# TEMPERATURE EXPERIMENTS AT LAHORE.

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## Preliminary.

When the design for the new Punjab Government Press in Lahore was under preparation, stress was laid on the necessity for keeping down the temperature of the machine room as much as possible, and it was decided to experiment with some of the various roofing materials on the market, with a view to ascertaining which would be most suitable for the purpose.

The new building was to consist of a single room 217 feet by 159 feet, with one end partitioned off to form the confidential section and type and paper godowns. This meant a very large roof as compared with wall area, and made the roof the most important factor affecting the temperature inside the building. Investigations were not however entirely confined to roofing materials. Some experiments were also made to ascertain the effect of different kinds of walls on the inside temperature, with the results noted.

## First set of experiments.

The experiments were made on some lines of quarters which had to be provided for the menial staff employed at the Press. The rooms were all the same size, and as the buildings faced in the same direction—nearly due east—the results are quite comparable. A thermometer was also kept in the gate lodge, (a small isolated building twelve feet by eight, with a flat mud roof, and a tiled verandah six feet wide on the east side) so as to act as a standard with which the temperature in the rooms with different kinds of pent roofs could be compared.

The first range of quarters consisted of a row of rooms, each twelve feet by eight, separated from one another by a $13\frac{1}{2}''$ brick in mud partition wall carried right up to the roof, and mud plastered on both sides.

These rooms were roofed as follows :—

| No. of room. | Roofing material. | Cost of roof per hundred square feet laid in position. |
| --- | --- | --- |
| | | Rs. a. p. |
| 1 | Red Eternit F. pattern tiles on battens, with an Eternit ceiling fixed below the rafters. | {42 4 0 plus {45 6 0 for ceiling. |
| 2 | Grey Eternit F. pattern tiles on battens ... | 40 14 3 |
| 3 | Grey Eternit F. pattern tiles on ¾ inch boards | 53 12 0 |
| 4 | Asbestone sheets on battens ... ... ... | 32 5 0 |
| 5 | Asbestos corrugated sheets on battens ... | 65 1 6 |
| 6 | 22 B. W. G. corrugated iron sheets laid directly on ¾ inch boards with 3-16 inch fibro cement ceiling below the rafters. | 84 13 11 |
| 7 | 22 B. W. G. corrugated iron sheets laid directly on ¾ inch boards. | 46 5 3 |
| 8 | 22 B. W. G. corrugated iron sheets on 2 inch battens over ¾ inch boards. | 50 2 3 |
| 9 | 22 B. W. G. corrugated iron sheets on battens. Sheets painted two coats of white corrugal paint. | 31 6 3 |
| 10 | 22 B. W. G. corrugated iron sheets on battens. | 28 6 3 |

The rates shewn include everything except the truss across the centre of the room and the wall plates, and, in order to eliminate differences in railway freight they are based on the assumption that all the material could have been obtained *via* Karachi.

### Eternit tiles.

Eternit tiles are said to be composed of pure long fibre asbestos and hydraulic cement, and are consequently incombustible. Being tough, strong and easily packed, they travel well. The tiles are of different colours, but uniform in composition, and the slightly higher price of the red tiles is said to be entirely due to the colouring matter used—grey being the natural colour These continental tiles are largely used in India, and are stocked by Messrs. William Jacks and Co. of Bombay, and others.

### Asbestone.

Asbestone is manufactured by the British Uralite Company, Ltd., at their works at Grays in Essex, from asbestos and silica, formed with a bonding agent, under a pressure of twenty tons to the square inch, into flat sheets of a standard size and thickness of $6' \times 3' \times 3/16''$ nominal, weighing about twenty-four ounces per square foot, though other thicknesses up to one inch are procurable if specially ordered from the works. In roof construction the sheets are overlapped six inches, and jointed, in a similar manner to corrugated iron, with galvanised mushroom headed bolts and washered nuts, the overlapped portion having a piece of soft twine smeared with white and red lead putty inserted between the surfaces to ensure a water-tight joint. In the case of wooden framing, the sheets are either nailed down with large headed clout nails, or screwed down with one inch rose headed screws. With steel framing, hook bolts are used. It is claimed that the material will carry over the span of half the length of a sheet without a bearer, but our experience was, that if the roof is to be strong enough to support an occasional workman, the bearers should not be further apart than fifteen to sixteen inch centres, Standard asbestone sheets are stocked by Messrs. Hoare Miller and Co. of Calcutta, in red and neutral colours, like eternit, but the British Uralite Company have not been able to make special ridging to match the sheets, so that galvanised iron or other ridging has to be used. We found asbestone brittle, and that it required careful handling. The sheets absorbed moisture, giving a damp appearance underneath in wet weather, and when kept for twenty-four hours in water they absorbed fourteen per cent. of moisture, as compared with four per cent. in the case or eternit and poilite.

### Asbestos corrugated sheets.

Asbestos corrugated sheets or Corrament is manufactured by the Asbestos Manufacturing Coy. at La Chine in Canada, and appears to be very similar in composition to asbestone. Grey in colour, the sheets are made in four to ten foot lengths $27\frac{1}{2}$ inches wide and 3/16 to $\frac{1}{4}$ inch in thickness. The pitch of the corrugations is $2\frac{1}{2}$ inches, and the sheets weigh about three pounds per square foot. They are laid in the same way as ordinary corrugated iron, with an end lap of six inches, and side laps of two corrugations. When laying on a steel roof, the method of fastening should be such as to allow of the expansion of the steel work without injury to the asbestos sheets, which neither expand nor contract with changes of temperature.

Asbestos cement ridge rolls are obtainable, but the manufacturers recommend using galvanised iron or other type of ridging. The Indian agents are Messrs. Heatly and Gresham, Ltd. of Bombay and Calcutta.

## First series of temperature readings.

As soon as the quarters were completed all the windows were bricked up, and a maximum and minimum thermometer suspended in the middle of each room five feet above the floor level. Every precaution was taken to eliminate error. All the thermometers were first hung up in the centre of the same room for several days before starting the experiment, and the readings compared. At a later stage this operation was repeated, and the readings again compared, not only with one another, but also with some standard thermometers supplied by the Meteorological Department. The differences between the thermometers however were not constant from day to day even at approximately the same temperature—the greatest difference being about four degrees. There was also some variation between the standard thermometers. From this series of readings the average error in the case of each instrument was worked out, and applied as a correction to be added to or subtracted from the actual reading recorded by the thermometer.

The thermometers were also periodically changed from room to room in order that any irregularities might further help to neutralise one another. They were read daily at 8 A. M., and as the first series of readings extended over a period of nearly four months, with twelve to twenty-four thermometers to read daily, it represented over five thousand observations. These were plotted, but, as the lines would only be confusing on a small scale diagram, the following table giving the average of the daily readings for the last ten days of September 1913, is reproduced for information :—

| No. of room. | Roofing material. | Thermometer readings. | | |
|---|---|---|---|---|
| | | Maximum. | Minimum. | 8 A.M. |
| 1 | Red Eternit on battens with eternit ceiling ... ... ... | 89·0 | 83·9 | 85·3 |
| 2 | Grey Eternit on battens ... | 87·3 | 80·6 | 82·2 |
| 3 | Grey Eternit on ¾″ boards ... | 86·8 | 82·6 | 83·2 |
| 4 | Asbestone on battens ... ... | 86·7 | 79·6 | 81·7 |
| 5 | Asbestos corrugated sheets on battens ... ... ... ... | 85·3 | 77·1 | 80·1 |
| 6 | Corrugated iron sheets on boards wi h fibro cement ceiling ... | 84·7 | 81·1 | 82·2 |
| 7 | Corrugated iron sheets on boards | 85·7 | 82·1 | 82·1 |
| 8 | Corrugated iron sheets on battens over boards ... ... .. | 84·9 | 80·7 | 81·6 |
| 9 | White painted corrugated iron sheets on battens ... ... | 86·6 | 77·4 | 81·9 |
| 10 | Corrugated iron sheets on battens ... ... ... ... | 87·5 | 77·9 | 81· |
| 11 | (Gate Lodge) Second class mud roof ... ... ... ... | 90·2 | 83·1 | 85·1 |
| 12 | In open verandah ... .. | 96·0 | 68·0 | 83·8 |
| 13 | Meteorological observation recorded at the Observatory ... | 102·5 | 68·0 | 84·4 |

These readings were taken with the rooms practically hermetically sealed day and night.

