFFERENT DATES.			Total (water) absor-bed.	Moisture per cent. on the brick.
		30-5-38	3-6-38	10-6-38		
Untreated brick.	3437 gr.	3872 gr.	3889 gr.	3901 gr.	464 gr.	13·5 p.c.
Treated brick.	3694 gr.	3694 gr.	3695 gr.	3694 gr.	*Nil.*	*Nil.*

It will be seen from these results that, whereas the untreated brick absorbed as much as 13·5 p.c. of its weight of water the treated bricks remained unaffected, *i.e.*, no water was absorbed by them.

At this stage it was decided that the bricks should be tested actually in the field where the water-table was high and where the brickwork of buildings was actually distintegrating. Chuharkana was considered most suitable as the water-table in this rest house compound is high. It was within easy reach of one of the authors who was posted as Executive Engineer, Drainage Division, at Sheikhupura. Five walls, each 1·7 ft. thick, 5·75 ft. long and 5·0 ft. broad were built in September 1930. The following is the description of the walls :—

(*i*) No damp proof course. Masonry in lime and surkhi mortar (1 : 2).

(*ii*) Damp proof course of 1½″ cement concrete (1:2:4), sand and shingle. Masonry same as in (*i*).

(*iii*) Damp proof course of 1½″ cement concrete as in (*ii*) with a mixture of Pudlo compound. Masonry as above.

(*iv*) No damp proof course but all masonry in cement and sand mortar (1 : 4).

(*v*) Damp proof course of one course of bitumen impregnated bricks, manufactured at the Irrigation Research Institute by the method described.


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Observations on the conditions of these walls have been made and the following notes have been recorded at the end of 8 years.

(*i*) 7 courses of bricks from bottom upwards are affected by salts and have disintegrated.

(*ii*) The cement concrete layer, together with three courses of bricks above it, has been affected.

(*iii*) The damp proof layer has been attacked by salts. In addition, two courses of bricks are also affected.

(*iv*) The brickwork has disintegrated to a height of 10 bricks from the plinth level.

(*v*) The walls are in a perfectly sound condition. Photographs 1, 2, 3, 4 and 5 very clearly show the condition of these walls.

After such a conclusive proof of the effectiveness of bitumen treated bricks in preventing the rise of moisture and salts into the brickwork of buildings it was decided that a rest house in the Lower Jhelum Canal which had been attacked by salts should be provided with a course of bitumen treated bricks. This was done mainly with the idea of studying the difficulties in manufacturing bricks on a large scale and also the method of laying them under existing buildings. Ludewala rest house was selected for the purpose. This rest house is situated in the fork between the Northern Branch (just below a fall at R. D 1,69,000) and a distributary taking off on the left of this branch, above the fall. The spring level is high, *viz.*, about 8·0 feet from the ground, and the rest house compound presents a snowy appearance in winter due to the salts which appear in the surface. The walls of the rest house were affected to about 4·0 feet above floor and floors were all damp and disintegrated. The plaster from the walls had fallen. Actually the rest house was not fit for occupation and it was a matter for consideration whether it should not be abandoned. The proposal to provide Ludewala rest house with a damp-proof course consisting of a layer of bitumen treated bricks was brought to the notice of K. B. Sh. Abdur Rahman, Superintending Engineer, Lower Jhelum Canal who sanctioned an estimate for the purpose.

4. Making Bitumen Impregnated Bricks.

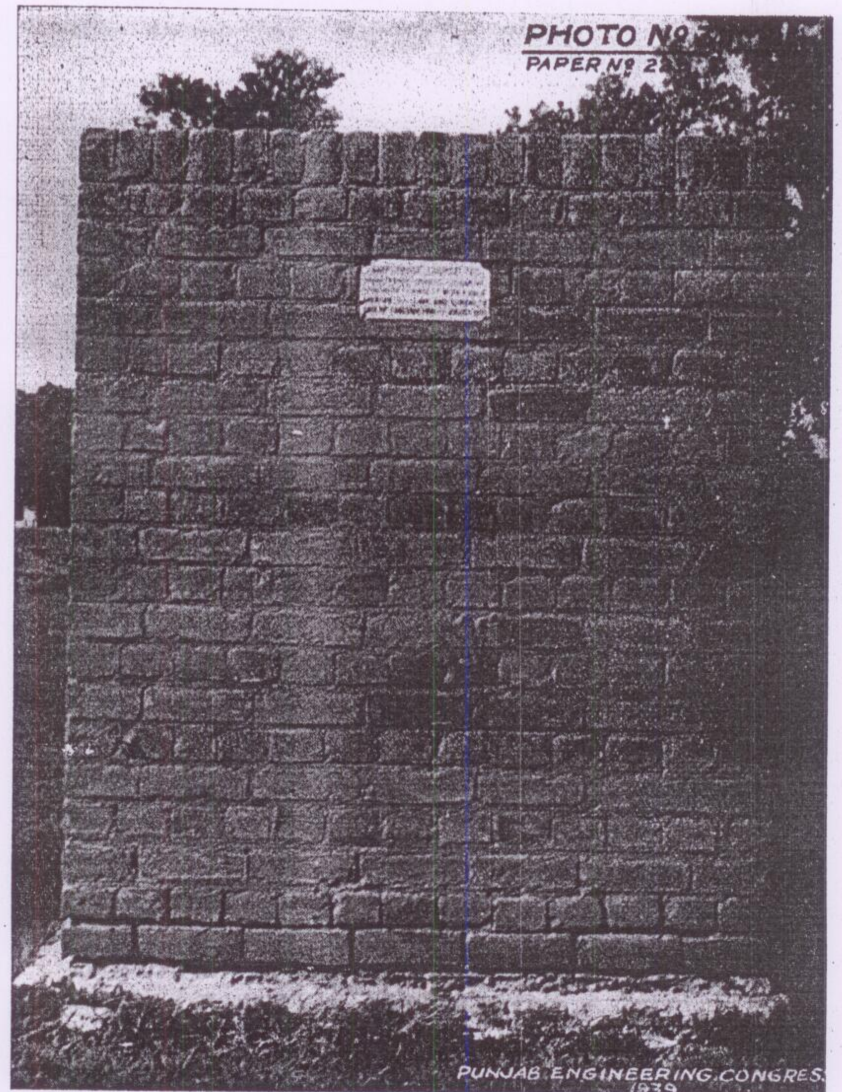
Standard canal-size bricks were purchased from the market at Sargodha. The exhaust pump used in tests in the Research Laboratory at Lahore was brought down and installed in hired premises, where power was available. An iron pan for heating bitumen and an air tight drum with a removable top, made in the workshop attached to the Irrigation Research Institute in Lahore, was used. A dimensioned sketch of this apparatus in position is shown in Plate I. It is so simple that it needs no further description. The drum is large enough to take 30 to 40 bricks at a time and the iron pan can take enough bitumen for impregnating this number.

The process consists in placing the dry bricks in the drum and working the exhaust pump till a vacuum of 20 lb. per sq. inch is attained in the drum. Meanwhile the bricks as well as the bitumen are heated, the latter to as thin a consistency as possible. The stop-cock is then opened to allow melted bitumen from the pan to enter the drum and impregnate the bricks, the vacuum being kept up for about an hour after closing the stop-cock. The pump is then reversed and a pressure of 20 lb. per sq. inch created. Thus all surplus bitumen is forced back into the pan. The lid of the drum is then opened and the bricks taken out. The whole process takes about 3 hours for one batch and in a whole day 3 or 4 batches can be taken out. Owing to the fact that private premises and power had to be hired at a monthly rental and on account of several charges that normally would not occur if manufacture were undertaken on a commercial scale, the work as carried out was expensive. However, the aim was to demonstrate the practicability of the process on a field scale and this was achieved. The bricks that turned out were tested for the amount of bitumen they had absorbed. The quantity absorbed varied from about 10 oz. to 25 oz. per brick. This appears to be due to the variation in quality of the bricks. The quality of bitumen itself may have had something to do with the matter.

Tests carried out showed that if a brick absorbed 18 oz. or more of bitumen then it becomes absolutely impervious to water. Those absorbing less than 18 oz. showed some amount of absorption. Bricks of the latter type have been used in the walls indicated in the plan which is shown in Plate II. Effects will be watched.

