THE USE OF MUD IN BUILDING CONSTRUCTION.

By D. MACFARLANE,
Executive Engineer.

The object of this paper is to invite attention to the possibilities of ordinary mud in building construction, primarily as a saving in cost over burnt bricks, stone or concrete, and econdarily as a means of rapid construction for temporary buildings.

The disadvantages of mud either in the shape of unburnt bricks, pise walling, plaster or roofing material are obviously the following :—

(1) Structural weakness,

(2) Rapid deterioration on exposure to weather,

(3) High cost of maintenance as the result of (2) above.

The author has conducted a certain number of experiments with a view to overcoming or minimising these disadvantages and the results are, it is hoped, not without interest.

The primary advantage in the use of mud is of course its cheapness. The problem of the construction of residential buildings with reasonable rents is one of increasing difficulty. Hitherto the rental of Government residences has been charged at 3½ % on the capital cost plus the annual cost of repairs which in the case of an officer's bungalow is normally fixed at between 2% to 2½% of the original capital cost. In the case of pre-war buildings, however, the present cost of repairs is far in excess of the above percentage with the result that rents are having to be raised to protect Government from loss ; whereas in the case of present day buildings the cost of construction is so enormous that the rents are becoming prohibitive. (As an instance of this may be quoted the recently constructed residence for the Deputy Commissioner of Sheikhupura, the rent of which is computed to be Rs. 183 per annum.) Further the rate of 3½% as interest on capital cost is of course far below the present value of money and it is understood that new rules are about to issue raising it to the current rate which will mean an increase of nearly 60%.

The rent problem is therefore about to become even more acute than it is at present, and in view of the "10% of salary" rule and the fact that Government is not prepared to construct residences at a loss, engineers will be faced with two alternatives only, *i.e.*, either (*a*) to reduce the accommodation below the normal requirements of the tenants concerned or (*b*) to effect drastic economies in the quality of material and workmanship.

The almost insuperable difficulty of obtaining coal, coupled with the high cost of labour, has caused and is continuing to cause an abnormal rise in the price of burnt bricks, and one of the obvious channels through which economy can be effected is the substitution of unburnt for burnt bricks if a satisfactory job can be made thereby. On the assumption that this can be done and that it is possible to substitute mud bricks throughout the whole of a building, with the exception of the foundations, string courses, sills and copings, the author has taken a certain number of residential buildings in the Rawalpindi and Lahore Divisions and deduced the percentage reduction in capital cost which would have been incurred had this substitution of unburnt for burnt bricks been made.

The reduction, though considerable, is not as great as was expected and is as follows :—

Residences and rest-houses .. 19¼ per cent.

Out-houses and barracks .. 16 ,,

In each case of course the cost of the building only is taken and not that of the site.

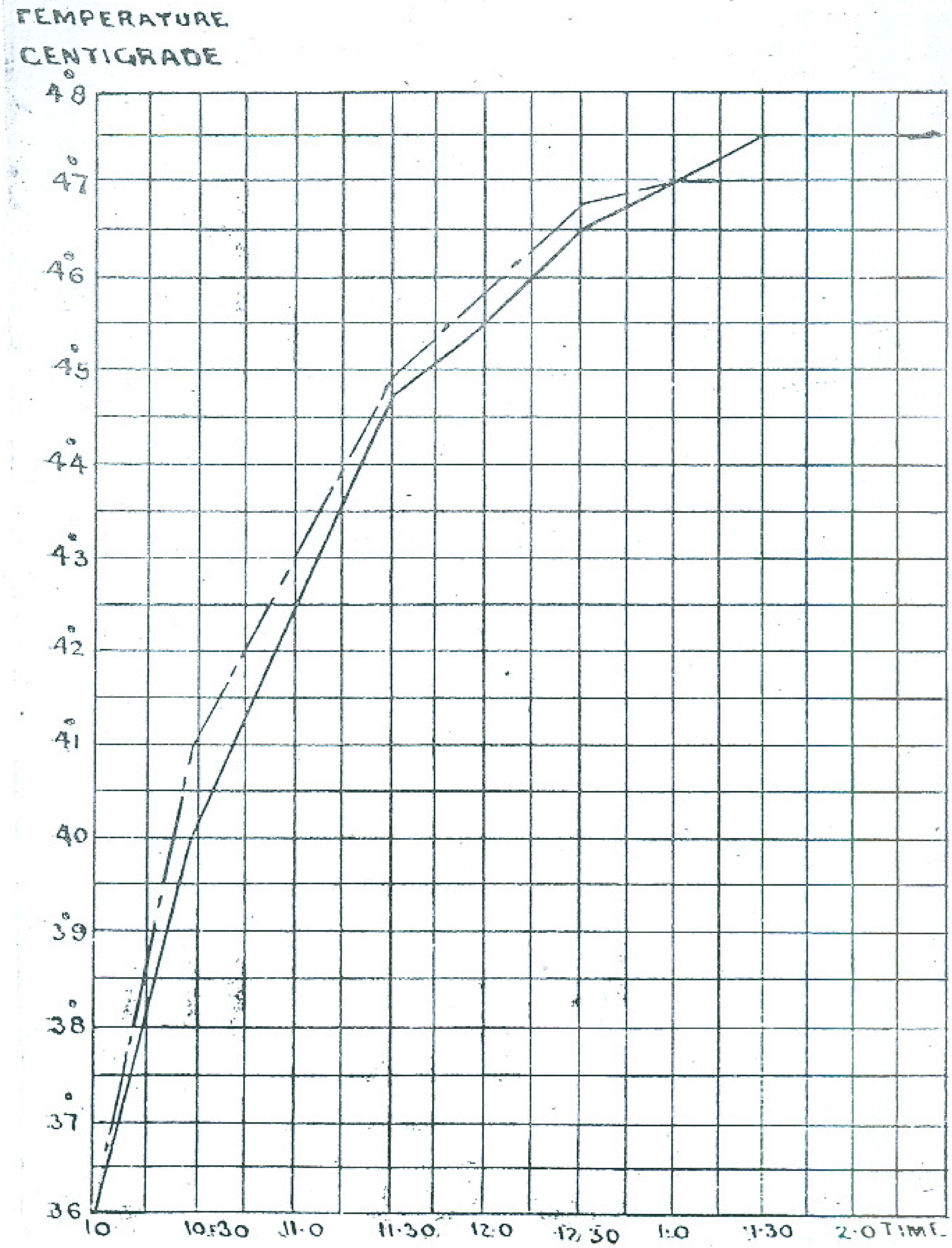
Comparison of temperature between burnt brick and mud brick buildings.

Before proceeding to discuss the extent to which mud bricks can be substituted for burnt ones, the author will deal with the relative heat resisting powers of the two classes of wall. The general theory amongst laymen, as well as engineers, is that the good old fashioned mud bungalow is far cooler than the more modern burnt brick one and the author has endeavoured to investigate this theory and to determine, if true, to what extent it is due firstly to the greater thickness of the mud walls and secondly to the lesser heat conductivity of the material.

To determine this the author sent some burnt and unburnt bricks to Colonel Black, the Chemical Examiner, Lahore, who very kindly conducted some most interesting tests.