A glance down the table would seem to indicate that the flat mud roof in the gate lodge was the hottest of the series. This was further investigated by taking a series of hourly readings throughout the day, with the following result on the 27th September 1913 :—

| No. of room. | Roofing material. | Temperature reading each hour. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 8 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 1 | Red Eternit with ceiling ... | 84 | 86 | 86·5 | 87 | 87·5 | 88 | 88 | 88 |
| 2 | Grey Eternit on battens ... | 81 | 84 | 85 | 86 | 86 | 85 | 85 | 84·5 |
| 3 | Grey Eternit on boards ... | 82 | 84 | 84·5 | 85 | 85 | 85 | 86·5 | 86·5 |
| 4 | Asbestone on battens .. | 80·5 | 83·5 | 84·5 | 85 | 85·5 | 85 | 84·5 | 84·5 |
| 5 | Corrugated Asbestos on battens ... ... ... | 78 | 82 | 83 | 84 | 84 | 84 | 84 | 83 |
| 6 | Corrugated iron on boards with fibro cement ceiling | 80·5 | 82·5 | 83 | 83 | 83·5 | 83 | 83·5 | 83·5 |
| 7 | Corrugated iron on boards | 80·5 | 83 | 83·5 | 83·5 | 84 | 84 | 84·5 | 84·5 |
| 8 | Corrugated iron on battens over boards ... ... | 80·5 | 81·5 | 82·5 | 83·5 | 83·5 | 83·5 | 83·5 | 83·5 |
| 9 | White painted corrugated iron on battens ... ... | 80 | 84 | 85 | 85 | 85 | 85 | 84·5 | 84·5 |
| 10 | Corrugated iron on battens | 80 | 84 | 85 | 85 | 85 | 85 | 84·5 | 84 |
| 11 | Second class mud roof ... | 85 | 83 | 84 | 84 | 85 | 86 | 86·5 | 87 |
| 12 | Open verandah ... .. | 81 | 93 | 98 | 96 | 95 | 91 | 87 | 85·5 |

The maximum temperature recorded in the gate lodge during the night on this date was 89°, and the table brings out the interesting fact, that when the rooms with pent roofs were approaching their maximum, the gate lodge was touching its minimum temperature for the twenty-four hours, and only reached its maximum long after sunset, when the outer air had cooled down. This was, of course, due to the heat absorbed by the mud roof during the day being radiated at night into the building ; and herein lies the value of the thick mud roof, that it offers sufficient resistance to the heat rays to prevent their affecting the temperature of a room shut up during the day, while opening out the room at night allows the air, which is being heated by contact with the warm roof, to escape through the clerestory windows, and be replaced by cool air entering at the doors. It further emphasises the necessity of keeping the clerestory windows as near the ceiling as possible.

Could the room have been opened out at sunset so as to allow a free circulation of air, the maximum temperature would probably not have exceeded 87° F.

### Analysis of results.

A further analysis of the results as plotted brings out the following points :—

(*a*). In any ten day period the maximum temperature readings in all the rooms have seldom varied by more than five degrees.

(*b*). An experiment made before ceiling the first room shewed that the difference in the colour of the eternit tiles made practically no difference in the temperature of the rooms.

(*c*). The addition of an eternit ceiling immediately below the rafters was of no advantage in keeping down the temperature, but rather the contrary. This was probably due to the marked action of the ceiling in retarding the dissipation of the heat at night through the thin roof of the closed room, thereby causing the unventilated ceiled rooms to start warming up from a higher minimum temperature, and thus reaching a slightly higher maximum than the unceiled rooms, though actually moving through a smaller range of temperature.

(*d*). In the case of grey eternit, the substitution of boards for battens, at an increase in rate of Rs. 12-13-9 per hundred square feet, reduced the maximum temperature by two degrees, while the minimum temperature was one degree higher.

(*e*). Asbestos corrugated sheets, while double the cost of asbestone roofing, is only one degree cooler. It is however much stronger.

(*f*). Corrugated iron on battens was also only one or two degrees hotter than the asbestos corrugated sheets during the earlier months, and later on, with more moderate temperatures, actually cooler, while only one-third the price.

(*g*). Painting corrugated iron roofs with two coats of the special white paint, supplied by the Shalimar Paint Coy. for the purpose, had practically no effect in reducing the temperature.

(*h*). The substitution of boards for battens under corrugated iron sheets not only slightly reduces the maximum temperature, but also keeps the room from heating up quite so soon. It also keeps up the minimum temperature four to five degrees in a closed room, which would be appreciated by the occupants in the cold weather.

(*i*). The addition of a fibro cement ceiling under the rafters, with a view to keeping down the temperature in a building roofed with corrugated iron on boards, is waste of money. It costs with woodwork Rs. 38-8-8 per hundred square feet.

(*j*). There is no advantage in interposing battens between the boarding and the corrugated iron sheets with the idea of creating an air space.

## Second set of experiments.

In the second set of quarters to be completed there were five rooms with pent roofs, flanked at one end by the flat roofed cook house, and at the other by a coach house, so that in the rooms under experiment there were no end walls exposed to the sun.

These rooms were roofed as follows :—

| No. of room. | Roofing material | Cost of roof per hundred square feet laid in position. | | |
|---|---|---|---|---|
| | | Rs. | a. | p. |
| 13 | Three ply Genasco on $\frac{3}{4}''$ boards ... ... | 36 | 7 | 3 |
| 14 | Three ply Malthoid on felt on $\frac{3}{4}''$ boards ... | 56 | 7 | 0 |
| 15 | Red Poilite tiles on battens with $\frac{1}{2}''$ pine ceiling. | 40<br>plus Rs. 14<br>for ceiling. | 1<br>4 | 3<br>3 |
| 16 | Roman tiles on battens ... ... ... | 50 | 7 | 0 |
| 17 | Single Allahabad tiles on battens ... ... | 22 | 0 | 0 |

Genasco.

Genasco manufactured by the Barber Asphalt Co., at Maurer, New Jersey, is advertised as a densely compressed wool felt, saturated with a specially prepared asphalte mixture and having a layer of viscous Trinidad asphalte on each side. It is said not to contain any coal tar or stearin pitch. Messrs. Burn & Co. are the Indian agents for the material, stocking it in three thicknesses ; namely one, two and three ply. It was supplied in rolls 81 feet long and 32 inches wide, containing 216 square feet, with liquid cement, nails, and full directions for laying, packed in each roll. It is now supplied with patent fasteners known as " Kant-Leak Kleets, " which do away with the need for using cement, and for which it is claimed that they make a tighter and more weather proof join than the old method of fastening. Genasco is easy to fix, and so far (after one hot weather and a monsoon) has shown no tendency to become brittle and crack. The manufacturers however recommend that the material should be painted with some of their "liquid roof coating" after two years, and thereafter at intervals of three to four years, in order to preserve it indefinitely.