5. Laying Bricks in Situ.

This part of the work is ordinarily considered to require centering under arches and roofs, to support the weights from above. As this was an expensive item, it was decided to try taking out bricks from under half the thickness of each wall, in lengths of about three feet at a time. After replacing these by bitumen impregnated bricks the half thickness on the opposite side was treated in the same way. Then the next piece of wall was dealt with similarly. In *pacca* and *kachha-pacca* walls no difficulty was experienced. In *kacha* or mud-brick walls, however, it happened that pieces of brick fell down. In such cases a temporary support was given until the refilling was done. Originally in *kacha* walls it was intended to insert two courses of bitumen impregnated bricks, but as the cost of treating them was high it was decided to try only one course of these bricks with a second course of untreated *pacca* bricks. The joints were laid in cement and sand mortar (1 : 3), both horizontally and vertically. The bottom (at plinth level) was covered with coal tar and later with bitumen. The whole work was completed without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much difficulty by ordinary trained masons and coolies under the supervision of an overseer. No centering of any kind was used except under one verandah arch which had previously cracked and was in danger of collapsing. No fresh cracks in any verandah, doors, windows or roof arches have been noticed. The method employed is perfectly simple, safe and inexpensive.

All floors made of lime concrete had also been attacked by salts and were relaid. Later, in some floors, a coat of bitumen, left over from the manufacture of bricks and considered too thick for impregnation, was given under cement concrete slabs. The work as executed is shown in Plate II. The building now presents a very neat and healthy appearance.

6. Cost of Work.

The cost actually incurred in making bricks is not a correct indication of such work on a commercial scale as the work was experimental and the plant used was very small. Also there were many setbacks which caused delay and waste of labour. Furthermore material obtained at short notice was expensive and the cost of tools and plant when spread over such a small outturn was relatively high. The daily outturn was reduced on account of delays. An analysis of rates at the beginning of the operation, including all these factors, is worked outand given in Appendix II. According to this the cost of one brick is 3·5 annas. Another analysis of the same work, when things were running smoothly is also given therein and according to this the cost is 2·5 annas a brick. A third analysis is given assuming a plant large enough to contain 100 bricks at a time which gives a cost of 1·7 annas per single brick. This last analysis naturally gives a lower rate than the other two and it could be further reduced if a still bigger plant were employed Tests are in progress to ascertain if, instead of full-sized bricks of 3-inch thickness, tiles of half the thickness (*i.e.*, $1\frac{1}{2}''$) would also serve the purpose. If they prove as effective as bricks for a damp proof course, the cost will be further reduced. A tentative analysis (4) is given in Appendix II. An analysis of the total cot of laying bricks is also given in Appendix II. This works out at about 5·6 annas per foot of wall. The total expenditure under various sub-heads for treating Ludewala rest house which has a plinth area of 2655 square feet will be as follows under normal conditions :—

			Rs.	A.	P.
2000 No. bitumen impregnated bricks at 1·7 annas each	..	..	212	9	0
3770 l. ft. laying under walls at 5·6 annas per l ft.	..	..	131	15	0
2250 sq. ft. renovating floors at Rs. 11-8-0 per % sq. ft.	..	..	258	12	0
	Total	..	603	3	0

Thus the cost of the whole operation amounts to about Rs. 3-8-0 per sq. ft. of plinth area of the building. Even at this cost., there should be no hesitation in saving all the buildings affected by efflorescence (but not yet beyond repair) by this simple yet effective method, of which the practicability has been shown beyond doubt. The method is so simple that no highly skilled labour is required and costs are so little.

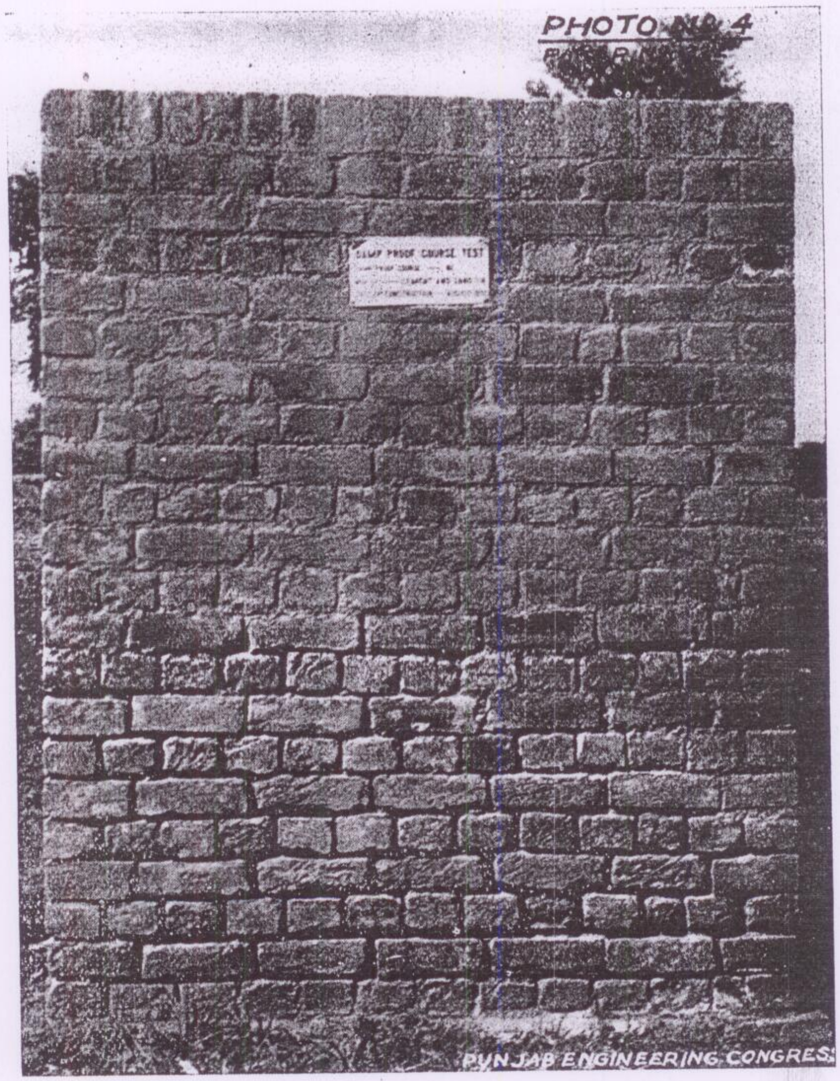
More about Bitumen.

In the work described in this Paper, bitumen is a very important factor and a few remarks about its source, qualities, etc., will not be out of place. After the extraction of aviation spirit, motor spirit, high grade kerosene oil, low grade kerosene oil, lubricating oils and diesel oils, the residue left is called asphalt (bitumen). This residue is again further divided into :—

1. Straight asphalt.
2. Cut back asphalts.
3. Blown or oxidized grades.

Each grade has a number of grades in itself and these are distinguished from each other by their degree of penetration. Only straight asphalts and blown or oxidized asphalts are suitable for treating bricks for the purpose of making them damp-proof. The oxidized asphalts have a much higher melting point than the straight ashphalts. The oxidized grade are more expensive than the straight asphalts. The prices of straight asphalts vary from about Rs. 112 to Rs. 129 depending upon the quantity ordered and the channel through which it is purchased. Purchases made through the Indian Stores Department are effected at a slightly cheaper rate. Burmah-Shell are the manufacturers of all genuine types of bitumen and deal with this material direct, *i.e.*, they have no sale agents for this commodity. It is, therefore, advisable to place orders direct with Burmah-Shell instead of buying bitumen in the bazaar.