The bricks were subjected to two experiments, A and B, the results of which are plotted on diagrams. In experiment A the source of heat was kept at a constant temperature of 94°C. Thermometers were sunk deeply into the substance of the bricks about 1 inch from the end remote from the source of heat and temperature readings were taken at half-hour intervals. It will be seen that up to 1 o'clock the mud brick gave slightly lower readings than the burnt one showing that its conductivity is slightly less. At 1-30 the temperature of the mud brick had risen above that of the burnt one and continued to remain so till the end of the

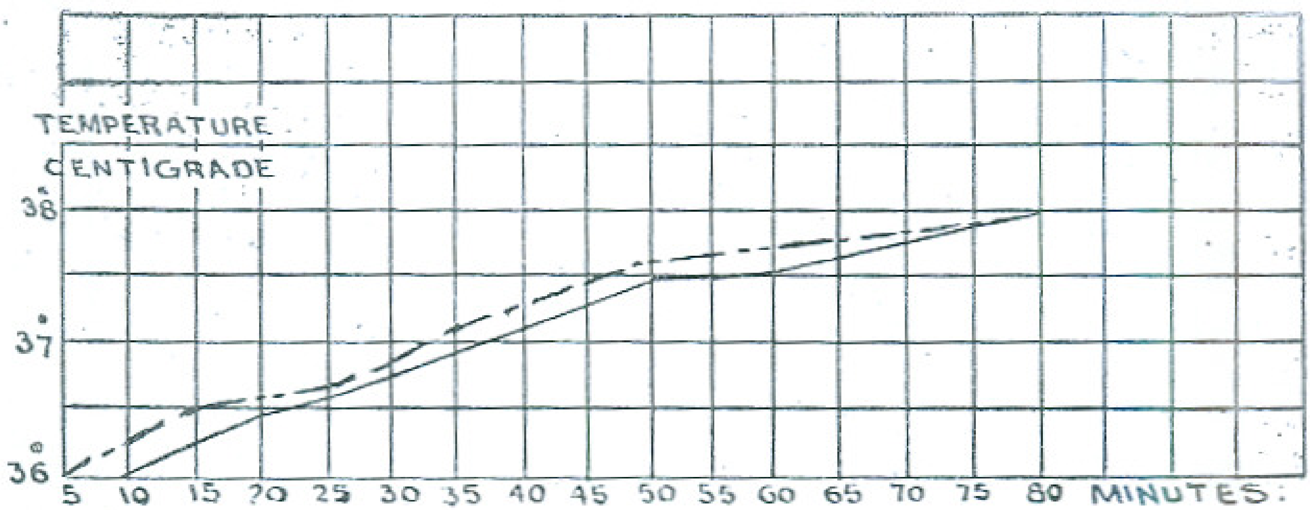
TEST "A" FOR RELATIVE CONDUCTIVITY OF MUD & BURNT BRICKS.



MUD BRICK SHOWN. ————

TEST "B" FOR RELATIVE CONDUCTIVITY

OF MUD & BURNT BRICKS



MUD BRICK SHOWN ————

BURNT BRICK ,, —— - ——

experiment. This is attributable to the greater loss by radiation from the latter which in fact showed no rise between 1 to 1-30, so that the loss by radiation must have been exactly equal to the gain by conduction. In experiment B the source of heat was raised to 90°C and then cut off so that it slowly cooled down during the experiment. Readings were taken at 5 minute intervals and later at 15 minute intervals as shown. Results very similar to those of experiment A were obtained, the burnt brick showing slightly higher conductivity and greater loss by radiation so that after 80 minutes the two readings were identical. The specific heat of each brick was then taken and it was found that there was very little difference between them, the mud brick being 0·170 and the burnt one 0·166. Apparently therefore burnt bricks are slightly better heat conductors than mud ones and require rather less heat to raise their temperature, at the same time cooling down rather more quickly. There is, however, very little to choose between them and the author is forced to the conclusion that the comparative coolness of old fashioned mud bungalows is due mainly to the enormous thickness of their walls.

Strength of mud walls.

The author will next investigate the question of the strength of mud walls and the necessity, apart from coolness, of adopting thickness greater than that of ordinary burnt brick masonry. The two determining factors are of course tensile and compressive strength. The attention of the author was first drawn to the considerable tenacity of mud mortar some years ago when he was constructing a rest-house at Gharinda in the Amritsar District. He there found that the mud when tested in a cement testing machine broke at a load of 85 lbs. per square inch which is considerably greater than the results generally obtained from Kankar lime.

For the purpose of this paper 3 tensile tests were made of mud from the Chenab Bridge brick fields at Kathala, the results being 100, 125 and 140 lbs. per square inch, respectively, the tests being made a couple of days after moulding. The mud concerned has not been chemically analysed but as far as could be seen was a typical example of the average brick field earth of the Punjab plains and consisted of clay with about 7% of sand.

As regards compressive strength, the author next constructed with ordinary unburnt bricks (10″ × 5″ × 3″) a jack arch 5 feet long with a span of 4 feet and a 6″ rise. This arch was uniformly loaded with pig iron. At 7 tons it started to crack at the haunches and these cracks sheared through at 9 tons. Taking the breaking load at 7 tons, this works out to a load of 784 lbs. per square foot, or nearly 8 times the amount ordinarily allowed as the safe load for burnt brick in lime jack arches. Further with the 7 tons load the compression at the centre of the arch works out at 2·37 tons per square foot and the shear breaking stress at the haunches at 5·9 tons per square foot.

The author had some years previously tested a mud brick arch of similar dimensions at Sheiba. In that case the arch showed no signs of failure under a load of 7 tons and further loading was stopped. The arch was then surrounded by a clay pushta and covered with a layer of 1" of water and loaded with one bar of pig-iron only, as the result of which it collapsed completely after ½ hour. The composition of the mud in this case was somewhat different to the Kathala mud, having a very high percentage of sand (about 40%). As the result of this experiment a large number of quarters were constructed at Sheiba entirely of mud with mud brick jack arch roofs, the haunches only being made of burnt bricks in lime, the whole roof being covered with a 6" layer of mud coated with one layer of bitumen. The walls were plastered externally and internally with gypsum which is readily obtainable there. These buildings have proved entirely satisfactory. They were exceptionally cool in the hot weather and suffered no damage during the rains.

The ordinary specification laid down by the Ministry of Health in England for pise walls is 18" thick for the bottom storey walls and 14" thick for the upper storey.

From the above it would appear therefore that as far as tensile and compressive strength is concerned mud bricks and mortar are quite capable of withstanding the strains to which burnt bricks and lime are normally subjected and there is no reason why they should not be used in ordinary structures provided that they can be completely protected from damp.

As an instance, however, of the extreme importance of protection from damp might be cited the case of the S. D. O.'s temporary bungalow at the Ravi Bridge. This bungalow was constructed entirely of sun-dried bricks and the contractor, having run short of dry bricks, constructed the last few courses with bricks which had not been properly dried. The roof girders were then erected on wall plates and a few hours afterwards—aided by the vibration caused by a passing train—one of the girders ploughed its way through the bricks at one end and collapsed on to the floor below.

Protection against weather.

This is of course the most important factor of all and one on which the adoption of mud construction for permanent buildings entirely depends.

Unfortunately experiments in this direction are rather difficult to conduct. In the first place, the action of rain on various samples can be gauged by artificial means, but these may or may not approximate to the real action of rain and cannot attempt to include the action of wind, sun, changes in temperature, frost, etc. In the second place, in the case of experiments made on actual buildings, a considerable time has to elapse, depending on the weather, from which any satisfactory conclusions can be drawn.

One method for the protection of outer walls which has been employed to some extent in the Punjab is the use of Kutcha Pacca masonry, *i. e.*, the outer bricks being burnt and the remainder unburnt. This, however, is not satisfactory for the reason that the burnt bricks are smaller on account of shrinkage and the settlement is usually found to be uneven, so causing internal cracks in the walls.

In recent years, owing to house shortage and high prices in England, pise walling has come very much to the fore and the author has been in correspondence with engineers in the Ministry of Health on the subject. The following is an extract from their pamphlet of December 20th, 1920, dealing with the protection of pise walls against the action of rain :—

> "Protection against rain may be afforded either through the whole thickness by using a waterproofing liquid, such as silicate of soda, or on the external surface by a waterproof coat such as creosote oil, lime wash made with boiling water, or a solution of bitumen resin, or paraffin wax, in light oils. All such coats are better spread than brushed on. Roughcast may be used, but it is apt to crack and fall away; in any case, the lime or cement would probably be doing more good in the wall itself.
>
> "There should be efficient damp-courses not only at the base of the wall, but on the top of it, and under all window sills. The great enemy of mud walls is water: once let into a wall it will certainly bring it down".

An extract from "Building News" of 11th February 1921 on the same subject reads as follows :—

> "External plaster—In addition to bituminous coatings the following external finishings have been tried :—
>
> A. Sand and ground lime 1 : 1 Brushed on
>
> B. Sand and chalk lime 1 : 1 do.
>
> C. Sand and cement 1 : 1 do.
>
> "The last named is quite satisfactory, but the colour is not attractive and needs a wash accordingly".