Malthoid.

Malthoid is a heavy wool felt, saturated in gummy compounds, and having a coating of the same character rolled evenly over both sides of the felt. It is manufactured by the Paraffine Paint Company of San Francisco in various thicknesses, and sold in rolls 36 inches wide and 72 feet long. Messrs. McKenzies' Saw Mills, Ltd., Bombay, are the agents for the Punjab. In the experiment, the malthoid roofing was laid, as specified by the makers, over a double layer of pabco asphalte saturated felt, to which it was cemented with " floatine " which is the material also supplied for sticking the felt on to the boards. The felt is supplied in rolls 32 inches wide and 136 feet in length.

This roof proved a failure. The original intention was to test the Pabco S/S roofing, which is really malthoid with a layer of asbestos incorporated in the under surface where it is protected from the weather, manufactured by the same firm, but the agents sent up malthoid by mistake, and as there was some delay in getting pabco, and the rains were at hand, we decided to try the malthoid. The floatine, which is a refined Californian asphalte, gave us a lot of trouble. It steadily refused to flow, and it was only by selecting one of the hottest days of June, and heating the floatine on the roof itself, that we were finally able to stick down, first the felt, and then the malthoid, in accordance with the manufacturers' instructions. As soon as the malthoid was in place however the floatine began to ooze out and drip from the eaves, as well as finding its way through the cracks in the boarding into the room below whenever it was extra warm Finally one day one of the lengths of malthoid floated bodily down the roof, and was torn in the effort to replace it.

The manufacturers attribute the failure to using too much floatine, while Messrs. McKenzie's Saw Mills, Ltd., claim to have successfully laid over 700,000 square feet of reinforced malthoid roofing themselves, which they say is giving unqualified satisfaction. They advise however that arrangements should be made with the supplying agents for laying the material as they do not consider it a job to be lightly undertaken by inexperienced workmen.

### Poilite.

Poilite tiles are practically identical with eternit. A strip of red eternit four inches in width, laid flat on bearings about twelve inches apart, broke under a central load of 24 lbs. while grey eternit sustained a load of nearly $28\frac{1}{2}$ lbs. before breaking. A similar strip cut from a red poilite tile supplied by Messrs. Martin & Co., was only able to support a central load of $15\frac{1}{2}$ lbs. before breaking, but a four inch strip cut from one of the blue tiles obtained through the India Office, took no less than 35 lbs. under the same conditions. These blue tiles were nearly thirty per cent. heavier than the tiles obtained locally. They travel well. Out of seven thousand in the consignment obtained for the new Veterinary College only one tile was broken in transit. They are manufactured by Bell's United Asbestos Co., Ltd., at their works at Harefield, Middlesex, and stocked by Messrs. A. & J. Main & Co., and Martin & Co., of Calcutta, and by Messrs. T. Cosser in Karachi, as well as by other firms.

### Roman Tiles.

Roman tiles are also manufactured by Bell's United Asbestos Co. They are flat tiles, four feet by two feet, with a tapered roll along one long side to secure a water tight side joint. This roll however is very liable to be broken in transit, when, owing to the slight taper, the whole tile is rendered useless. About half the tiles supplied by Messrs. Martin & Co., for the experiment were broken en route, but the suppliers think that with a through truck full, the tiles would travel all right.

## Second Series of readings.

In the second series of readings, made during the hot weather of 1914, the windows of the rooms were kept open all night and closed during the day. Moreover each room had been provided with a small roof ventilator. The average of the readings taken during the last ten days of May 1914 is shown in the following table, while the temperatures recorded on the 28th May, the hottest day of the ten day period under review, are given in italics :—

| Number of room. | Roofing material. | Thermometer Readings. | | |
|---|---|---|---|---|
| | | Maximum. | Minimum. | 8 A. M. |
| 1 | Red eternit on battens with eternit ceiling. | 91<br>*99·5* | 83·4<br>*90* | 85·8<br>*91* |
| 2 | Grey eternit on battens ... | 92·5<br>*99·5* | 88·0<br>*86* | 84·5<br>*90* |
| 3 | Grey eternit on $\frac{3}{4}$" boards ... | 92·2<br>*99·5* | 78·8<br>*89·5* | 84·2<br>*90* |
| 4 | Asbestone on battens ... | 91·5<br>*98·5* | 81·3<br>*86* | 83·8<br>*89·5* |
| 5 | Asbestos corrugated sheets on battens. | 91·5<br>*99* | 78·5<br>*83* | 83·7<br>*89·5* |
| 6 | Corrugated iron sheets on boards with fibro cement ceiling | 89·3<br>*96* | 88·3<br>*88* | 85·4<br>*90* |
| 7 | Corrugated iron sheets on boards | 92·2<br>*96* | 81·1<br>*86* | 83·6<br>*89* |
| 8 | Corrugated iron sheets on battens over boards. | 89<br>*95·5* | 80·3<br>*85* | 83·9<br>*89* |
| 9 | White painted corrugated iron sheets on battens. | 90·9<br>*98* | 79·8<br>*85* | 83·7<br>*90* |
| 10 | Corrugated iron sheets on battens. | 92 9<br>*100* | 80·5<br>*85·5* | 85·3<br>*91·5* |
| 11 | (Gate Lodge) Second class mud roof. | 90<br>*97·5* | 84·4<br>*91* | 87<br>*93* |
| 12 | In open verandah ... | 102·8<br>*113* | 75<br>*79·5* | 89·1<br>*97·5* |
| 13 | Genasco on $\frac{3}{4}$" boards ... | 92·6<br>*100* | 84·3<br>*90* | 86·2<br>*92* |
| 14 | Malthoid on felt on $\frac{3}{4}$" boards | 93·7<br>*100* | 84·9<br>*91* | 86·6<br>*93* |
| 15 | Red poilite tiles on battens with half inch pine ceiling. | 92·2<br>*101* | 84·6<br>*90* | 86·1<br>*92* |
| 16 | Roman tiles on battens . | 92·8<br>*100·5* | 80·5<br>*86* | 85·1<br>*91·5* |
| 17 | Single Allahabad tiles on battens. | 92·6<br>*99·5* | 79·7<br>*84* | 83·5<br>*90* |