For the manufactures of bricks for Ludewala rest house, bitumen of 20/30 Mexphalte grade was used. Mexphalte 20-30 has a Ring and Ball melting point of approximately 62°—70°C. While the manufacture of bricks was in progress the Authors got in touch with Mr. Kerr of the Burmah-Shell Co., Karachi who became interested in the problem. After paying a visit to the walls in the Chuharkana rest house compound he was satisfied that the treatment would be successful. He very kindly offered his support in these experiments and suggested that another grade, Mexphalte E. H. 75/85, might be more suitable. Mexphalte D. H. 75/85 is known as Dubb's Bitumen. It has an approximate melting point range, Ring and Ball, of 75°-85° C. The penetration of D. H. 75/85 is nil, that is to say it is a very hard asphalt, but its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DAMP PROOF COURSE TEST
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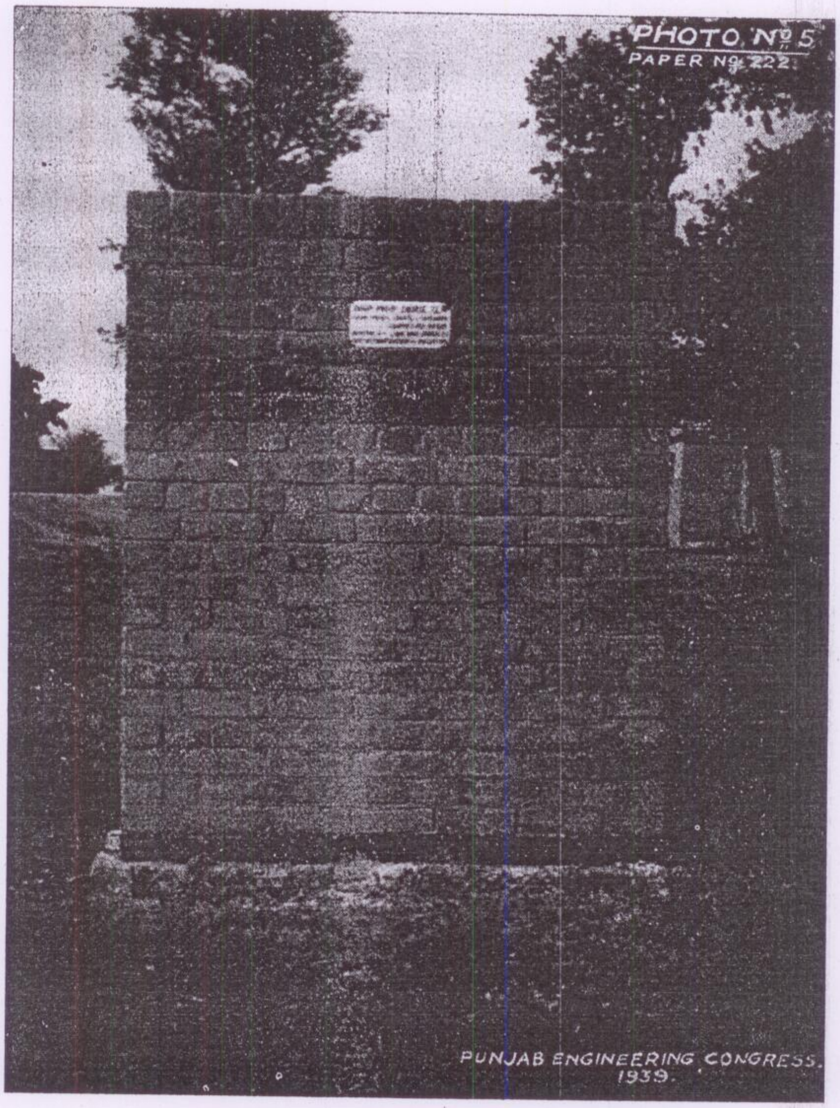
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melting point is very little higher than 20/30 grade; it is for this reason that this grade may be more suitable than the grade 20/30. Mr. Kerr has very kindly placed at the disposal of the Authors one ton of Mexphalte D. H. 75/85 free on rail Karachi and experiments with this grade are in progress.

Shell Primer No. 1 and Shelspra F 70 are two other grades, according to Mr. Kerr, which are worth trying for the purpose of making damp-proof bricks.

Acknowledgements.

The Authors take this opportunity of thanking :—

(*a*) K. B. Sh. Abdur Rahman, Superintending Engineer, Lower Jhelum Canal, for the keen interest he has taken in the experiment and for giving the Authors an opportunity of treating Ludewala rest house with this new type of damp-proof course.

(*b*) Mr. Kerr of the Burmah-Shell Company, Karachi, for the interest taken in this investigation, for suggesting other grades of bitumen for further experiments and for supplying, free of cost, one ton of bitumen.

(*c*) Dr. E. McKenzie Taylor for allowing the use of the plant developed and manufactured in the workshop of the Irrigation Research Institute.

(*d*) Mr. E. O. Cox, Chief Engineer, Irrigation Branch, for the very useful suggestions in extending the investigations.

(*e*) Mr. Kirpal Singh, Research Assistant, for having erected the machinery at Sargodha and for giving a demonstration of the manufacture of bricks to the local staff at Sargodha.

APPENDIX I.

Table No. 1.

Showing distribution of Moisture in Soil which has never been irrigated.

Field No. 12 Sq. No. 30, Chak No. 185/91 Montgomery District.

Depth from N. S. at which sample was taken.	% Moisture on dry soil.	% Clay on dry soil.	Total Soluble matter % on dry soil.
1st foot. ..	6·17	*Nil*	1·12
2nd ,, ..	4·22	*Nil*	0·63
3rd ,, ..	5·24	17·2	0·60
4th ,, ..	6·25	27·86	0·53
5th ,, ..	5·83	27·80	0·60
6th ,, ..	5·65	21·14	0·46
7th ,, ..	2·78	7·4	0·41
8th ,, ..	3·25	10·7	0·39
9th ,, ..	1·89	5·76	0·26
10th ,, ..	1·77	*Nil*	0·32
11th ,, ..	3·35	7·6	0·27
12th ,, ..	2·62	5·54	0·28
13th ,, ..	2·45	5·42	0·22
14th ,, ..	3·38	12·3	0·33
15th ,, ..	3·49	6·46	0·31
16th ,, ..	2·91	*Nil*	0·31
17th ,, ..	7·66	11·22	0·37
18th ,, ..	7·80	7·12	0·26
19th ,, ..	8·35	11·54	0·30
20th ,, ..	27·27	30·88	0·45
21st ,, ..	31·79	*Nil*	0·40
22nd ,, ..	22·55	44·78	0·43
23rd ,, ..	22·05	17·78	0·22
24th ,, ..	15·31	13·6	0·18
25th ,, ..	25·49	15·98	0·19
26th ,, ..	27·90	17·5	0·14
27th ,, ..	27·96	25·14	0·25
28th ,, ..	25·15	20·0	0·18
29th ,, ..	21·14	8·42	0·16
30th ,, ..	26·45	19·74	0·14
32nd ,, ..	16·27	17·2	0·18
33rd ,, ..	30·24	10·64	0·16
34th ,, ..	22·19	7·2	0·09
35th ,, ..	5·78	*Nil.*	0·07
36th ,, ..	11·23	1·52	0·09
37th ,, ..	29·28	0·12	0·13
38th ,, ..	27·70	2·00	0·13

TABLE No. 2.

Showing distribution of Moisture in soil which has been under irrigation and cultivation since about 1923.

Field No. 15 Square No. 30, Chak No. 18?-9?, Montgomery District.

Depth from N. S. at which sample was taken.	% moisture on dry soil.	% clay on dry soil.	Total soluble matter % on dry soil.
1st foot. ..	*Nil*	12·8	0·19
2nd ,, ..	16·43	21·98	0·13
3rd ,, ..	22·16	24·98	0·24
4th ,, ..	27·40	38·32	0·35
5th ,, ..	25·39	32·22	0·34
6th ,, ..	16·54	10·8	0·24
7th ,, ..	11·82	7·88	0·20
8th ,,	14·38	9·34	0·30
9th ,, ..	17·43	*Nil*	0·26
10th ,, ..	16·59	7·42	0·26
11th ,, ..	13·86	6·30	0·24
12th ,, ..	22·68	7·66	0·28
13th ,, ..	23·66	7·22	0·30
14th ,, ..	26·50	6·6	0·28
15th ,, ..	30·52	6·52	0·26
16th ,, ..	29·26	12·86	0·30
17th ,, ..	28·50	11·3	0·35
18th ,, ..	34·00	48·7	0·65
19th ,, ..	30·66	36·84	0·71
20th ,, ..	30·64	34·62	0·76
21st ,, ..	33·36	38·2	0·71
22nd ,, ..	36·10	56·42	0·74
23rd ,, ..	22·54	20·16	0·59
24th ,, ..	8·42	6·10	0·39
25th ,, ..	22·58	21·24	0·50
26th ,, ..	16·19	14·8	0·33
27th ,, ..	19·26	24·52	0·19
28th ,, ..	24·26	23·48	0·19
29th ,, ..	6·62	6·7	0·14
30th ,, ..	3·72	1·34	0·11
31st ,, ..	4·72	3·4	0·11
32nd ,, ..	5·91	2·08	0·09
33rd ,, ..	6·33	*Nil*	0·11
34th ,, ..	7·13	1·8	0·11
35th ,, ..	16·24	2·5	0·11
36th ,, ..	18·41	1·46	0·11
37th ,, ..	32·45	*Nil*	*Nil*
38th ,, ..	34·73	1·48	0·13

TABLE No. 3.