The following is a description of the Silvester Process taken from the American Civil Engineer's Pocket Book :—

> "In the Silvester Process alternate washes of alum and soap are applied to the dry surface, the soap solution being hot. Each is allowed to dry before the next coat is applied. By applying several coats very good results may be obtained. The alum solution consists of 1 lb. alum per gallon of water. The soap solution consists of 2·2 lb. soap per gallon of water".

Treatment of roofs.

Before enumerating the tests which the author has made with various materials he will describe experiments which have been made recently in the protection of roofs.

1. In the Spring of 1921 an old roof at Fattehjang was divided into 4 areas and covered with mud plaster mixed with water and various proportions of Khour oil. In the absence of rain, water was poured on to the various areas and it was found that, whereas they all leaked, the area containing the largest amount of oil, *i. e.*, equal parts of oil and water, leaked the most. The roof was inspected again after the heavy rain of August 1921 and was found to be leaking badly everywhere.

2. One of the roofs of the new school buildings at Campbellpur was treated prior to the last monsoon with Gobri plaster mixed with water and various proportions of Khour oil, but the roofs being new no leakage occurred during the rains, even in the case of the one in which no oil was used—so that no conclusions can be drawn from this experiment.

3. An old roof at Campbellpur—that of the petition-writer's shed—was treated with various proportions of oily plaster before the last monsoon. The extra earth was removed from the roof leaving only 3″ thickness of earth over it. The roof was then divided into two equal parts; part A was treated with mud plaster containing Khour oil and the other part, BC, with ordinary mud plaster. The area A was Gobri leeped using Khour oil, whereas the area BC was sub-divided into two equal parts, the area B being treated with oily Gobri and C with ordinary Gobri. In each case the proportion of oil to water was 1 to 2. None of these 3 surfaces leaked during the monsoon so that, as with the case of the school buildings, no conclusions can be drawn.

4. The following experiments were made by the Executive Engineer, 2nd Lahore Provincial Division, on the roof of the new Council Chamber. The roof was treated in three ways :—

(1) With Khour oil painted on,

(2) With ordinary crude oil obtained from the bazar,

(3) With coal tar.

Nos. (1) and (2) were washed out during the rains and it was clear that, though beneficial, they would require a fresh coat every year. No. (2) lasted longer than No. (1). No. (3) was entirely satisfactory, having rendered the roof completely waterproof and having prevented the mud surface beneath from being washed away.

The roof surface had in each case been previously covered with the ordinary Gobri plaster.

In the case of No. (3), the tar was heated to about 280° Fahr., and applied with squeegees made from old motor tyres, one coat only being applied sufficiently thick to leave a thin film on top after soaking well into the mud.

Experiments with specially prepared samples.

The author has conducted a series of experiments on the waterproofing effect of various preparations. These experiments may be divided into two groups :—

(A) Those in which the pre-paration were used as a wash only on the surface of ordinary sundried mud briquettes.

(B) Those in which the mud briquettes were themselves mixed with the preparations concerned.

The tests consisted of allowing continuous drops of water to play on the samples from a fixed height at a fixed rate. The apparatus used consisted of a reservoir containing 4 gallons of water with a carefully regulated nozzle of 1-32″ diameter. The height of the drop was $4\frac{1}{2}'$ and the rate of dropping was regulated by means of a tap to 300 drops per minute. In each case the samples were 3″ square.

In the case of (A), they were 1″ thick, and the time taken to penetrate the wash to the ordinary mud below was carefully noted.

In the case of (B), they were $\frac{1}{4}''$ thick, a note being made of the time taken to penetrate through the entire thickness of the slab.

The results are tab ulated below :—

STATEMENT A (Surface washed with preparation).

	Preparation.	Time of penetration.			Remarks.
		H.	M.	S.	
1	1 coat of whitewash ..	0	0	15	
2	2 coats of whitewash ..	0	0	20	
3.	3 coats of whitewash ..	0	4	58	Sample cracked at sides at once through swelling of damp mud beneath.
4	1 coat of Silvester's Process 1 coat whitewash.	0	0	42	
5	1 coat of Silvester's Process 2 coats whitewash.	0	15	30	Failed through undermining. Surface intact at time of collapse.
6	1 coat of Silvester's Process 3 coats whitewash.	0	41	15	
7	2 alternating coats of Silvester's Process and then 1 coat of whitewash.	0	5	8	
8	2 alternating coats of Silvester's Process and then 2 coats of whitewash.	0	13	2	
9	2 alternating coats of Silvester's Process and then 3 coats of whitewash.	0	18	30	
10	1 coat of cement (1 cement 1 sand).	0	4	35	
11	1 coat of cement (1 cement 2 sand).	0	5	34	
12	2 coats of silicate solution (1 pt. silicate 5 pts. water).	4	10	0	*Failed through undermining. Surface slightly pitted at time of collapse.
13	2 coats of silicate solution (1 pt. silicate 5 pts. water).	5	20	0	*Failed through undermining. Surface intact at time of collapse.
14	1 coat of neat silicate.	1	5	0	*Ditto.
15	1 coat of tar.	5	0	0	No effect. Experiment stopped.

**i. e.*, the water pouring off the intact surface gradually moistened the mud beneath till it fell away, leaving the thin prepared surface only above.

EXPERIMENT B (Mud slab mixed with preparation).

Preparation.	Time of penetration.			Remarks.
	H.	M.	S.	
Plain Gobri plaster	0	41	30	
Mud mixed with Silvester's mixture.	0	30	5	
Mud mixed in with Khaur oil and water in equal parts.	0	16	40	
Mud mixed with 1 pt. of silicate to 5 pts. of water ..	14	0	0	Slab intact. Experiment stopped.

From the above it will be seen that, with the exception of the tar coat which, in the case of walls, would be expensive and difficult to apply, the silicate of soda unquestionably stands out beyond all the other preparations used as a waterproofing material, even the single wash of one part of silicate to 5 parts of water producing the most surprising results.

As a further experiment an old wall surface was treated with one coat of this mixture and a 1-32" jet of water was allowed to play on it horizontally at a distance of 1 foot. After 5 hours it had not produced the sightest impression and the experiment was stopped.

Cost of Silicate of Soda.

Silicate of soda is a sticky treacly substance readily soluble in water (a fact which renders its impervious qualities all the more surprising!). It is obtainable from Messrs D. Waldie & Co., Ltd., Konnagar, Bengal, at Rs. 33 per cwt. (a price which they hope to reduce shortly).

One pint of solution in the proportion of 1 part of silicate to 5 parts of water was found to cover 18 sq. feet.

$\frac{1}{2}$ pint of neat silicate weighs $\frac{3}{4}$ lb.

∴ 1 gallon ,, ,, ,, 12 lbs.

∴ 1 cwt. ,, ,, occupies $\frac{112}{12}=9{\cdot}3$ gallons

Allowing Rs. 3 per cwt. for carriage, or Rs. 36 per cwt. in all, the cost of 1 gallon of silicate works out at Rs. 3-14; silicate 1/6 pint (mixed with 5/6 parts of water) covers 18 sq. feet.

∴ 1 gallon covers 864 sq. feet at a cost of Rs.	3	14	0
∴ cost per 100 sq. feet amounts to ..	0	7	3
allow for labour ..	0	0	9
Total cost per 100 sq. feet ..	0	8	0

A cost which compares very favourably with ordinary whitewash. If we assume from the foregoing