Readings taken every two hours on the 2nd June were as follows :—

| Number of room. | Roofing material. | Temperature Readings. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 8 | 10 | 12 | 2 | 4 | 6 |
| 1 | Red eternit on battens with eternit ceiling ... | 93·5 | 95·5 | 97·5 | 98·5 | 99·5 | 99 |
| 2 | Grey eternit on battens | 93 | 97 | 99·5 | 102 | 101 | 100 |
| 3 | Grey eternit on $\frac{3}{4}''$ boards | 93 | 95 | 97 | 99·5 | 99 | 98 |
| 4 | Asbestone on battens ... | 92·5 | 96 | 98·5 | 100·5 | 100·5 | 99 |
| 5 | Asbestos corrugated sheets on battens ... | 92·5 | 96 | 99 | 101 | 100·5 | 99·5 |
| 6 | Corrugated iron sheets on boards with fibro cement ceiling ... | 93·5 | 95 | 96 | 97 | 98 | 98 |
| 7 | Corrugated iron sheets on boards .. ... | 92 | 94·5 | 96 | 97·5 | 93 | 98 |
| 8 | Corrugated iron sheets on battens over boards | 92 | 95 | 95·5 | 97 | 97·5 | 97 |
| 9 | White painted corrugated iron sheets on battens ... ... | 93 | 96 | 98·5 | 100·5 | 100 | 99 |
| 10 | Corrugated iron sheets on battens .. ... | 94 | 98 | 101 | 102·5 | 102 | 100·5 |
| 11 | (Gate Lodge) Second class mud roof ... | 95·5 | 96 | 96 | 97 | 97·5 | 99 |
| 12 | In open verandah ... | 98 | 107 | 110 | 111 | 108·5 | 104·5 |
| 13 | Genasco on $\frac{3}{4}''$ boards... | 94·5 | 97 | 99·5 | 101 | 101·5 | 101·5 |
| 14 | Malthoid on felt on $\frac{3}{4}''$ boards .. ... | 95·5 | 97 | 99 | 100·5 | 101 | 101 |
| 15 | Red poilite tiles on battens with half inch pine ceiling ... ... | 95 | 96·5 | 98 | 99·5 | 100 | 100 |
| 16 | Roman tiles on battens | 94 | 97 | 99 | 102·5 | 102 | 101 |
| 17 | Single Allahabad tiles on battens ... ... | 92· | 94·5 | 97 | 99 | 100 | 100 |

These results confirm the earlier ones in shewing that as far as the temperature is concerned there is very little difference in the roofing material employed. Architectural considerations or exceptional reasons may demand other treatment in the roof of a building, but where a pent roof must be used, so far as the temperature inside is concerned, corrugated iron on boards is as good as any for all practical purposes. The last table brings out well the modifying influence of boards in a roof in place of battens, where the temperature jumps up sharply for a few hours in the middle of the day.

Final decision—

The practical outcome of the experiments has been to adopt corrugated iron as the roofing material for the new Press. The sheets were rivetted together as far as possible on the ground, and then secured with hook bolts directly to the purlins. A half inch Norwegian pine ceiling was fixed immediately below the purlins, mainly with the idea of hiding the sheets from view, and this painted white has considerably improved the lighting of the building.

One great drawback to this type of ceiling however is that in case of leakage it is extremely difficult to locate the hole, and water trickling down over the boards, causes the latter to swell and bulge outwards, as well as causing unsightly marks on the paint. As there is no way of tightening the rivets, the only remedy is a haphazard method of smearing white lead round all the rivet heads above the leak on the chance of getting the right one, and this does not improve the outside appearance of the roof.

Roof Ventilation—

We also tried an experiment to see whether making openings at the eaves and ridge to provide free circulation for the air between the ceiling and roof would make any difference in the temperature of the room, but could not detect any.

A further experiment was made to determine the best kind of ventilator for a flat mud roof. Three adjacent rooms towards the middle of the Superintendent's line of out-houses were selected. The first had no roof ventilation. In the roof of the second, the ordinary pattern nine inch diameter rose ventilator was fixed ; and in the third an opening two feet by two feet was left, over which the roof was raised, and given a considerable projection all round, large openings being left in the sides of the raised portion. The temperature readings were not conclusive, but generally in the unventilated room indicated both a maximum and a minimum temperature a couple of degrees above the others, between which no difference could be detected.

## Wall experiments.

The final experiment was to try to find out the effect of different kinds of walling on the temperature of a building, and for this purpose the married menials' quarters were selected. This was a row of six rooms, each 15′ × 10′, with a verandah seven feet wide on the east side. A second class flat mud roof covered the lot, and the only difference was in treatment of the 13½ inch west wall, which got most of the afternoon sun.

This wall was as given in the following statement in which two temperature figures, are shewn opposite each room, the upper in each case representing the average of a series of ten days readings, taken in the middle of June, and the lower the average of another set, taken during the first ten days of July.

| Number of room. | Kind of wall. | Temperatures. | | |
|---|---|---|---|---|
| | | Maximum. | Minimum. | 8 A. M. |
| 1 | Burnt brick in mud, lime pointed outside and mud plastered inside ... | 97·0<br>93·8 | 90·5<br>88·5 | 93·5<br>90·2 |
| 2 | Burnt brick in mud—mud plastered on both sides ... ... ... ... | 95·5<br>93·8 | 88·5<br>88·2 | 92·0<br>90·9 |
| 3 | Burnt brick in mud, lime plastered outside and mud plastered inside ... | 94·0<br>92·9 | 89·0<br>89·1 | 91·0<br>90·0 |
| 4 | Burnt brick in lime, lime plastered on both sides ... ... ... | 95·3<br>93·4 | 88·5<br>88·1 | 90·8<br>90·5 |
| 5 | Hollow wall of burnt brick in lime with a 2¼″ cavity between the inner 9″ and the outer 4½″ wall. Lime pointed outside and mud plastered inside ... ... ... ... ... | 96·6<br>94·2 | 90·5<br>90·0 | 92·3<br>91·0 |
| 6 | Burnt brick in mud, lime pointed outside and mud plastered inside ... | 95·5<br>93·9 | 90·7<br>88·8 | 92·1<br>90·2 |

Omitting room No. 1, which was the end room on the south side and consequently had a second wall exposed to the sun, it will be noticed that room No. 5, which had a hollow wall, gave the highest maximum and minimum readings. Curiously enough, rooms Nos. 2 and 4, the one built in lime mortar and lime plastered, the other in mud with mud plaster on both faces, gave identical results, while No. 3, with a brick in mud wall lime plastered outside and mud plastered inside, had the lowest maximum.

These results are not however altogether conclusive, as more heat must have been transmitted through the roof than through the walls under examination.

**Conclusion.**

The author would here express his indebtedness to B. Lal Chand, Overseer, in charge of the Press Building, who made most of the observations from which this paper has been compiled.

## DISCUSSION.

MR. DORMAN, in introducing his paper . nothing to add to the tests recorded, but wished to or two remarks about the materials used in the experi

Bell's United Asbestos Co., in protesting ag comparison on page 84 of the relative strengths of poi eternit, had pointed out that the strength of such tiles dep on the direction of the fibre and the age, as well as the thic of the sample, and that, consequently, unless the ages of the were known, strength tests were not fairly comparable. It w apparently impossible to secure the uniformity obtainable for instance, in the case of Welsh slates, in either the strength or thickness of asbestos cement sheets.

Grey tiles, being self-coloured, were fifteen to twenty per cent. stronger than either blue or red, the admixture of bi-oxide of manganese to produce the blue colour, and hæmatite to obtain the red, causing a slight reduction in the mechanical strength of the coloured tiles ; while a tile tested with the grain would average twenty per cent. stronger than when tested against thé grain. Only an expert could tell the direction of the fibres, while an almost imperceptible difference in thickness might mean a considerable difference in the strength of the tiles. When testing, it was not sufficient to just measure the thickness of a sample at the four edges—the fractures should be measured as well.

Roman tiles are said to be now made with taper rolls of heavier section than those used at the Press, and the manufacturers point out that broken tiles can be cut for use at the eaves or ridge.

The suppliers of malthoid claim that this material was not given a fair trial, as its great merit lies in its lasting qualities, which, they claim, has been proved by their ever-increasing orders during the last six years.

MR. ASTBURY said that the problem investigated by the author was of much interest to Punjab engineers, and any reliable information as to the best way of keeping a bungalow cool in the hot weather was welcome. He had not heard of any previous full-size experiments on the subject.