Showing distribution of moisture in soil which has never been irrigated.

Field No. 5, Sq. No. 6 Chak No. 468 G. B. Samundri, Lyallpur Distt.

Depth from N. S. at which sample was taken.	% Moisture on dry soil.	% Clay on dry soil.	Total Soluble matter % on dry soil.
1st foot. ..	1·4	11·0	0·78
2nd ,, ..	3·2	13·6	0·78
3rd ,, ..	2·7	12·5	0·60
4th ,, ..	2·2	10·6	0·42
5th ,, ..	1·9	6·5	0·39
6th ,, ..	2·8	7·7	0·38
7th ,, ..	1·3	0·9	0·19
8th ,, ..	1·0	1·6	0·14
9th ,, ..	0·8	3·8	0·14
10th ,, ..	1·0	1·6	0·11
11th ,, ..	1·1	1·9	0·19
12th ,, ..	1·0	1·4	0·13
13th ,, ..	0·7	1·8	0·16
14th ,, ..	0·7	1·0	0·13
15th ,, ..	0·8	*Nil.*	0·10
16th ,, ..	0·9	1·8	0·09
17th ,, ..	0·7	*Nil.*	0·09
18th ,, ..	0·9	2·0	0·09
19th ,, ..	0·6	*Nil.*	0·07
20th ,, ..	0·7	*Nil.*	0·07
21st ,, ..	0·6	*Nil.*	0·09
22nd ,, ..	1·1	*Nil.*	0·10
23rd ,, ..	3·2	1·6	0·20
24th ,, ..	9·0	3·4	0·40
25th ,, ..	8·7	2·3	0·24
26th ,, ..	3·6	2·5	0·155
27th ,, ..	4·2	1·4	0·18
28th ,, ..	6·0	1·8	0·19
29th ,, ..	11·3	1·9	0·12
30th	30·0	1·6	0·14

TABLE No. 4.

Showing distribution of Moisture in soil which has been under irrigation and cultivation since about 1902.

Field No. 15, Sq. No. 6 Chak No. 468 G. B. Samundri, Lyallpur District.

Depth from N. S. at which sample was taken.	% Moisture on dry soil.	% Clay on dry soil.	Total Soluble matter % on dry soil.
1st foot ..	1·6	12·4	0·12
2nd " ..	5·8	13·2	0·15
3rd " ..	6·9	11·5	0·08
4th " ..	9·6	13·1	0·07
5th " ..	11·2	15·6	0·34
6th " ..	12·3	13·2	0·10
7th " ..	13·6	13·5	0·13
8th " ..	16·7	7·8	0·11
9th " ..	14·6	4·4	0·11
10th " ..	8·2	4·0	0·09
11th " ..	7·2	3·6	0·07
12th " ..	5·2	2·2	0·07
13th " ..	3·4	*Nil.*	0·07
14th " ..	3·6	1·5	0·07
15th " ..	4·2	1·0	0·07
16th " ..	4·5	*Nil.*	0·07
17th " ..	5·2	1·7	0·07
18th " ..	3·2	*Nil.*	0·09
19th " ..	3·0	*Nil.*	0·12
20th " ..	3·7	*Nil.*	0·13
21st " ..	2·8	*Nil.*	0·12
22nd " ..	4·4	*Nil.*	0·11
23rd " ..	2·7	*Nil.*	0·10
24th " ..	3·3	*Nil.*	0·09
25th " ..	3·5	*Nil.*	0·09
26th " ..	2·8	*Nil.*	0·09
27th " ..	3·6	*Nil.*	0·07
28th " ..	2·1	*Nil.*	0·09
29th " ..	14·0	3·5	0·12
30th " ..	30·0	0·9	0·11

APPENDIX II.

Analysis of rates for impregnating bricks with bitumen for Damp-proof Course at Ludewala Rest House.

I. Rate at the beginning of work for one brick, 10″×5″×3″.

		Rs.	A.	P.
1.	Cost of one brick at the kiln at Rs. 13 per thousand..	0	0	2·5
2.	Carriage of one brick from kiln to Workshop, distance 1 mile at 1-10-0 per thousand	0	0	0·30
3.	Cost of 10 chtk. bitumen absorbed by the brick at Rs. 7-8-0 per md.	0	1	10
4.	Rent charges for 60 bricks daily at 1-10-4 per day ..	0	0	5·27
5.	Establishment charges for 60 bricks daily at 1-6-5 per day	0	0	4·5
6.	Stores, etc., for 60 bricks daily at 0-12-0 per day ..	0	0	2·4
7.	Depreciation charges for apparatus. Total cost of Tools and Plant=Rs. 130. Out of this Rs. 80 credited to the Estimate. Balance of Rs. 50 is for 6 working weeks hence charge per day is Rs. 1-3-0 for 60 bricks; for 1 brick ..	0	0	3·8
	Total ..	0	3	4·77
	Say ..		3·5 annas.	

II. Rate in the settled operation.

		Rs.	A.	P.
1.	Cost of one kiln at the kiln at Rs. 13 per thousand..	0	0	2·5
2.	Carriage of one brick to workshop, distance one mile at 1-10-0 per thousand	0	0	0·25
3.	Cost of bitumen absorbed, 10 chtk at 6-2-0 per md.	0	1	6
4.	Rent charges for 105 bricks daily at 1-10-4 per day	0	0	3·03
5.	Stores, etc., for 105 bricks daily at 0-12-0 per day ..	0	0	1·34
6.	Establishment charges for 105 bricks daily at 1-0-0 per day	0	0	1·83
7.	Depreciation charges for 105 bricks daily at 1-3-0 per day	0	0	2·17
	Total ..	0	2	5·12
	Say ..	2·5 annas.		

III. Rate per brick at commercial scale.

		Rs.	A.	P.
1.	Cost of one brick at kiln at Rs. 13 per thousand ..	0	0	2·5
2.	Carriage of one brick to workshop distance one mile, at 1-10-0 per thousand	0	0	0·25
3.	Cost of bitumen absorbed, 10 chtks. at 5-5-0 per md.	0	1	4
4.	Rent charges for 400 at bricks daily at 0-5-4 per day	0	0	0·16
5.	Establishment charges for 400 bricks daily Rs. 1 per day	0	0	0·48
6.	Store, etc., for 400 bricks for 1 day at 0-4-6 per day	0	0	0·13
7.	Depreciation charges for 400 bricks daily at Rs. 2. per day	0	0	0·96
	Total ..	0	1	8·48
	Say ..	1·8 annas.		

IV. For 1½" thick brick (tile).

1.	Cost of one brick at kiln at Rs. 13 per thousand ..	0	0	2·5
2.	Carriage of one brick to workshop distance one mile at 1-6-0 per thousand	0	0	0·25
3.	Cost of bitumen absorbed 6 chtks at 5-5-0 per md...	0	0	9·56
	Other charges, same as items 4, 5, 6 and 7 in III above..	0	0	1·73
	Total ..	0	1	1·404
	Say ..	1·1 annas.		

Analysis of cost of laying impregnated bricks in walls per foot.