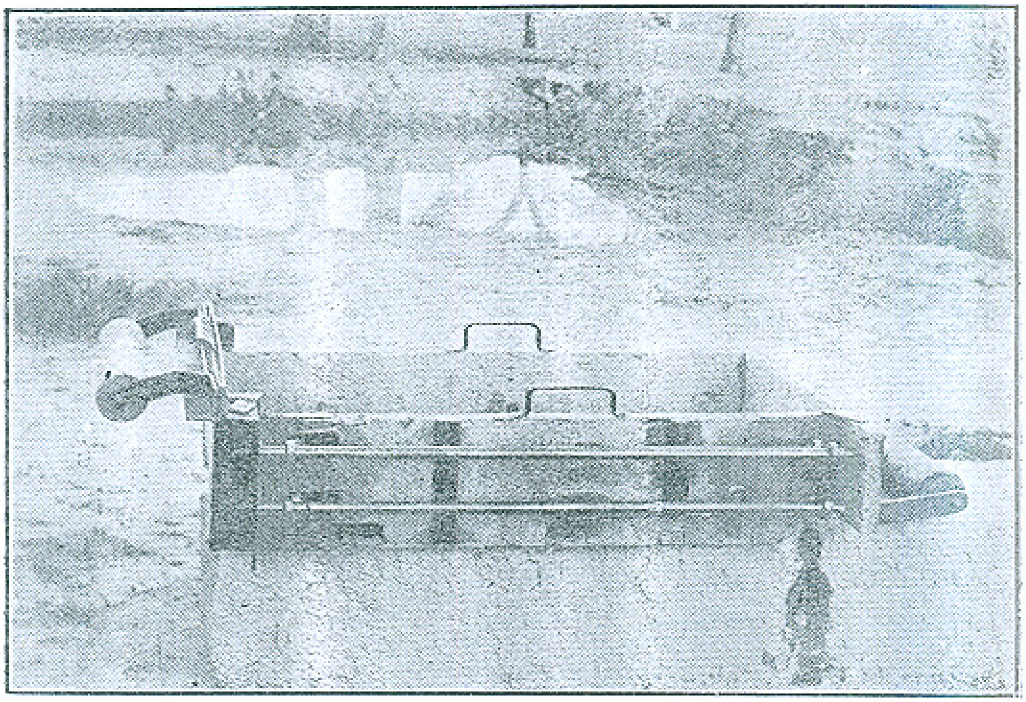
Rapidity of construction.

(1) that the substitution of mud for burnt bricks in house construction is a feasible proposition and (2) that it is possible to protect buildings so constructed from the action of rain, the problem that next presents itself is whether it is not possible even to eliminate the sun-dried brick and save both time and cost by constructing pise walling *in situ*. As already mentioned, this form of construction has come very much to the fore of late in England and interesting articles appeared on the subject in "Country Life", "Building News" and "Indian Engineering". In all cases, however, fixed shuttering has been used and the author knows of no case where a travelling mould has been adopted.

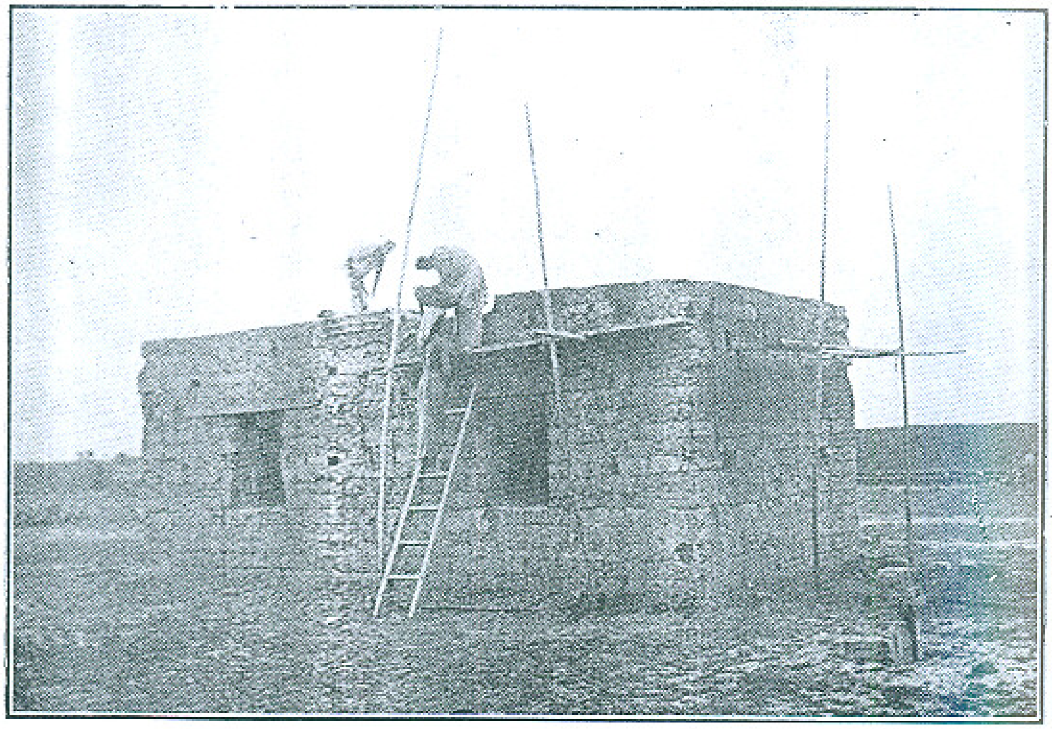
When on leave in 1920 the author saw a practical demonstration of the use of a patent travelling mould for constructing hollow cement concrete walls given by "Concrete Dwellings, Limited" in London (the agents for this machine in India are the Empire Engineering Company, Cawnpore). The author was very struck with the simplicity and rapidity of the working of this machine, which is now largely in use in England, and it occurred to him that a similar principle might be adopted for the construction of mud walls *in situ*. An illustration of the machine is given, taken from a pamphlet issued by the Ministry of Health entitled "Particulars of Systems of House Construction approved up to April 1920".

The machine in question consists of a 3-sided mould with an internal core. The sides and the core are actuated by a cam action, which on raising a lever causes the former to expand and the latter to contract, so freeing the mould after filling to roll along to its next position. For mud walls, however, no core is feasible or necessary and the author has therefore devised a mould which, while capable of travelling, is actuated by a very much simpler mechanism—one of the side walls being hinged so as to come away, when lifted, 2″ sideways, the whole mould being then freed to roll by giving it a slight tap in the opposite direction. The mould is designed to construct walls 18″ thick, in layers 3′ long and 6″ deep. It was found from repeated experiments that layers thicker than 6″ are apt to bulge slightly under their own weight when the mould is removed and that a mould longer than 3 feet cannot be handled conveniently. The sides of the mould are carried down 2″ below the construction level on each side as a means of keeping it in the correct position on the layer below and as a preventive to bulging. Simple minor appliances have been introduced to facilitate the construction of corner and party walls.

As regards the consistency and quality of earth to be used for pise walling, the problem in the Punjab is by no means on all fours



VIEW OF TRAVELLING MOULD.



VIEW OF HUT CONSTRUCTED WITH TRAVELLING MOULD BY 1 MASON 4 COOLIES IN 11 DAYS.

with that in England. In the latter country the residual moisture in the soil is generally sufficient without the further admixture of water, the problem being the quality of the soil rather than its humidity. In the plains of this province the quality of brick earth is practically uniform and is admirably suited to pise walling. The question of humidity, however, is one of some difficulty. In the dry weather there is absolutely no residual dampness in the earth as there is in England and the right consistency has to be produced by artificial means. Clay which is overdamp will crack badly when drying and will moreover bulge when the mould is removed and will be incapable of bearing any weight when the new layer is superimposed. The whole idea of rapidity of construction is of course defeated if it is not possible to work the mould continuously. The author has found that in the dry weather the best consistency is obtained by covering the ground to be used, the previous evening, with a layer of water about 9″ deep, when it is found next morning that the clay below is suitable to be worked to a depth of about 3. After rain of course it is usually possible to find the right consistency at depths below the surface varying with the intensity of the rain.

Cost of Travelling Mould.

The author conducted his experiments with the mould as regards cost of working mostly during the rains, *i. e.*, when no artificial addition of water was found necessary. After frequent alterations in various minor details in the machine a house was constructed consisting of 2 rooms, $10\frac{1}{2}' \times 10\frac{1}{2}'$ internal dimensions, with one door and one window, each $6' \times 3'$ and $3' \times 2\frac{1}{2}'$, respectively. The walls were 18″ thick and the height of the building 9′. Wooden lintels were provided for the doors and windows, and wooden cleats for the subsequent fixing of door and window frames. It was found that the whole process of digging, pugging, carrying and moulding could be carried out by 4 coolies with the assistance and superintendence of one mason mistri, 1 of the 4 coolies being employed in pugging with his feet, a process which was found better and quicker than hand ramming.

The building, excluding the roof, doors and windows, took 11 days to construct; the rate of drying of each layer, however, was such that two moulds could have been used, reducing the time to $5\frac{1}{2}$ days. The time taken to complete one mould and move it to the next position was approximately 10 minutes.