The problem was intimately connected with ventilation. If the temperature of the fresh air supply was too high for comfort, and was higher than the temperature in the rooms, it became undesirable to allow continuous ventilation. In practice many

. kept close shut in the hot weather from sunrise . ventilating was only done when the outside air .ıan that in the rooms.

comparative facility afforded by various building for transmitting heat was given in Hurst's Pocket ' Two extremes might be considered. The temperature a black sheet iron shed would have a range of variation .sponding fairly closely to the range outside and no one .ıld like to inhabit it. Inside a house, with thick mud walls .d roof, the temperature would lag behind the temperature out-.ıde, and the amplitude of the variation curves would be reduced practically to nil. A brick wall seven centimetres thick would reduce the amplitude by one-twentieth. In a paper on "Air-cooled jacketing in hollow walls by electric fans*" Mr. J. W. Meares had described an artificial method of cooling bungalows, which he believed was about to be tried in Delhi, but the present problem was to find the best design for a structure with reference to heat resistance without artificial aid.

On page 79, the average daily range for the last ten days of September 1913 in the outside shade temperature was shown at item 13 to be 34·5 degrees. The range to which the upper surface of the roofs were subjected was, however, greater than this, as they were exposed to the direct rays of the sun.

Useful information might be gained from the experiments by adding a column to the tables on pages 79 and 85 to show the difference between maximum and minimum temperatures, and a table of the roofs arranged in order of increasing difference. Thus on page 79, item 13 (the outside shade temperature) would be at the bottom of the table with a difference of 34·5 degrees while rooms 6 and 7 would come at the top. Similarly, on page 85, the second class mud roof would come out top.

It seemed to him that the best roof was that which gave the least difference between maximum and minimum, or, in other words, which damped the amplitude of the outside range the most effectively. In fact, non-conductivity, combined with adequate ventilation under complete control, appeared to him to be the main objects in designing a bungalow to withstand heat.

Without artificial aid it was impossible for a bungalow, sealed night and day, to have the mean temperature in the rooms less

* *Vide* "Journal of the Institution of Electrical Engineers" Volume 51, Part 220.

than the mean outside shade temperature. That the best, whose variation from the mean was the a bungalow would exhibit the lowest rise during the day. By ventilating freely at night, and sealing up d. day, a slight reduction of temperature over continuous might be secured, but the thermal capacity of the wa great compared with that of the air, and the walls of the would soon warm the night air to their own temperature and very little of their own heat in the process.

Judging the roofs by this standard the experiments on pag 85 gave the best six in descending order of merit as follows :—

1. Second class mud roof.
2. Corrugated iron on boards with fibro cement ceiling.
3. Red eternit on battens with eternit ceiling.
4. Malthoid on felt on $\frac{3}{4}''$ boards.
5. Corrugated iron sheets on boards.
6. Genasco on $\frac{3}{4}''$ boards.

He thought a more suitable title for the paper would have been " Experiments to determine the relative thermometric conductivity of certain roofing materials. " A good deal of labour in recording the temperatures might have been saved by the use of self-recording thermographs.

RAI BAHADUR GANGA RAM said be must first of all be allowed to express his satisfaction that an officer of the Buildings and Roads had come forward with a paper.

Mr. Dorman had ignored the old fashioned types of roofing such as double Allahabad tiling, slates, and jack-arched roofing, and it would be interesting to know, for example, how the temperature found by the author in his experiments would compare with the temperature in a building roofed with double Allahabad tiling such as the Chief Court, Telegraph Office, etc. This type of roofing had, however, apparently not been tested.

In his opinion the coolest and most satisfactory roof would be jack-arching with a ceiling, and six inches of crushed mica over the ceiling.

He had tried a new method of bringing down the temperature in connection with the Patiala water works where he had to erect a steel cylinder reservoir about forty feet diameter and thirty-seven feet high. Round this he bolted angle irons, $3'' \times 3'' \times \frac{1}{2}''$ three feet apart vertically, on the outside of the on these angles laths of wood $3'' \times 3''$ were ɛet apart, thus making panels three feet square all cylinder. These panels were filled with crushed ɩhe whole exterior when finished with boarding, and presenting a surface like that of the boiler of a ; engine. This reservior was roofed with corrugated iron ɪ trusses, under the tie rods of which arrangements had made for a wooden ceiling, on the upper side of which bags .e placed, containing six inches of crushed mica.

This contrivance had proved eminently successful, and to this day kept the water wonderfully cool. The speaker had tried a similar experiment to bring down the temperature of rooms. In one room where he had put a corrugated iron roof he tried a ceiling with six inches of mica on top, and this brought down the temperature by fifteen degrees. He had unfortunately, however, not been able to complete these experiments before he left Patiala soon afterwards.

RAI BAHADUR BISHAMBER NATH said he had a good idea for a new kind of roofing to reduce the temperature. This consisted of corrugated sheets placed at a slope of one in five, with the side over-lapping three corrugations, and an end overlap of nine inches. The sheets were not to be bolted together, but laid one upon the other, with four inches of sand on top. In order to prevent the sand being blown away one inch thickness of bujjree might be placed on top, while to prevent its being washed away by rains five inches of bujjree might also be placed, a foot wide along the eaves against a batten laid for retaining it. This roof could then be sprinkled with water. With the heat of the sun evaporation would take place and make the building cool.

MR. DUTHY said that the paper opened up a subject in which they were all more or less interested both from a professional and a selfish point of view. They had all to design and erect buildings for various purposes, and their object in all cases was to erect a building, which would be as suitable as possible either for living or working in, and in this country the suitability of any building for either purposes was largely determined by its ability to keep out the heat of a hot weather day. The cold in the cold weather could be easily counteracted by a well designed system of fire places stoves or other warming appliances but the heat could only be mitigated by punkhas, fans, or ventilation, and these had little effect if the walls and roof of the

building were not capable of keeping out to a la
direct heat outside.

His own experience had been entirely confine
dential bungalows, rest-houses, offices, subordinates' an
quarters, but he had had experience both of living in, a
in charge of, a large number of these with different ty
roofs, and it was from this point of view that he wanted to
a few remarks on the paper as far as it concerned roofs.

He noticed that Mr. Dorman had only attempted
experiment with various types of patent tiles and other pate
roofing materials and corrugated iron, all of which entailed a considerable use of wood as battens, rafters, and ceiling boards, but in view of the very short life of wood-work out here on account of rot, white ants, and other causes, he thought any roof containing much wood-work was bound to be expensive in upkeep, and to have a very short life, which would largely counteract any saving from the first cost being low, and it seemed to him from the rates given by Mr. Dorman that the first cost of none of the roofs was particularly low.

He thought, from the point of view of economy, the cheapest roof in this country, taking first cost, life, and cost of repairs into consideration, would be found in one containing only iron, pacca masonry, and concrete, and that if such a roof also served to keep out the heat as well, or better than other roofs, which did not answer these conditions, it would be the ideal roof for most purposes. Such a roof would possess the additional advantages of being fire and vermin proof.

He had lived in bungalows with roofs of the following types, which he placed in the order of their unpleasantness in the hot weather the first being the worst.

1. A roof consisting of sarkandah grass and matting laid over wooden battens with six inches of earth on top.

2. The Sindh tile type of roof used largely during the early days of the Sirhind canal. This consisted of hollow tiles in the form of a hexagonal flower pot, closed at both ends, and moulded to form an eight inch radius semi-circular arch.

3. The roof largely used in rest-houses consisting of flat bricks or tiles laid on wooden battens with concrete and earth above.

4. An eight inch thatched roof.

.ype of jack-arch roof now largely used in the .lmost invariably adopted by the Irrigation Branch .t buildings, consisting of jack arches supported on beams, filled in with concrete to three inches above the arches, and six inches of earth plastered over that.