Labour :—2 masons at Re. 1-12-0 each ..	3	8	0
3 Coolies at 0-8-0 each	1	8	0
Total ..	5	0	0

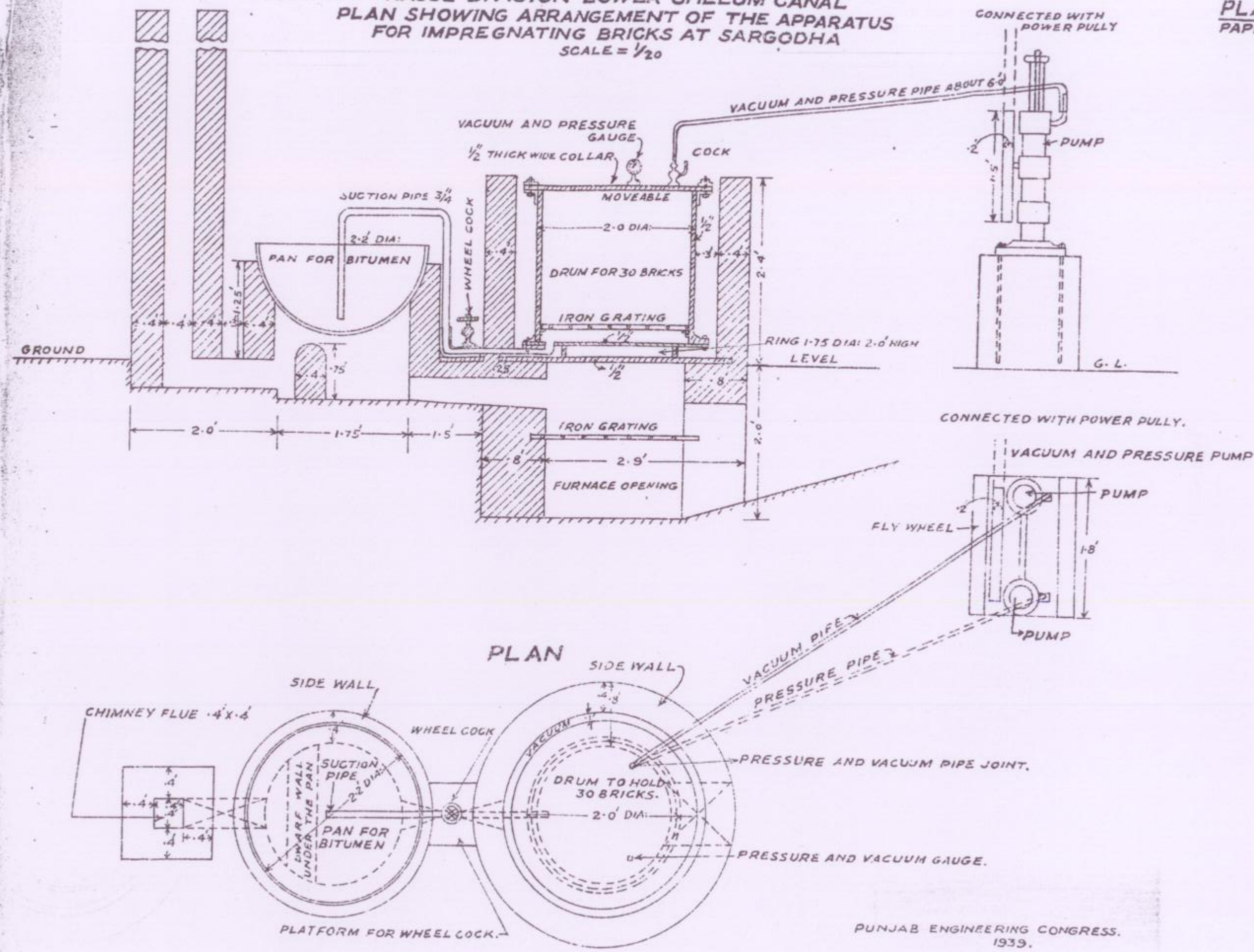
Progress of making slit and laying damp proof bricks :—

2·3 ft. thick *kacha* walls—14 ft. for Rs. 5 ..	0	6	0 l. ft.
1·7 ft. thick *pacca* walls—12 ft. for Rs. 5 ..	0	6	9 l. ft.
1·3 ,, ,, ,, —20 ft. for Rs. 5 ..	0	4	0 l. ft.
Total ..	1	0	9 for 3 l ft.

Average 5·6 annas per 1 ft.

PLATE I
PAPER NO. 222

RASUL DIVISION LOWER JHELUM CANAL
PLAN SHOWING ARRANGEMENT OF THE APPARATUS FOR IMPREGNATING BRICKS AT SARGODHA
SCALE = 1/20



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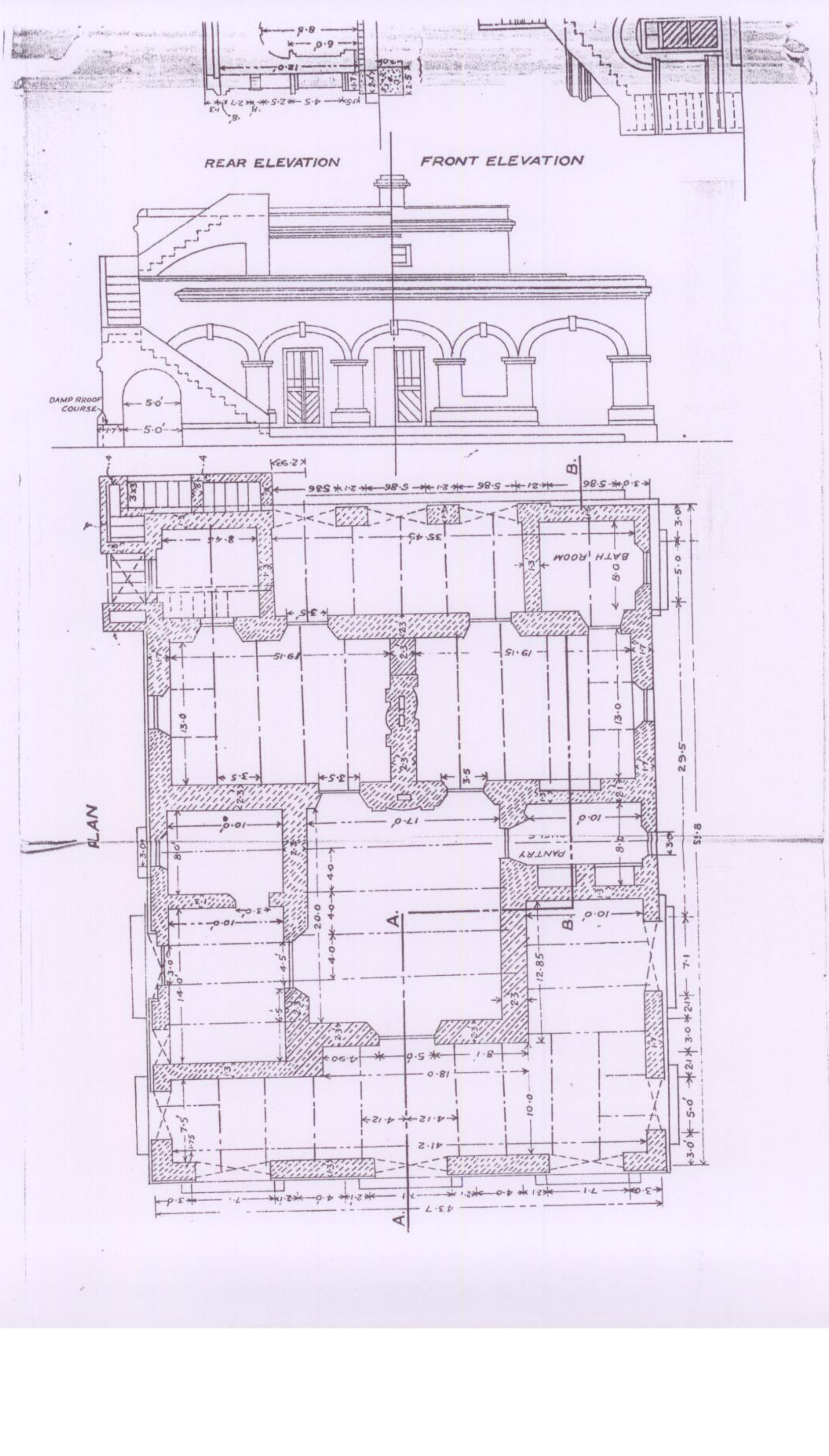
1939.