Total volume of masonry constructed .. 1024 c.ft.

		Rs.	a.	p.
Cost per day 4 coolies at 0-11-0	..	2	12	0
„ 1 mistri at 2-4-0	..	2	4	0
		5	0	0
Total cost for 11 days	..	55	0	0

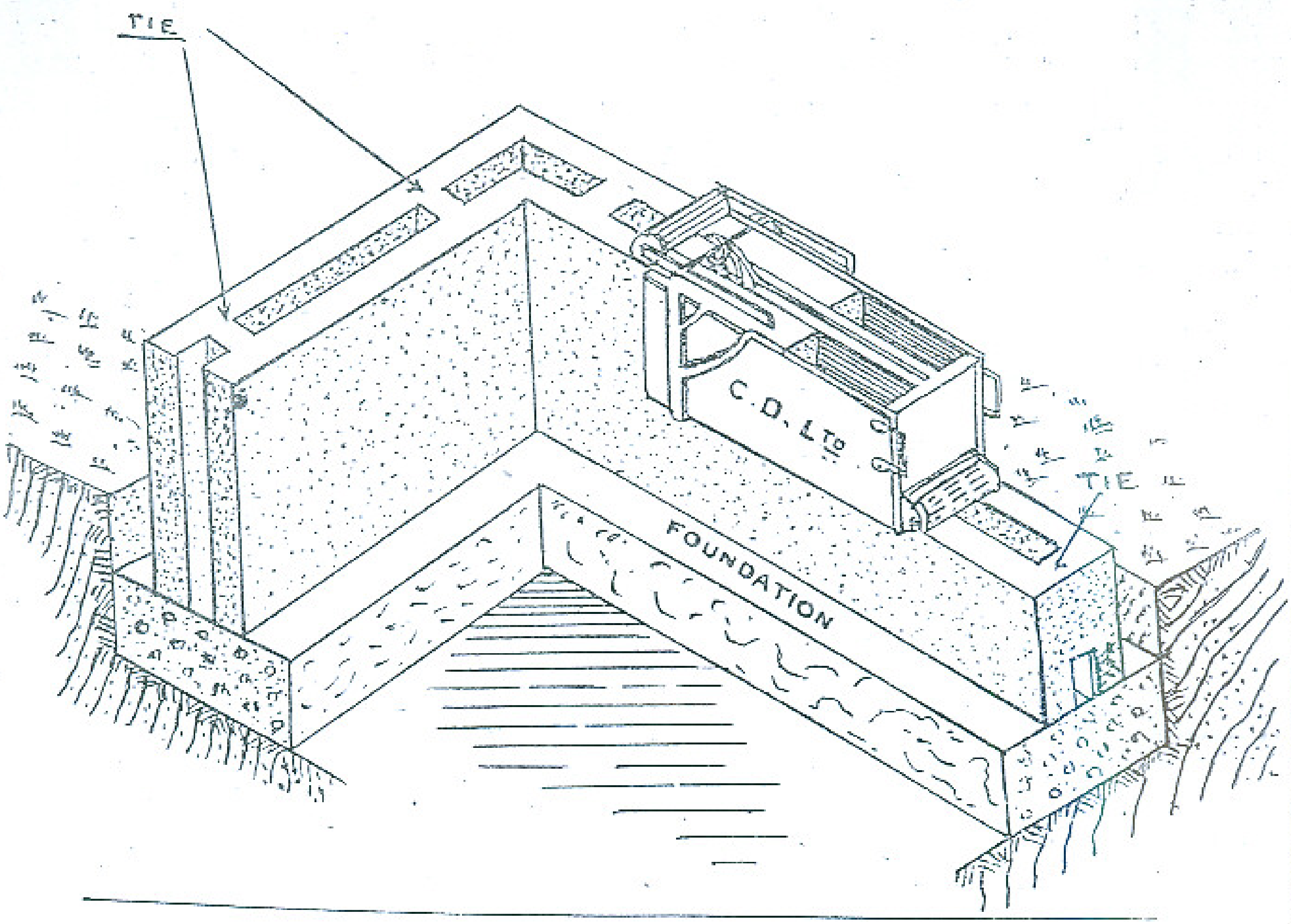
$$\text{Cost per 100 c. ft.}\ \frac{55 \times 100}{1024} = 5{\cdot}47, \text{ or say}$$

5-8-0 per 100 c. ft.

against Rs. 10 % c. ft. for sundried bricks in mud
and Rs. 40 ,, burnt ,,

As regards the rate of working, the task of burnt bricks in lime laid down in the Military Works Handbook for one mason is 15 c. ft. per day. Assuming the rate for sun-dried bricks in mud to be the same as for burnt bricks in lime, and the staff of coolies per mason to be the same as for the mud mould (although actually much more), this means that a mason working the mould can turn out $\frac{1\ 24}{11}$ 93 c. ft. per day against 15 c. ft. of ordinary sun-dried bricks in mud. In other words, the machine is roughly capable of turning out mud masonry at half the cost, and six times the speed, of ordinary sun-dried brick-in-mud masonry. The author admits that for the construction of permanent and complicated buildings the machine has its drawbacks, but suggests that, for plain, straight-forward and urgent works such as barracks, coolies, huts, etc., the machine would be of great assistance. Illustrations of the machine and the building constructed with it are given at the end of the paper.

The author would like to conclude by expressing his thanks to Mr. H. A. Harris for his valuable assistance in conducting his experiments.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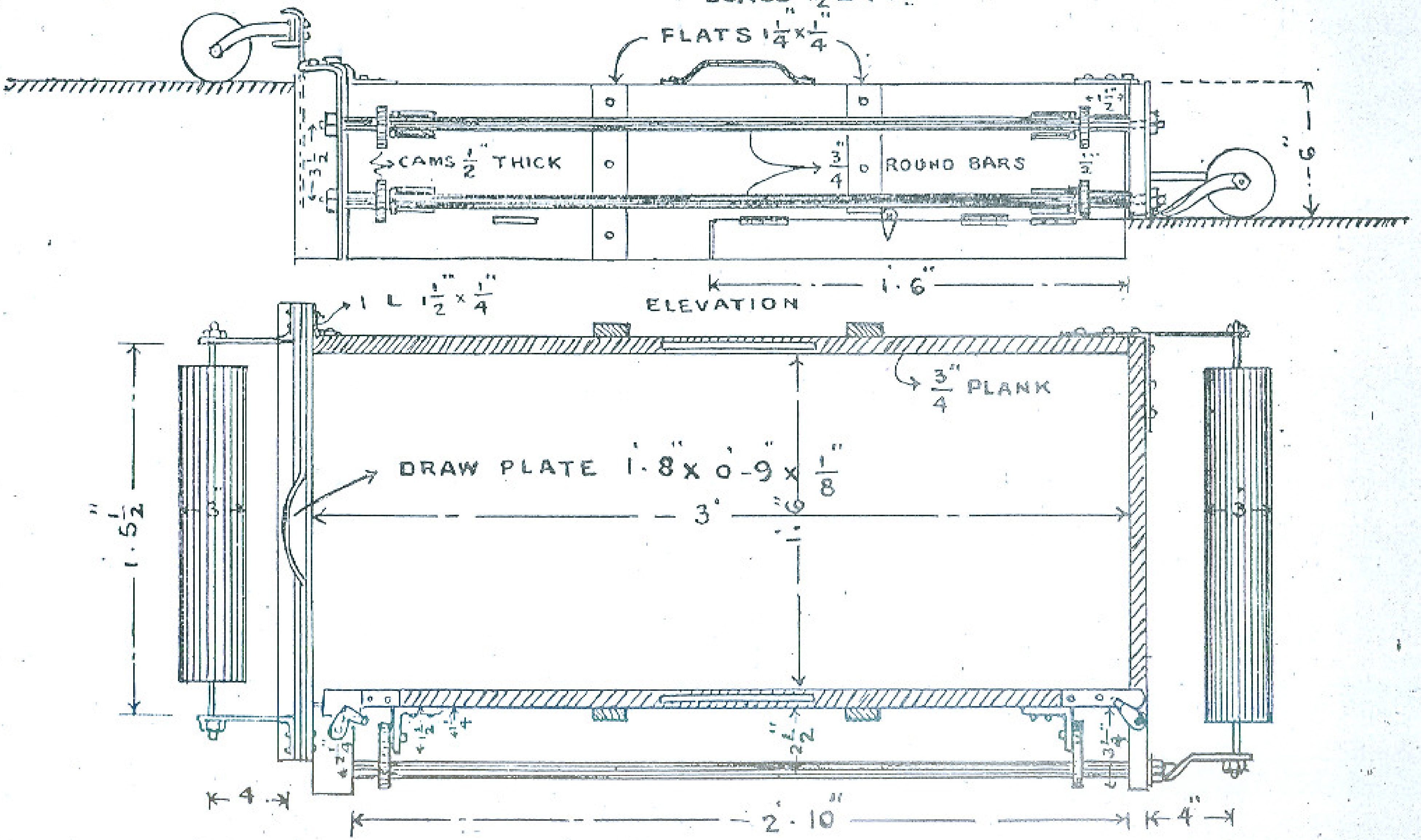
TRAVELLING MOULD FOR PISE WORK

SCALE 1½" = 1 FT.