.e first of these was a type which he considered should .oe built. It leaked, and often collapsed when it rained ; vhile it kept out neither heat nor cold, it harboured vermin .n awful extent. It was very liable to attacks of white ants .l had to be so frequently renewed, that although the cost of .newal was very low (say Rs. 5 per cent.) it eventually worked out as the most expensive form of roof possible.

He remembered being in charge of a large number of temporary subordinates' and menials' quarters with roofs of this type, when it was generally necessary to completely re-roof the whole twice a year, and he found from the records that this had been necessary since the quarters were built some five years before. Thus in the five years the quarters had cost some fifty rupees per hundred square feet for roofs alone, for which sum, or a good deal less, a very much superior form of roof could have been built originally which would have been permanent.

He asked the Congress to picture to themselves the discomfort summed up in a petition of the following type, which used invariably to come in by scores before it had been raining for six hours. "A large hole has come in the roof of my house and now the floor is covered with water and I and my family are sitting in this under an umbrella and suffering great inconvenience. Please arrange," but of course it was quite impossible to arrange anything till the rain stopped. He did not think this type, even if it was as a rule only used for subordinates and menials, required any further comment.

With regard to the Sindh tile type, it was an early attempt to construct a roof without woodwork. It was admitted at the time that it was not proof against the direct rays of the sun, and was abandoned, he believed, before the Sirhind canal was completed. It had the additional disadvantages that it was not possible to sleep on it in the hot weather, and the size of the rooms was limited to either eight or sixteen feet in width.

He had found the third type a very good roof, but it was liable to leak, was not so cool as a jack-arch roof, and contained wood.

A thatched roof was probably the coolest of was rather dangerous owing to the way it harboured it required a good deal of repairing, but he tho useful for temporary buildings, where thatching materia got locally.

The jack-arch roof so largely used in the Punjab wa mind the ideal roof for this country in most cases. It wa manent, and its cost of upkeep was practically nil, while its firs was not very high. It contained no wood, was fire and ver proof, and kept out the heat well. In very hot places it might improved by laying lines of bricks as headers ten inches centre t centre with stretchers over them and three inches of concrete over all, thus providing a well ventilated air space between the concrete and the earth.

He did not believe any patent roofing material at present on the market, or likely to be introduced, would ever beat this either in cost or efficiency, except in special cases, and he did not see why patent materials should be tried when they had this type of roof which was cheaper and better, ready to hand.

He admitted that special cases existed, and the Press building referred to by Mr. Dorman was no doubt a case in point. He quite saw that if no arrangement of intermediate supports was permissible, the enormous span would have necessitated very heavy girders to carry the jack-arches, and the great weight of the roof would have necessitated very thick walls which however would have been of much service in keeping the building cool, and very strong founds, which would very likely have rendered the cost prohibitive, but he should ask Mr. Dorman if some arrangement of supporting the girders say every twenty feet with iron, brick, or perhaps reinforced concrete pillars had ever been considered, or whether this was inherently impossible in view of the purposes for which the building was required.

MR. SLEIGH said that Mr. Dorman's paper was particularly welcome to him, as the most suitable type of roof for the conditions prevailing on the lower half of the Kalka-Simla Railway, where the temperature was high and the rainfall heavy, had been under consideration for some time.

Generally speaking, the type adopted had been corrugated sheets laid on boards or battens, but as these roofs were not carefully constructed, insufficient slope being one of the many defects, the roofs leaked and the rooms were found to be uncomfortably hot. Covering the roofs with six inches of mud was might have been expected, the extra weight bent .d loosened the fastenings, and the roofs leaked e: the leakage probably being assisted by the growth .on in the mud covering.

. first reading Mr. Dorman's paper, he had received the ion that, though a corrugated iron type of roof was the which his temperature observations proved to be the most ble, there might perhaps be some scientific reason for the comfort which one experienced when residing in a room with is type of roof. He had therefore consulted Colonel Hendley, Deputy Director of Medical Service in India, on this point, and asked him whether, in his opinion, it would be possible for any of the sun's rays to penetrate a corrugated iron roof and produce the discomfort complained of. Colonel Hendley replied that some time ago it had been suggested that, by covering the inside of soldier's helmets with red lining, better protection from the sun would result, but, though this suggestion received no support from the exhaustive experiments carried out by the various brigades in India and Burma, a reference had been made to the Director-General of Meteorological Observatories, and, by the courtesy of Colonel Hendley and Dr. Simpson, he was able to reproduce verbatim the note which the Meteorological Department had written on the subject* : —

"Treated simply as a problem of physics the case is not difficult. The sun may have two effects : —

(*a*) A physiological effect due to the short rays on the analogy of Finsen rays as used for medical purposes.

(*b*) An effect which is the direct result of high temperature.

The red lining was proposed with reference to (*a*) as the result of a peculiar mixture of ideas. It was desired to get rid of the blue or short rays, and, because red glass and fabric are used in some cases for this purpose, the red lining was suggested. It was entirely overlooked that red materials are used to cut out short rays *only when it is required to let the long rays pass at the same time.* The best way to cut out chemical rays, or any other rays, is to use an opaque material.

All helmets are made of opaque material, and no rays which are known to be present in sunshine, chemical or otherwise, can

*It is understood that similar experiments were undertaken by the Phillipine School of Scientific Research about four or five years ago, when it was shown, by the use of thermopiles, that no benefit resulted from lining clothes and helmets with red or orange cloth.

pass through the walls of the helmet. Hence the red lining can be dismissed as of no value for the purpose for which it was proposed.

As regards the temperature effect, the main thing to be aimed at is to keep the temperature within the helmet as low as possible. The fundamental physical fact is that every surface exposed to the direct rays of the sun becomes warmer than the surrounding air. The amount by which it becomes warmer depends chiefly on the colour and nature of the surface. We may take it that a white surface exposed to the sun is much cooler than a dark one, but *both are warmer than the air.* Now the relatively hot outer surface of the helmet causes heat to pass inwards, but the amount of heat which passes depends on the power of the helmet to conduct heat and inversely on the thickness of the helmet. As pith and cork are both bad conductors of heat, and as they are so light that thick walls are possible without the helmet becoming too heavy, these materials are usually used for helmets.

As the surface of the whitest helmet on the side exposed to the sun is always warmer than the air, and as no material is a non-conductor of heat, the air inside the helmet will always in time warm up. Hence the only remedy is to remove the warm air as often as possible and replace it by the relatively cool air outside. In other words the best ventilated helmet will under all circumstances be the coolest.

In this respect it might be mentioned that in the present design of helmet the warm air leaves through the top ventilator, while it is replaced by air drawn in through the holes around the head band. This is obviously the wrong place from which to draw the new air for it is warmed up and made damp by the head of the perspiring man. If narrow tubes sloping downwards to the outside were inserted around the helmet above the brim, it would be easy to arrange that no direct radiation could enter, while the supply of cool air could be made as great as one wished.

To sum up we have :—

(*a*) The ventilation should be as good as possible.

(*b*) The walls should be made of the best non-conductor available and as thick as is consistent with a reasonable weight.

(*c*) The outside of the helmet should be of as light a colour as possible.

(*d*) The colour of the lining can have no direct effect."

They had, therefore, in selecting the correct type of roof, to bear in mind the following points brought out in this note :—

(*a*) To use an opaque substance for the purpose of cutting out chemical or any other rays.