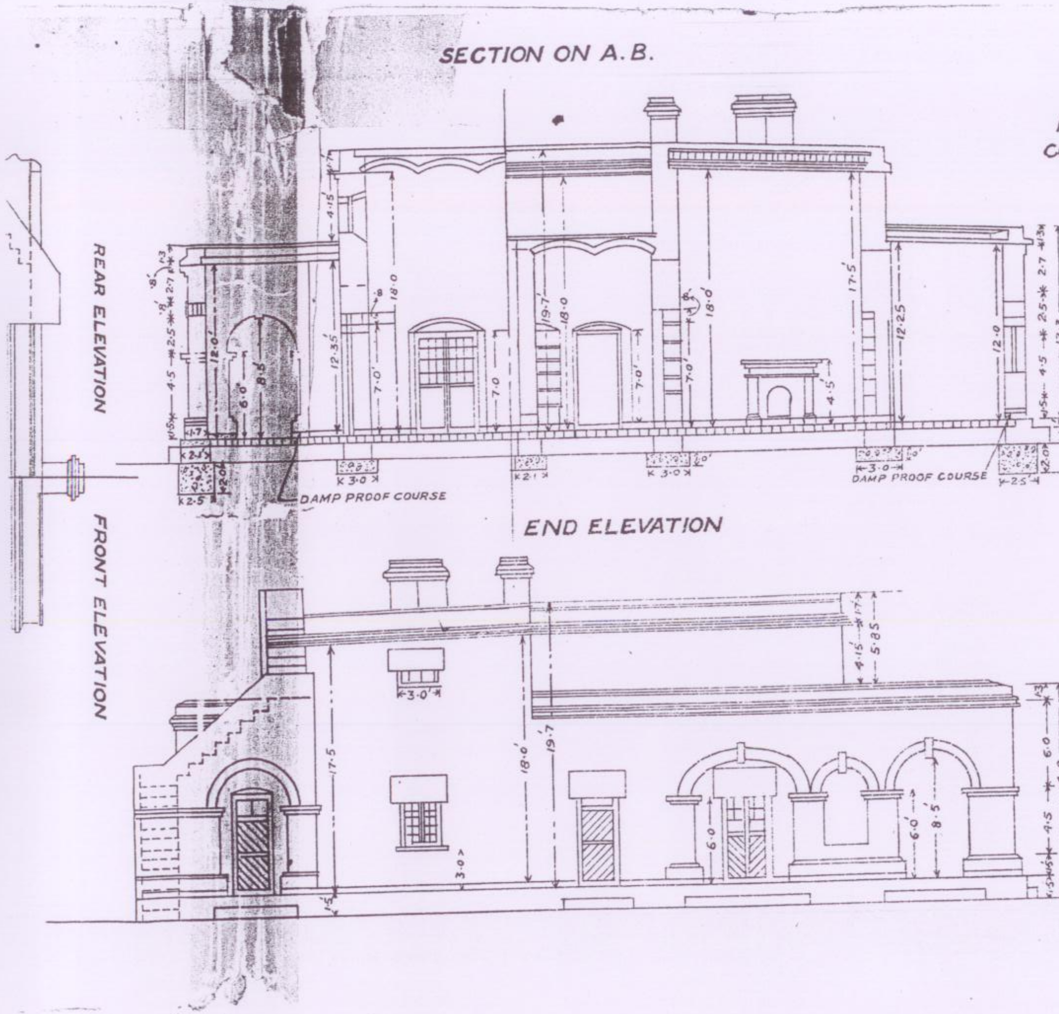


REAR ELEVATION
FRONT ELEVATION
DAMP PROOF COURSE
5·0'
PLAN
BATH ROOM
PANTRY
A.
B.

PLATE II
PAPER NO. 222

RASUL DIVISION LOWER JHELUM CANAL
COMPLETION PLAN OF SPECIAL REPAIRS TO LUDEWALA REST HOUSE

SCALE = 1/100



REFERENCES.

- ONE COURSE OF BITUMEN IMPREGNATED BRICKS IN CEMENT AND ONE OF ORDINARY BRICK IN CEMENT OVER IT.
- TWO COURSES OF BITUMEN IMPREGNATED BRICKS IN CEMENT & ONE OF ORDINARY BRICKS IN CEMENT OVER IT.
- ONE COURSE OF BITUMEN IMPREGNATED BRICKS IN BITUMEN & ONE OF ORDINARY BRICKS IN CEMENT OVER IT.
- CEMENT CONCRETE FLOOR.

PUNJAB ENGINEERING CONGRESS.
1939.

ERRATA.

Page 59 line 13 from bottom :—
For " Manuana " read " Nanuana"

Page 63 line 17 from bottom :—
For " Showy" read " shadowy".

Page 64 line 6 from top :—
For " 20 lbs." read " 10 lbs."

Page 66 line 1 from top :—
For " 3-8-0" read " Rs. 0-3-8".

DISCUSSION.

The **Author** introducing the paper said that the chief merit of the method of curing efflorescence suggested in the paper is cheapness combined with efficiency. The method described in Mr. Sharma's paper "Underpinning Satghara Rest House" in the Congress of 1931 has proved to be efficient so far, as Satghara rest house shows no signs of damp or salt rising in the walls, but it must be remembered that the cost was about four times as high.

The experimental walls referred to in the paper and built in Churkhana Rest House compound are easily accessible being at mile 33, just beyond the crossing of Upper Gugera Branch canal, on the arterial road from Lahore to Sargodha on the right as we go to Sargodha.

Since the paper was written some work has been done to gauge the effect of variation in temperature of bitumen 75/85 for impregnation. It is found that for complete impregnation 300°C is about the best. Bricks made at 250°C get only a partial impregnation in a fringe of about 1". This reduces the bitumen absorbed to about half the quantity, i.e., only 10 oz. per brick. Tests for absorption indicate that such bricks also do not absorb any water even under pressure due to 12 feet head of water. It is however not known how these may behave under field conditions against salt rising. If satisfactory, cost will be materially reduced. This variety of bitumen 75/80 is 25% cheaper than the one allowed for in the analysis of rates. As a result of investigations in progress, it is expected that the cost of bricks will not be much in excess of one anna per brick. The authors hope that the members of this Congress will try to make use of this method when they have to treat a building affected by salts.

Another possibility for the use of bitumen impregnated bricks is as lining material for irrigation channels. Tests to this end have been taken in hand.

Mr. **G. R. Sawhny** criticizing the paper said it is not a method of curing but of preventing efflorescence.

The trouble is not so much due to the rise in water table as the joint authors keep on bringing home to the Congress as it is due to the way in which rain water is allowed to drop all round a building and so into the foundations instead of being made to run off and away from them as is done in other places. He also blamed the use of Surkhi in concrete under floors for encouraging the appearance of salts.

In this connection he drew the attention of the Congress to the fact that in 1919 he had constructed certain buildings in Khanewal in which he had used ground coal clinker in concrete instead of Surkhi and sand and in which he had made arrangements to drain off rain water without allowing it to soak into the foundations. He said that these buildings showed no signs of being attacked by salt whereas other buildings built in Khanewal both before and after 1919 in which these precautions had not been taken have all been attacked in the usual way.

Therefore, in his opinion the whole trouble is not due to the rise in the subsoil water level but is mainly due to faulty workmanship.

Now coming to the question of underpinning, on taking over Balloki Division in 1932 he found an estimate for underpinning the entire building of Halla Rest House sanctioned and waiting execution but there was no note or report as to how this work was to be carried out. He scratched his head and mapped out a plan and programme which to the then S.D.O. Headworks seemed rather risky but as the building was already more or less condemned and never lived in for some years. Mr. Sawhny thought taking a little risk with it was quite permissible. The entire under-pinning was done by making holes in the walls at different points immediately above the height upto which the walls had to be dismantled and rebuilt and passing sleepers through those holes and fitting and fixing them very tightly over dry brick supports and later on jacks which were available in the Balloki Workshop were also made use of in place of these supports. The entire work thus became so simple and cheap that 4 to 5 feet length of walls at different parts of the building were taken in hand at a time and the entire Rest House except the length of fire places was under-pinned in less than $2\frac{1}{2}$ months. The Rest House is now cured from all kallar on the walls and entirely under-pinned at the total cost of Rs. 1,050. The mortar used was the same as used at Khanewal which is 3 ground 2 cinder white lime, and 5% cement. Similar methods have lately been very successfully employed at Lahore by the Public Health Department with kallar affected Government buildings.