DISCUSSION.

Mr. Macfarlane in submitting this paper to the members of the Engineering Congress said that he had no doubt that he would be subjected to considerable criticism in advocating what, to a great extent, would appear to be a policy of "jerry building." Very briefly what he had endeavoured to point out was the following :—Firstly that to construct buildings entirely of mud was a workable proposition. Secondly that such buildings when constructed could be rendered extremely water proof by the application of silicate of soda. Thirdly that the cost of their construction could be very greatly reduced by the use of the travelling mould, the working of which he hoped to demonstrate on Saturday morning to those who were interested. The first criticism which he would naturally expect concerned the question of white ants and saltpetre. He had intended to extend his experiments to this subject and try and discover some cheap solution which when mixed with the mud would effectively exterminate white ants but he had unfortunately been unable to do this for want of time. It was possible of course that the silicate itself had some beneficial effect in this direction but this he was at present unable to say. At the present stage all he could advocate was a careful selection of the earth used which should be free from both white ants and saltpetre. He would also point out that this criticism could also be levelled at their present policy of construction with burnt bricks in mud mortar although of course the presence of white ants in the latter would not be as great when it occurred in the mortar only instead of in the whole wall. Next came the question of architecture and the difficulty of introducing any form of ornamental work in buildings constructed with the mould. Here however he would draw attention to the last paragraph but one of his paper in which he admitted that the mould was primarily for rapid construction of coolie huts, barrack etc., where no ornamentation was wanted, although he had no doubt that further developments of the machine would make it more adaptable for the construction of more important structures. Since writing the paper he had completed the experimental hut at Kathala and coated both the walls and roof with silicate solution with the result that it had stood the action of the weather for the last six months without any signs of wear whatsoever. He had also tested the effect of the silicate on ordinary clayey soil from the United Provinces (Lucknow). Two slabs each ½" thick were tested, one being mixed in the ordinary way with water the other being mixed up with a solution consisting of 5 parts by volumes of water to 1 of silicate. Each was subjected to continuous drops of water at the rate of about 160 drops per minute from a height of 4'. The former shewed signs of pitting after two minutes and was completely pierced in ten minutes. The latter withstood the test intact for 22 hours after which the sides began to laminate, caused, possibly, through the swelling of salts in the clay from damp. He had also conducted some experiments on the tensile strength of silicate-treated mud briquettes and found that they broke at 70 lbs. per square inch against an average of 115 lbs. in the case of ordinary briquettes made at the same time.

To revert to the question of the travelling mould he had introduced several small improvements in the machine illustrated in the paper which he would explain on Saturday morning. He might draw attention to one point however, that for the purposes of breaking joint it was simpler to lay one course clockwise and the next anti-clockwise.

Assuming, therefore, that the scaffolding was on one side of the wall only, and as, for easy working, the open side of the mould should be on that side, it was advisible to have a second reverse-constructed mould for the anti-clockwise course which could be working at the same time on another part of the wall.

Mr. Sullivan, remarked that Mr. Macfarlane, somewhat cautiously, had given no definite conclusions in his paper as the result of his experiments with *pise*. He himself had carefully read Mr. Macfarlane's interesting paper and would risk giving his own conclusions. He thought there was no question that *pise* was cheaper than brickwork but, from his own calculations, he doubted if it was as much so as Mr. Macfarlane had stated, though accurate comparisons were difficult until checked by practice. The structural stability of *pise* entirely depended upon absolute protection from water but, in spite of strenuous efforts, such as those made by the Department of Industrial and Scientific Research in England, no satisfactory method of water-proofing had been arrived at whereby one could be reasonably certain that, once built, such a structure would be safe from the catastrophic effects of ordinary rain, much less from the tropical downpours experienced in the Punjab. One leak through a roof on to the top of such a wall, where protection had been omitted or had disappeared, might bring the girders down in half an hour. He asked the members to consider the responsibility weighing upon the designer's mind whenever a cloud appeared on the horizon or a drop of rain fell and to ponder the awful thought that one's Chief Engineer might be peacefully sleeping in such a house at one moment and cut in halves by a girder the next. He stated that the impossibility of protecting *pise* from water, and other difficulties, had caused the practical abandonment of its use in England, where samples of its failure were numerous. The attempts at its use there had the same origin as had caused Mr. Macfarlane to write his paper—scarcity of houses, high cost of brick construction and lack of skilled-labour.

One needed only to read the various Government pamphlets on the subject to realize that the style of construction was not put forward as one for permanent adoption but to tide over a temporary period of scarcity when any experiment was worth trying. It was greatly advertised at the time but wholesale failures turned opinion against its use and it was now as dead as the Sandringham hat. Sir Lawrence Weaver, Director-General of the Land Department, Ministry of Agriculture and Fisheries had reported as follows :—

"We built cottages to every sort of plan and in every sort of material, five of them to the specifications of building experts of the Department of Industrial and Scientific Research. These are our conclusions. Traditional cob gives an admirable house but is hopelessly expensive. *Pise* with the chalk soil of Amesbury is about the same price as brick. Timber houses we found no cheaper than brick. Various patent methods of concrete block building wrought no deliverance. The greatest novelty devised by the Research Department was a concrete of chalk and cement 20 to 1, mixed quite dry and rammed between shuttering, which proved satisfactory but no better than brick. Brick indeed held its own admirably".

He thought it might be of interest to point out that the first bungalows for the Irrigation Department at Rasul were built of unburnt bricks, as a temporary measure, but were afterwards retained for permanent use. However the resulting settlements and collapses after the monsoon were so extensive that the cost of annual repairs caused the Accountant-General to raise serious objections and a scheme was consequently considered for entirely rebuilding them.

When he considered the building disadvantages of the Punjab, monsoon, white ants, unskilled labour, lack of chalk soil, large heights and spans of rooms and when he remembered the very faint praise meted out to *pise* by the Ministry of Agriculture and Fisheries in England where it had been used under much more favourable conditions than obtained here, he was forced to the conclusion that neither in cost nor in efficiency could it form a substitute for brick in the construction of residences. He, probably, as an architect, had the reputation of desiring to throw away money on mere beauty, or, at any rate, at attempts at it. Whether this were true or not he thought that houses were usually occupied by tenants of sufficient education to desire and expect their houses, while not being elaborate, to be built somewhat better than a coolie's hut or a lime godown and to have more than a mere chance of standing up during the monsoon. Having said this he thought perhaps, it was scarcely fair to draw the attention of the members to the photograph facing page 106 but it made one think furiously.

He thought it would have leaked out by now that he was not enamoured of *pise* construction for houses which, generally speaking, were of one storey in the Punjab and he asked them to consider the difficulties involved when public buildings of three stories, Indian houses of four and five stories, and so forth were contemplated and he thought it would be obvious that *pise* construction would be useless for this large class of building for which however, Mr. Macfarlane had not advocated its use. He thought that the only use to be found for *pise* construction would be for temporary hutting, material godowns and so forth and engineers already built those of sundried brick.

Reverting to the question of the cost of bungalows he said he believed that every avenue had already been explored with a view to obtaining reasonably sound and, at the same time, cheap construction by the use of the most economical materials which would effect this object but he thought more could possibly be done in the following directions :—

(*a*) Houses, where possible, might be built in larger numbers instead of two or three at a time.