(*b*) As every substance exposed to the direct rays of the sun became warmer than the surrounding air, to an extent depending chiefly on the colour and nature of the surface, it was therefore necessary to remove the hot air by ventilation, and to use roofing material light in colour and smooth in surface.

(*c*) The roofing material should be a poor conductor.

In addition to these conditions they must consider—

(*d*) The durability of the material.

(*e*) The impermeability of the material to damp or rain.

(*f*) If the roof was to be constructed by an engineer, the American definition of an engineer should be borne in mind as one who could do for a cent what a bungler could do for a dollar, and, finally, if the engineer desired public approbation, he should make the roof pleasing to the eye.

They had now to consider which of the roofs experimented upon by Mr. Dorman satisfied these conditions.

He could not agree with the remarks given in paragraph (*f*) of "analysis of results"* nor with those in the first paragraph under "Roof ventilation," which suggested that there was no advantage in having an air space, and ventilating that air space. On the contrary, he considered that the results of the experiments proved that there had been a considerable decrease in the temperature where an air space had been provided and properly ventilated.

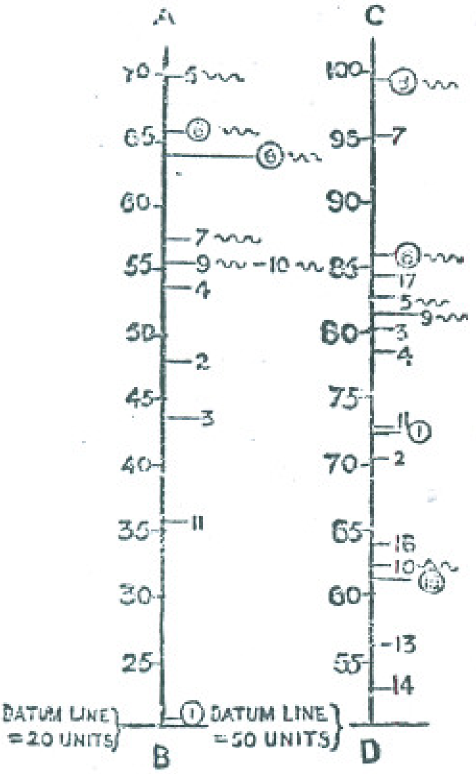
He had prepared a statement,† in which he had tabulated the differences between the temperature of the open verandah (No. 12 in the serial number of rooms) and the temperature in the various rooms. Column 15 was the total of these various differences for each individual room, for the temperatures recorded during the last ten days of September 1913, and on 27th September 1913, when the rooms were kept closed night and day. Column 28 gave the totals for the last ten

* See page 81. † Vide page 89*g*.

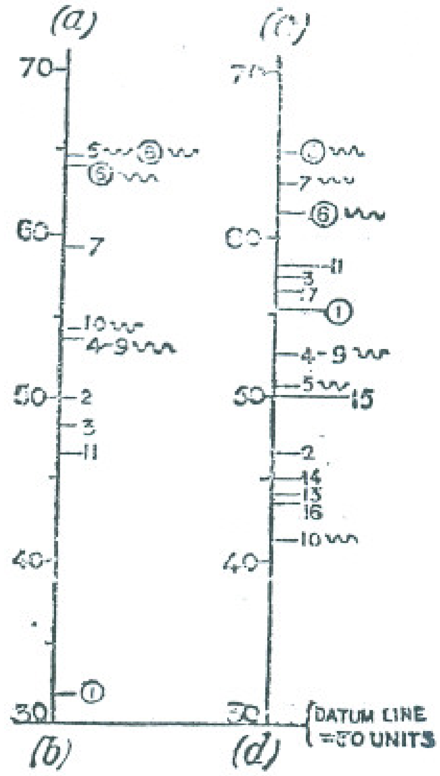
days of May 1914, for 28th May 1914, and 2nd June 1914, when the rooms were closed during the day, but opened at night, and the roofs had been provided with ventilators.

He had also diagramatically shown these totals.

DIAGRAM.




CORRECTED DIAGRAM.




The line A B represented column 15, and the line C D the totals given in column 28. The left hand figures on lines A B and C D showed the total differences in column 15, and the right hand figures the serial numbers of the rooms. The rooms which had been provided with a ceiling had a circle round them, thus ⑤, and those which had been roofed with corrugated material were distinguished by the mark ∿∿

The rooms nearer A and C were cooler than the open verandah, on the totals computed as above, by the distance of the room from the datum points B and D respectively. Thus in the totals shown in column 15, on the line A B, room No. 7 was 56·9 degrees cooler than the verandah, and 35·8 degrees than room No. 1, which, correspondingly, was 21·1 degrees cooler than the verandah. A glance at line A B brought out the interesting fact that the six coolest rooms, when kept shut night and day, were those covered with corrugated material. Comparing line A B with line C D, it would be noted that roof No. I had improved in its capacity for keeping the room cool, and that room No. 8 was far ahead of room No. 10, thereby showing the superiority of rooms provided with ceilings. It might, however, be argued that room No. 6 showed an opposite effect, but he did not consider the behaviour of this room could nullify the results of the other rooms, coupled with the scientific reasoning put forward by Dr. Simpson in his Note, and he was therefore of opinion that the temperature observations showed an advantage in having a ventilated air space.

It would, therefore, appear that a corrugated roof with a ceiling was the best type, and that the only objection to it was its appearance, but he considered the time had now come for a revision in the design of bungalows suitable for the heat of the plains of the Punjab, and he would suggest having double-storied bungalows with hollow walls fitted with ventilators at floor level of each storey, which would allow a continual flow of comparatively cool air up the hollow spaces of the walls and out through the chimneys or ventilators in the ridge. A fairly high parapet would block out most of the corrugated iron roof from sight. The suggestion was not entirely novel, as Mr. Begg, the Consulting Architect to the Government of India, had informed him that the Residency at Gwalior was built more or less on these lines, but he understood in this case no provision had been made for placing ventilators in the hollow walls at floor level. He put forward the suggestion of a new design for a plains bungalow as a subject on which, perhaps, some member might be tempted to write a paper for the next Congress.

RAI BAHADUR BAIJ NATH drew attention to the fact that Mr. Dorman began his paper by saying that the new Printing Press—the building in connection with which these experiments had been carried out—consisted of a very large room 217 feet by 159 feet, and that this meant a large roof compared with the wall area, and asked whether the temperature experiments carried out in small rooms with small roof areas would apply in the case of the big room.

MR. RODGERS said that the temperature observations conducted by Mr. Dorman had been carried out so thoroughly, and were so complete for the various types of roof in general use in that part of the country, that there was little information to add to his valuable paper.

The little he had to say on the subject merely verified the author's conclusion that a double roof, with an air space between, scarcely made any difference in the temperature of the room it covered. The North-Western Railway's Central Offices were double-storeyed, and the unfortunate officers, whose lot it was to occupy the upper rooms, complained of the heat in them as compared with those on the ground floor, and, to mitigate this, they demanded a second roof over the upper storey. Before, however, committing themselves to any expenditure on such a scheme, they had thought it prudent to make an experiment. They accordingly erected a roof consisting of corrugated asbestos and cement sheets laid on battens, resting on small brick pillars, over the Traffic Manager's room, and then took daily temperature readings over a period of about five months, at 9 A.M. and 3 P.M. inside his room, and also in the next room which had not been so protected.

The result of these observations shewed that the difference between the rooms on an average of the coolest days of the months at 9 A.M. was 0·6°, and at 3 P.M. 1·6°. On the hottest days of these months the difference at 9 A.M. was 1·2°, and at 3 P.M. 2·0°. On the general average for all days throughout the period the difference at 9 A.M. was 0·94°, and at 3 P.M. 1·6°. The differences being so small it was felt that they would not be justified in adding a second roof.