Sardar **Sujjan Singh** remarked that the experiments carried out by the authors entail impregnation of bricks under pressure. Messrs. Burmah Shell Oil Storage and Distributing Co., of India, Ltd., have recently completed experiments in Karachi with bricks obtained from the Haveli Project and also with local bricks to ascertain if it is possible to obtain impregnation by simple immersion and without resorting to complicated pressure and vacuum plants. It has been proved that if bricks are well brushed and heated to the same temperature as the temperature of bitumen at the time of application, very appreciable impregnation can be obtained merely by soaking the bricks in the heated bitumen for a period of three hours.

These experiments were carried out with 17 different grades of straight run bitumen, blown bitumen and cutback bitumen and although the impregnation varied owing to the texture of the bricks not being uniform, it was decided that the best results were obtained with mexphalte straight run 30/40 penetration.

The impregnation of bricks was primarily intended for experiments in damp proof coursing, but Burmah-Shell are considering its use for lining of irrigation channels to prevent seepage, and will shortly carry out lining trials at the Punjab Engineering School, Rasul. The impregnated bricks were seen being used for paving of roads in Austria in the year 1930. The impregnation was carried out on a large scale with the aid of a plant.

In the end Sardar Sujjan Singh congratulated the authors on producing such an interesting paper which is obviously the result of careful study.

Mr. **Som Nath Kapur** said that the problem of efflorescence in buildings is likely to assume a serious form in the towns where the water-logging menace is appearing and is therefore one which needs the attention of the profession.

This problem confronted Engineers at Trimmu where the general level of the station area is 4-5 ft. below the maximum pond level and in the construction of buildings at Trimmu a thick coat of mexphalte has been given over ·1 thick 1 : 2 : 4 cement concrete to function as a damp proof course. Cement concrete, as has been explained by the authors, by no means provides a final solution to the problem. It only delays the operation because the cement mortar which has been used will transmit the moisture. Therefore, he questioned the ultimate value of the process.

Two alternative methods are suggested which have yet to be tried. One is to place a steel plate with bolts both up and down at plinth level so that a bond is maintained in the two portions of the masonry wall and at the same time a permanent cut off is provided.

The other method is to place a glass or mica plate under the buildings. This is not a good solution, however, in places affected by earthquakes as it gives an easy plane of cleavage.

Underpinning, however, becomes prohibitive in cost in the case of high buildings. Some means have, therefore, to be devised to impregnate the existing masonry at plinth level and he suggested that a cover be bolted on both sides of the wall, the joints well tamped and bitumen impregnated under pressure in situ.

On page 66 the authors had stated that the cost of treating buildings comes to Rs. 3-9-0 per sq. ft. of plinth area of the building. On the face of it this seems very high and it is matter for consideration whether it would not be possible to dismantle the building and rebuild it with the same material at lesser cost. Looking at the analysis of rates it seemed that Bitumen was the main item and it is therefore a matter for investigation whether a cheaper material could not replace bitumen. All that is needed is a water tight material and for that reason the possibilities of a suitable cheap material like coaltar should be considered.

Mr. **S. L. Kumar,** Assistant Bridge Engineer said that the authors of of this paper had done a great service to the profession by bringing the problem of efflorescence in buildings to the forefront and also by having found a cheap and effective method for curing the trouble. As is clear from their experiments a damp proof course of $1\frac{1}{2}''$ thick 1 : 2 : 4 concrete is by itself not quite adequate for preventing disintegration of the brick work above it. The North Western Railway specification for buildings provides, in addition, a thin layer of asphalt above the concrete layer. This if properly done should be impervious to upward flow of water.

A problem which the Railway has to face is much more difficult of treatment. There are hundreds of bridges on the North Western Railway where efflorescence is playing havoc with the brick-work and where the maintenance charges on replacement of disintegrated bricks and pointing are several times more than those on bridges not thus affected.

So far the following methods have been tried, but not with success so far.

1. Soap and Alum Wash.
2. Cement Wash.
3. Coaltar Wash.

4. Washing the surface of brick work with a dilute solution of hydrochloric acid. This only removes the surface furring and thereby disturbs the chemical equilibrium which usually inhibits progressive deterioration.

5. Replacement of disintegrated bricks and pointing. This is not a cure and costs a good deal in recurring expenditure. Some Engineers prefer this method as it follows the line of least resistance. Although it temporarily restores the looks it means a loss of a certain percentage of the effective section of the bridge which carries the load. It is clear that when bricks are taken out for replacement from a wall, the load on the structure is redistributed on the remaining section and nothing will ever restore the original load distribution.

6. Lately whitewashing of the surface has been tried. Under the influence of the atmospheric carbon dioxide it is supposed to form a film of calcium carbonate which has been thought to give protection against external attacks of magnesium and sodium sulphates in solution.

In the case of bridges, it may be pointed out, it is not only the salts in solution rising from the foundations that are to be tackled but the salts that are diffused in the boundary brick work in summer when successive floods from a catchment affected by efflorescence pass through the bridge. The water dries up from the exposed surface of the brick work a few days later leaving the salt in the interstices of the brick work. It is therefore not sufficient to provide a damp proof course of bitumen impregnated bricks. To existing bridges this method cannot be applied at a reasonable cost.

The abutments and piers are much thicker than the walls of buildings. By dismantling one course the bricks in the interior are not easily approached and proper replacement is not possible till two or three courses are dismantled. For this purpose expensive temporary arrangements are necessary as otherwise the superimposed heavy loads, accompanied by vibration, are likely to damage the masonry.

In view of the above difficulties the solution offered by the authors is not applicable to Railway bridges. It can however be utilized while rebuilding existing bridges or building new ones. Besides having one or two courses of bitumen impregnated bricks, the facing should also be of such bricks. The only possible objection to this course would be the unattractive look of the finished work but in the case of bridges in the wilderness utility is far more important than appearance.

The major problem of tackling the existing bridges affected by sulphate still baffles solution. The cause of disintegration of brick work by efflorescence as has been clearly explained in this paper has been long known to Engineers. It may be argued that if by some means the continuous upward flow of water containing salts in solution from the foundation by capillary action and its subsequent evaporation on the surface of brickwork thereby leaving salts in the interstices could be prevented the problem would have been solved. Similarly it is further necessary to prevent soakage of flood water into the brickwork. Again the application of the method that is evolved should require no temporary arrangements so that the work could be carried out under traffic. These considerations rule out all methods except the surface treatment of the brickwork exposed to the atmosphere. Therefore if the surface of the existing brickwork is covered with an impervious layer of some material then on the one hand, surface evaporation of water rising from the foundation would stop and on the other, salts in the flood water would not gain entry into the brickwork.

It was from these considerations that it was decided last year to gunite a 12-40 ft. girder bridge about 80 miles north of Karachi. This bridge is all in brick work in lime mortar except one pier which is in limestone masonry. The masonry was not affected by efflorescence as the stone was not porous but the brick work was in a bad state. No signs of kallar could be noticed on the surface of the ground in the neighbourhood. It was therefore the flood water from the catchment affected by efflorescence that was the cause of the trouble. After replacing the disintegrated bricks and raking out mortar joints to a depth of about $\frac{3}{4}''$, one inch thick gunite was applied to the wet surface of the brick work.

Gunite of suitable thickness has been found to be impervious to water. The expert British Committee investigating the effect of sea-water on structures have mentioned in their interim reports that a cover of 2″ good concrete gives adequate protection to reinforcement. It is well-known that the effect of sea-water on structures is exactly similar to that of alakaline soils, the sulphates of magnesium and sodium being mainly responsible for the disintegration. In the case of the bridge in question a thickness of one inch gunite was considered adequate as gunite is more dense and watertight that ordinary concrete of the same thickness and again conditions were not as severe as they are in marine structures.

A total area of about 17000 sq. ft. was gunited at a total cost of Rs. 3,000. Of this amount labour charges accounted for Rs. 1,000 and stores and their carriage charges accounted for the remainder. The cost per sq. ft. of gunite works out at 3 annas per sq. ft. Work was completed in May, 1938. It is yet too early to claim success for this method but the present condition of the work bears promise of service over many years to come.

It may not be out of place here to mention that the patents of the original process of guniting expired in 1937. Guniting can now be used by anybody without infringing any proprietary rights. Complete equipment can be purchased at a total cost of Rs. 5,000.