(*b*) The purchase, in quantity and in the best market, of such items as ironmongery, electrical fittings, glass doors and windows of standard types, etc., which could be taken on to stock and issued as required. The Director of Industries could probably help in this direction.

(*c*) The formation of a standing Committee comprising representatives of the Buildings and Roads Branch, the Irrigation Department, the North-Western Railway, the Military Works Department and the Lahore Municipality to go into the question of rates with a view :—

(1) To stabilize rates and make them uniform for the Lahore and other districts where necessary.

(2) To avoid competition between the various departments.

He felt sure that only by dealing with the matter in some such way as this could an appreciable economy be effected either in bungalows or in other buildings.

If none of the above suggestions resulted in reducing the cost of bungalows then, until the cost of buildings, fell, the only thing left would be to build blocks of flats while, for people who insisted on houses, the present scale of accommodation, as far as official residences were concerned, must be reduced. He noticed that Mr. Macfarlane at page 98 of the Proceedings mentioned that the difficulty of obtaining coal, coupled with the high cost of labour, had caused and was continuing to cause an abnormal rise in the price of burnt bricks. Mr. Macfarlane's paper had been written some time back when conditions were at their worst but he thought that engineers would bear him out when he said that the upward cost of bricks had ceased and the tendency was now, if anything, downwards. This, he thought, was the universal trend in the cost of all materials and labour in England, the cost of house building having already dropped very considerably. He believed that in India too, the cost of materials and of labour had reached the top of the swing and that now the pendulum was just beginning to swing back towards normal. If this were so we should soon find no necessity to consider the question of the use of *pise* or of any form of mud as a building material for permanent structures. He concluded by asking Mr. Macfarlane to state the conclusions he had formed as the result of his experiments and thanked him for his stimulating paper.

Mr. Dorman protested against the misapplication of the term *kacha pacca* masonry on page 101. In the first place to apply the term masonry to brickwork was incorrect, as the word masonry was derived from the old High German *meizan*, meaning to hew, so that the term mason has become technically restricted to the worker in stone, and attempts of the bricklayer to imitate the stonemason's art were to be deprecated, as cutting a brick meant removing the fire skin. The term *kacha pacca* had also a well known technical designation meaning brickwork composed of burnt bricks laid with mud mortar. Sundried brick walling faced with burnt bricks was generally known as *ghilafi* work.

The author could offer only two solutions of the housing problem in Lahore, but was there not a further solution to be found by building houses large enough to be shared by two families as was already being done to a certain extent in the case of some of the larger bungalows in the Civil Station, or in the provision of flats like Curzon House in Delhi or Army Mansions in Lahore Cantonment? The problem of making both ends meet was becoming more and more difficult for junior married officers stationed in Lahore.

Turning to the test of a jack arch built of sundried bricks, mentioned on pages 99—100, it would be interesting to know how the loading had been applied and whether the spandrils had first been levelled up with mud concrete; also whether the initial failure had occurred at the crown or in the haunches. The usual practice was to limit the pressure on mud walls to one ton to the square foot, and this was the outcome of actual experiments made on loading mud walls to destruction. This was considerably less than even the poorest quality of burnt bricks would support.

Dealing with mud roofs, the author appeared to advocate painting the surface with silicate of soda, but would not this quickly lose its efficacy under traffic? Most mud roofs were occasionally walked on. Mixing the surface coat of mud plaster with the silicate solution sounded more hopeful, if the cost were not be prohibitive. It should save much annual plastering and also, by rendering the roof water proof, would prevent the unsightly efflorescence which periodically appeared after rain on the face of some buildings just below the cornice.

Finally, as regards cost, it would be interesting to know from what distance the earth had been carried for Mr. Macfarlane's experimental hut, and how the cost of the hut he was building for the benefit of the Congress near the Power Station of the North-Western Railway, compared with the hut illustrated in the paper.

The present tendency appeared to be for the rates of unskilled labour to rise more in proportion than skilled labour, and such being the case, any initial saving in capital cost through the use of *pise* walling would more and more tend to be counterbalanced by the cost of repairs, in all but a few localities with a small rainfall, where good clay was obtainable free from saltpetre.

Lieutenant Colonel B. C. Battye said that *pise* had been adopted successfully for some of the temporary buildings during the construction of the Simla Hydro-Electric Scheme, which was also the method universally employed by the villagers from time immemorial for constructing their houses in the same district near Basantpur.

Owing to the difficulties in obtaining good bricks or building stone for permanent buildings, *pise* was the only alternative to lime concrete: it was, therefore, decided to build the Resident Engineer's bungalow on this system.

As the bungalow was to be 16 feet high it was considered advisable to reinforce the walls with a light vertical rolled steel column under each roof truss and to use a certain amount of light galvanized iron wire reinforcement in the *pise* so as to hold it together in case of earthquakes.

This type of construction had two great enemies to be guarded against, white ants and water. In any *pise* building it was, therefore, essential to have an ant proof diaphragm right across the walls and floor and an absolutely watertight roof with wide eaves and a verandah all round to protect the walls from driving rain. All the buildings on the Simla Scheme were protected by rough cast, the specification for which was drawn up by Mr. Armstrong. All the servants' quarters were constructed in the same way but with stone door and window jambs and with sloping "Eternit" slate roofs. These, as far as he was aware, had required absolutely no expenditure for maintenance and none of the rough cast had cracked.

If the above precautions were not taken trouble was sure to accrue. For instance, the ant proof diaphragm should be constructed of 1" thick cement concrete, on 3" lime, across the walls floor and plinth so as to form a kind of flat tennis court platform before any further construction was started.

His experience with the temporary bungalow constructed last year at Rupar, when there was insufficient money to enable these precautions to be carried out, had proved the truth of the above theory conclusively. During the cold weather rains, following the completion of the bungalow, rain got into the walls and very nearly brought down a part of the building and when he visited Rupar the previous week he found the roof had been dismantled to replace the wood battens supporting the roof tiles, owing to these having been eaten away by white ants !!

COMMUNICATED LATER. The following was Mr. Amrstrong's specification for rough cast :—

This may be used on concrete, masonry, or lathing.

The process will be as follows ; one or two coats of lime plaster will be applied in the same manner as specified for ordinary lime plaster ; before the second coat sets, the roughing misture will be "dashed" into it.

The roughing mixture will be made by slaking one cubic foot of fresh stone lime over two cubic feet of clear gravel or bajri and melting in ¼ lb. of tallow.

The mixture must be dashed on hot starting from the top and working downwards.

MR. NICHOLSON congratulated Mr. Macfarlane on the high tensile stress which his mud carried, in fact one might be led to deduce that there was no need to spend money on lime mortars except in positions exposed to the weather. Unfortunately, if there was a saving in capital cost of a bungalow by using katcha bricks, in the long run the cost was much more owing to the high maintenance charges. To quote an instance at Rupar Headworks, an old Canal katcha bungalow was bought by the Civil Department in 1902 for the Assistant Commissioner to live in at the low price of Rs. 200, by 1915 the rent of the bungalow had risen to over Rs. 30 per month due to the fact that the maintenance charges in excess of the sanctioned percentage had to be added to the capital cost. Now the bungalow had been pulled down and a pacca one built and had the pacca one been built to begin with Government would have been saved much money.

The composite bungalow with external katcha walls faced with pacca bricks was an unsatisfactory arrangement as any leak in the roof in a night would bring it down, and like a katcha building it formed an acceptable house for vermin. There was no doubt that many bungalows had walls which were unnecessarily thick when built of pacca bricks. The speaker advocated a bungalow with a concrete floor laid over the whole plinth area on top of the ground with 6" of sand under it, this effectually kept out white ants. The walls to be constructed of the lightest section of pacca bricks feasible, this gave a bungalow which involved a negligible expenditure on maintenance.

BAWA BUDH SINGH said that the author in the beginning of his paper had mentioned three chief disadvantages of mud structures, and to his mind the very same disadvantages still clung more or less to the use of mud, at the close of the paper.

Firstly as to strength the author concluded from certain experiments, that the breaking stress was Tensile = 2·37 tons per square foot, Compressive = 5·9 tons per square foot.