Even cement concrete structures or those built in brickwork with cement mortar are not immune from the attacks of alkaline soils or sea-water. The cause of their vulnerability lies in the formation of hydroxide of lime when the cement sets. This hydrate in the nascent state combines chemically with the sulphates of magnesium and sodium. The products of the double decomposition are leeched out by the sea or floods or rains leaving the residual mass porous. The progressive deterioration reduces the structure to a mere skeleton and to its ultimate doom. In the case of structures exposed to efflorescence, if the products of the double decomposition are not washed away, they crystallize as explained and thus cause disruption. The remedies to save concrete bridges partially if not entirely therefore are :—

1. By making concrete impervious to water by suitable grading of aggregates and by carefully controlling the quantity of water in the mixture. A richer cement Mix : does not answer the purpose so well as it is liable to surface cracking and also the greater cement content increases the hydrate of lime formed on setting.

2. By painting the surface with a paint which is a compound of roofing asphalt (having a metling point of not less than 150°F) and 10% of raw China wood oil. The compound is applied hot and may be applied with a spray gun. The film formed by this paint does not harden and become brittle but retains its elasticity.

3. By using Puzzolanic materials such as well burnt and finely ground surkhi in the mixture. These react with the hydrate of lime and form silicates which add to the binding strength.

In this connection it may be mentioned that earthquake existing buildings completed in cement brick work in the year 1936 and 1937 in Quetta Division have already begun to show signs of disintegration below the damp proof course due to efflorescence. To combat this trouble in the buildings under construction the cement mortar now used consists of 1 part of cement, 1 part of surkhi and 3 parts of sand. The results of this experiment will be awaited with interest.

Mr. **G. L. Bhandari** thanked the authors for their valuable paper which puts forth a very suitable remedy for preventing further damage to old buildings by efflorescence.

The average cost of an impregnated brick size 10″ ×5″ ×3″ may be taken as 3 annas (appendix 11) or Rs. 187 annas 8 per % 0 Nos. The cost per hundred cft. of the damp proof course in a new buildings will then work out as follows :—

		Rs.	a.	p.			Rs.	a.	p.
1150 Nos. bricks	@	187	8	0	%0	..	215	10	0
5 cwts. cement	@	3	0	0	Cwt.	..	15	0	0
18 cft. clean sand	@	2	0	0	%	..	0	6	0
Labour	@	9	0	0	%	..	9	0	0
		Total				..	240	0	0 % cft.

This works out to Rs. 60 % sft. for single layer of bitumen—impregnated bricks.

As compared with the above the rate per % sft. for a 3-inch thick damp proof course of cement concrete (1 : 2 : 4) sand and shingle will be as follows :—

					Rs.	a.	p.
22 cft. fine shingle	@	40 %	cft.	..	8	13	0
11 cft. sand	@	2 %	cft.	..	0	4	0
4·5 cwt. cement	@	3	cwt.	..	13	8	0
Labour	@	3 %	sft.	..	3	0	0
		Total		..	25	9	0

say 26 % sft.

It is obvious that a three inches thick damp proof course of cement concrete will cost even less than half that of bitumen impregnated bricks.

Will the authors please let him know whether for the same thickness the damp proof course of cement concrete will be just as efficient as that of bitumen bricks or not.

The point in bringing out the above analyisis is that it is unfair to compare a $1\frac{1}{2}$ inches thick damp-proof course of cement concrete with a 3 inches thick damp-proof course of bitumen bricks.

It is a matter of common knowledge that the salts travel up the face of the damp-proof course when the surface is moist. The resistance to this capillary attraction will be doubled if the thickness of the damp-proof course is increased to 3 inches. Anyhow this is a question which may be settled by getting another experimental wall built at Chuharkana with a 3 inches thick damp-proof course of cement concrete.

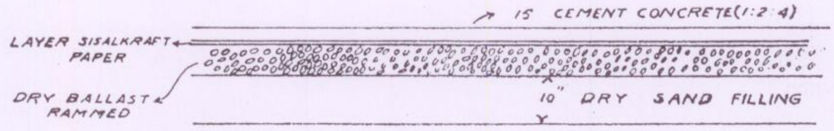
It may be added in this connection that for under-pinning old buildings the damp-proof course may consist of 3 inches thick pre-cast concrete blocks instead of concrete laid in situ. The cost may then be slightly higher say Rs. 30 per sft.

The authors have dealt only casually with the renovation of salt-affected floors. The plan of the building (Plate 11) shows no details of construction of the floors. A coat of bitumen under the cement concrete slabs is not likely to prove very satisfactory.

The floors in old rest houses consist of 3 inches of lime concrete over earth filling.

As the salts rise up, they press the concrete slab upwards and a hump is caused. This has been noticed in several rest houses on the Lower Bari Doab Canal. With the bulging of the floor, cracks appear in the concrete and the floor deteriorates.

Simple renovation of the floor by cement concrete slabs will not be a complete cure. Something should be done to guard against the upward thrust. One method of construction that has been tried with success may be indicated thus :—



The "Sisalkraft" paper is not meant to prevent the rise of damp.

The main idea underlying this type of construction is that the filling under the slab should be dry. Obviously the cement concrete laid over the dry material, will be spongy and weak. The "Sisalkraft" paper simply prevents the suction of moisture by the sub-grade from the concrete. The slab is also free to move as it does not stick to the subthe rise of moisture and the ballast filling not only forms a satisfactory bed for the concrete slab but is also elastic enough to prevent any upward thrust from damaging the overlying concrete slab.

Mr. Bhandari would be obliged if authors would kindly let him know what type of construction was adopted in Ludewala Rest House.

The **Authors** thanked the gentlemen who had evinced such interest in their work and had taken part in the discussion and also sent in written criticism. Unfortunately there was not time to reply to all on the platform and the authors have, therefore, furnished the following written reply :—

Mr. G. R. Sawhny's observations are very interesting. Salts never come in rain water. The amount of salt contained on surkhi cannot account for disintegration seen in buildings. More recent work in the Irrigation Research Institute has shown that in the alluvial soils of the Punjab there is a zone of accumulation salts in the soil crust some distance below the natural surface. The movement of this zone of accumulation of salts depends upon the irrigation and the climatic conditions. If the monsoon is poor or the irrigation scanty, then the zone of accumulation of salts has a tendency to move towards the surface. If the monsoon is good and irrigation normal then the zone of accumulation of salts remains stationary or has a tendency to move downwards. The attack on the building starts when the zone of accumulation of salts comes within such range from the natural surface that it is drawn up by capillary attraction or evaporation. Mr. Sawhny may have successfully dealt with the Halla Rest House but what about the buildings in towns which are two-storeyed or some times three or even four-storeyed?

Sardar Sujjan Singh's work in this direction is interesting and results will be awaited with interest. Further work by the authors is also in progress and an estimate for experimental lining of channels with the bitumen treated bricks has already been sanctioned.

With reference to Mr. S. N. Kapur's remarks, it is admitted that cement mortar is a weak point. In the original experiments carried out by the Irrigation Research Institute at Chuharkhana melted bitumen was used as a mortar. In the case of Ludewala Rest House both melted bitumen and cement have been used as mortars.

Time will show whether walls where cement mortar has been used show disintegration again.

Steel and glass plates do not afford an effective guard against salts.

It has been mentioned in the paper that the treatment of bricks was carried out in a tiny little plant built up for experimental work in the treated bricks is taken up on a commerical scale the cost would be reduced considerably. Further work is also in progress.

The authors have read with great interest the remarks made by Mr. S. L. Kumar. Although the problem of the attack of brick work in bridges by flood water containing salts has not been dealt with in the paper a new type of emulsion has been evolved by Mr. Uppal in the Irrigation Research Institute which if applied to brick work by means of a spraying machine renders the bricks waterproof. It is suggested that Mr. Kumar should give this new emulsion a trial on some of his bridges.

Mr. G. L. Bhandari while making out the cost of 3" cement concrete layer to be less than that of bitumen impregnated bricks does not take into consideration that laying slabs will require centrings and add considerably to the cost. Again it has been shown that cement concrete $1\frac{1}{2}$" thick is affected by salts to an appreciable extent. Double the thickness may take more time but is sure to be attacked. The method of treating floors suggested by the authors is only tentative and can be improved upon. Mr. Bhandari's observations of hump effect are true but if moisture and salts cannot go through the treated material no hump will occur.