But what was to be the factor of safety? P. W. D. Circulars laid down — 1 ton per square foot as the safe pressure on sundried brick in mud walls. For foundations on virgin soil they also took 1 ton per square foot as the safe pressure. This high factor of safety was due to risks one took when using mud, risks due to moisture, *reh*, rats, and white ants. The tensile strength of mud briquettes might be as high as those of lime mortar bricks, but the adhesive power of the former was much less than the latter. For an experiment one should join two bricks with the two mortars alternately and then note the force needed to separate them.

Secondly as regards rapid deterioration all applications of preparations to mud surfaces were apt to crack in this country of extreme temperatures. A small hole made accidentally by a nail, rat or scratch, would be a vulnerable point and liable to admit moisture. Therefore to depend upon the theoretical imperviousness of mud walls, was rather too risky.

Thirdly as regards the high cost of maintenance this was dependent on the first two disadvantages he had mentioned. The advantage in use of mud was saving in first cost, which the author calculated at 19¼ per cent. This saving would disappear in the long run by—

1. Shorter life of mud buildings than pacca structures.
2. High cost of maintenance.

But the problem of cheap buildings still stared them in the face. Should they have as large accommodation as they used to do in the pre-war times or days of plenty and accept inferior material or should they curtail extravagant accommodation and have good pacca buildings. He would recommend the latter course, as times had changed. One could not expect to have in Lahore as spacious compounds as in colony towns.

As regards change in specifications of our walls and roofs, to effect economy he would like to introduce concrete from bottom to top. He meant lime concrete for the present. Broken ballast could be easily had at kilns from Rs. 6 to Rs. 9 per hundred cubic feet and wall could be easily constructed either with removeable forms or travelling forms, preferably the former.

A concrete building would be rat and white ant proof. It could be made damp proof at very little cost. The whole structure would be free from obnoxious mud. The roofs could also be made of concrete in lime arches. If their designs were standardised, wooden forms for the concrete walls could easily be used for several buildings in succession. Concrete walls need not be thicker than brick walls, 15 inch walls had stood all night for a Dak Bungalow at Sakesar.

MR. W. P. SANGSTER said that adequate resistance to weather was the most important property to be considered when proposals were made for using mud as a permanent building material. For a long time it had been the custom in the Irrigation Branch to build the internal walls of canal rest-houses sundried bricks laid in mud mortar ; the foundations up to plinth level, and the topmost two feet of the walls were however built with burnt bricks laid in mud mortar. This form of construction was satisfactory so long as rain water was entirely excluded, and if there was no rain while the work was under construction. In some districts where rain was frequent during the working season, mud walls collapsed during construction, and this led to a general order that where the annual rainfall exceeded 10 inches mud brickwork was prohibited. On the other hand, Mr. Gebbie (Inspector-General of Irrigation) had assured him that in dry districts, such as Sind, there was considerable scope for the use of mud in building construction.

He thanked Mr. Macfarlane for an extremely interesting paper which had evoked much useful discussion.

CORRESPONDENCE.

MR. FOY wrote that Mr. Macfarlane's paper was of great interest to those who had to think of buildings and specially so to the officers of the Sutlej Valley Project who had to build their homes before they could begin actual work. Personally he was in favour of cheapening bungalows by a greater use of kucha bricks and considered that a fetich had been made of all pucca bricks and pucca plaster in residential buildings. He considered that where the rainfall was low as in the Multan District, southern part of Ferozepore District, Bikaner and Bahawalpore States kucha work could be usefully employed.

But precautions were necessary.

(*a*) Hand moulded bricks (not slop moulded) must be used and they must be absolutely dry.

(*b*) Put in good foundations and have 3 or 4 courses pucca bricks above the plinth. In damp localities put in a damp proof course.

(*c*) The floor concrete should be laid in one solid slab over the whole plinth area. Some of the previous speakers mentioned this as a novelty, but it was in the Standard Specification for buildings in the Irrigation Branch but unfortunately the rule had been chiefly observed in the breach.

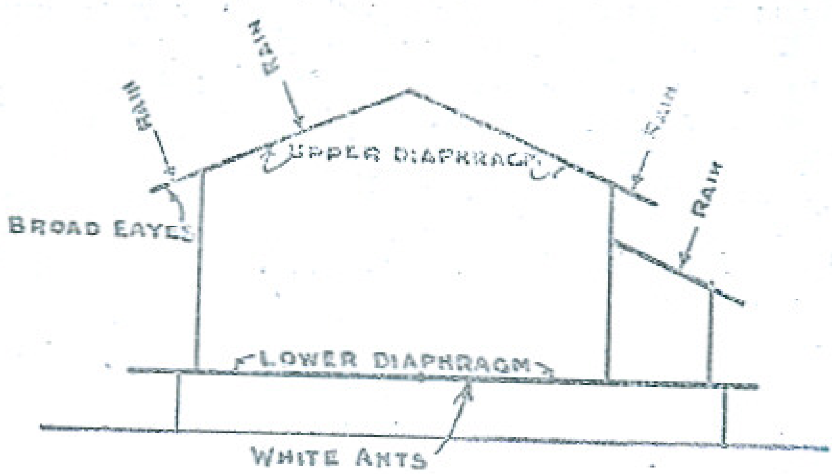
(*d*) Kucha walls should not be taxed with loads. So where the beams come kucha pucca pillars 26 inches wide should be built up in the walls from the floor upwards to carry the loads of the beams.

(*e*) Round all walls at roof level and at junction of verandah roof with main walls special precautions must be taken to keep out damp, by having a course of pucca bricks laid in lime, the full thickness of the wall.

A house using the precautions described above was built for him in 1906 and was still standing though the average rainfall of that district was about 30 inches. It was called a "temporary" residence, but it was not "permanent" and had been in continuous occupation by the Executive Engineers of that Division and many of them had since told him it was a delightfully cool house and the maintenance charges were the same as for other "all pucca" buildings of the same station.

Mr. Nicholson had emphasized the futility of having a pucca facing on a kucha wall. The speaker joined issue with him. The house described above had such a face on kucha outer walls. It was necessary in a district of good rainfall, but the house was still standing and did not leak between the skin and the backing.

LIEUTENANT-COLONEL B. C. BATTYE wrote that in continuation of his remarks he had intended to draw a sketch illustrating rather more clearly the main essentials of a mud or *pise* building.

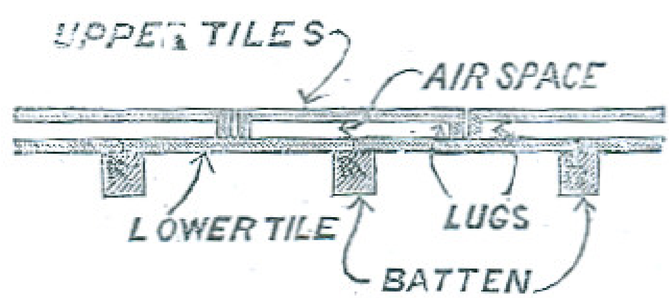


All mud construction must be enclosed between two diaphragms, the lower of which should be ant and damp proof and the upper one rain and heat proof.

There was little doubt that part of extra cost of construction at Chaba was due to the delays caused owing to their having to build the walls during the rains. Works often had to cease for several days at a time while everything was covered with tarpaulins.

As regards the exclusion of heat in 1904 he had built a number of quarters for subordinates at Ferozepore of burnt brick and had adopted hollow walls, using 18 inches × 13½ inches bonding bricks, specially moulded for the purpose.

He had also used two layers of roof tiles, the upper ones being fitted with lugs so as to form a hollow roof, thus :—



At the same time he had constructed a number of cordite stores, using the same methods. Experience, he thought, went to show that the stores, which had few doors and windows were perceptibly cooler for the hollow walls, but the quarters did not seem to be much affected. The conclusion arrived at was that most of the heat penetrated into the buildings through doors and windows, which was corroborated by the experience gained in Canada where the problem was inverted and heat has to be kept in. In such cases double windows and doors were usually adopted. Personally he was convinced that it was feasible to design and keep a large modern office building at cold weather temperature by the adoption of double doors and windows, hollow walls and roofs and a proper system of air conditioning and cooling such as was usually practised in all large office buildings in America. Presumably some such system was being incorporated into the new Secretariat buildings at Delhi.