MR. DORMAN, in replying, said his problem had been to secure a light type of roof which would give the best results in practice. Mr. Astbury had mentioned that the ideal roof was one which would give the least difference between the maximum and minimum inside temperatures, but this meant a heavy roof, with greater powers of resistance than the walls inasmuch as the roof got the more sun. Such a roof was out of the question at the Press, where a large uninterrupted floor area was required.

He regretted that he must disclaim the credit of being the first Buildings and Roads engineer to produce a Congress Paper which Rai Bahadur Ganga Ram had attributed to him. He thought the type of roof which the Rai Bahadur had advocated would be expensive. It was an attempt to increase the resistance of the roof to the transmission of heat, which his experiments had shewn the flat mud roof did sufficiently well. It was little use increasing the resistance of the roof much beyond that of the walls with their openings, and efficient ventilation was a necessary adjunct to any such scheme.

He thought a system of water sprinkling and evaporation, as suggested by Rai Bahadur Bishambar Nath, had a good deal to recommend it, but he felt there would be practical difficulties in his detailed scheme. He had more than once thought of instituting a roof garden on his own bungalow, but had been deterred by qualms as to the strengths of the beams, and a feeling that the Municipality, who had strong views on the question of using pipe water for watering gardens, might hesitate about giving him a bath connection on top of the roof. His wife, after having had once or twice hastily to remove the dining room durrie during the rains, had also not been enthusiastic, so that the scheme fell through. Still he thought a building could be fairly easily designed to surmount these difficulties, and the introduction of the roof garden, which was much appreciated in other parts of the world, might also contribute to keeping down the temperature inside their bungalows.

The claims of the jack arched type of roof advocated by Mr. Duthy had been considered, but finally rejected, when it was learned that the *Civil and Military Gazette* Press had to replace a jack arched roof in their machine room with eternit tiles, owing to the way in which particles of lime and brick, shaken loose by the slight vibration set up by the machinery, and also possibly by the action of salt-petre, penetrated and damaged their printing plant. The large number of columns would also have been objectionable. There were various types of double jack arches, with well ventilated spaces between the concentric arch rings, which he would commend to Mr. Duthy's attention. The only timber in the Press roof was the boarded ceiling—the corrugated iron sheets being supported directly on purlin joists carried by steel trusses, while the north glazing was secured in steel astragals.

He was sure every member would be grateful to Mr. Sleigh for pointing out that there was no advantage in having a red lining to an opaque substance, and that in future they would probably get nearer the American ideal engineer by saving eight annas on the red silk lining when buying their new topies. Mr. Sleigh had postulated a light colour and a poor conductor for a roof, but he did not think either, in reality, made much practical difference in a thin roof. On reference to his diagrams he found that there was very little difference between rooms roofed with red eternit, grey eternit, or corrugated iron. He had been led to expect a considerable diminution of temperature from the use of white paint, in fact a firm of paint manufacturers had informed him that a railway official in Lahore had experimented with painted and unpainted drums some years ago, with the results that a drum painted white had shewn a reduction in temperature, as compared with an unpainted drum, of twenty-five to thirty degrees. Unfortunately, however, the railway (not having a proper investigation section) could now find no trace of these records. His own experiments had satisfied him that whi e painting would not reduce the temperature by more than a degree or a degree and a half. He also thought that a bad conductor would eventually reach the same temperature as a better conducting material and would delay the transmission of heat so slightly as hardly to effect the ultimate result.

Mr. Sleigh's diagrams obtained by adding up the maximum, minimum, morning, and hourly temperatures were misleading. The results would have been fairly comparable had only the readings taken almost simultaneously in the different rooms at certain hours during the hottest portion of the day been considered, but the inclusion of the morning temperature, and still more of the average minimum temperature, obtained during a ten day period, tended to vitiate the results. The larger number of hourly readings had, to a certain extent, neutralised the error, but not to the same extent in the two series of figures, inasmuch as in the first series there were eight readings taken during a single day to minimize the error caused by the inclusion of one set of maximum, minimum and morning readings, while in the second series there were only six readings taken during one day to minimize the error caused by two sets of maximum, minimum and morning readings. He had taken the liberty of plotting two more lines of figures side by side with Mr. Sleigh's diagrams to shew the results obtained after eliminating the maximum, minimum and morning readings from Mr. Sleigh's figures. By just adding up the figures in the three columns on page 79 it would be found, on Mr. Sleigh's principle, that the open verandah was about the coolest spot.

He could not agree that the time had come for double-storeyed buildings with corrugated iron roofs, while so many had still to spend their hot weathers in the plains, and knew from experience the advantage of having a flat roof on which to sleep at night.

As pointed out by Rai Bahadur Baij Nath the temperatures in the small rooms were not directly comparable with that in the Press, but the experiments had been made under identical conditions, and on a sufficiently large scale, to give reliable results between the materials tried.

It was satisfactory to find independent corroborative evidence such as that brought forward by Mr. Rodgers.

COLONEL CRA'STER, in conclusion, thanked Mr. Dorman for his interesting paper, and the members for the way in which they had criticised it. As had been shown there was very little difference in the temperature experiments which had been carried out in the Railway Offices. As regards the different methods of roofing, jack arched roofing, he considered, was as good as anything, and seemed to recommend itself both by reason of its comparative cheapness in first cost and the low cost of maintenance.

| 8TH MAY 1914. | | | 2ND JUNE 1914. | | | | | | Total of columns 16 to 27. |
|---|---|---|---|---|---|---|---|---|---|
| *xi-m.* | *Mini-mum.* | *8 A. M* | 8 | 10 | 12 | 2 | 4 | 6 | |
| 9 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 3·5 | 10·5 | —6·5 | —4·5 | —11·5 | —12·5 | —12·5 | —9·0 | —5·5 | —71·7 |
| 3·5 | 6·5 | —7·5 | —5·0 | —10·0 | —10·5 | —9·0 | —7·5 | —4·5 | —70·4 |
| 3·5 | 10·0 | —7·5 | —5·0 | —12·0 | —13·0 | —11·5 | —9·5 | —6·5 | —80·2 |
| 4·5 | 6·5 | —8·0 | —5·5 | —11·0 | —11·5 | —10·5 | —8·0 | —5·5 | —78·3 |
| 4·0 | 3·5 | —8·0 | —5·5 | —11·0 | —11·0 | —10·0 | —8·0 | —5·0 | —82·2 |
| 7·0 | 8·5 | —7·5 | —4·5 | —12·0 | —14·0 | —14·0 | —10·5 | —6·5 | —85·9 |
| 7·0 | 6·5 | —8·5 | —6·0 | —12·5 | —14·0 | —13·5 | —10·5 | —6·5 | —95·0 |
| 7·5 | 5·5 | —8·5 | —6·0 | —12·0 | —14·5 | —14·0 | —11·0 | —7·5 | —99·2 |
| 5·0 | 5·5 | —7·5 | —5·0 | —11·0 | —11·5 | —10·5 | —8·5 | —5·5 | —81·5 |
| 3·0 | 6·0 | —6·0 | —4·0 | —9·0 | —9·0 | —8·5 | —6·5 | —4·0 | —62·2 |
| 5·5 | 11·5 | —4·5 | —2·5 | —11·0 | —14·0 | —14·0 | —11·0 | —5·5 | —72·0 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 3·0 | 10·5 | —5·5 | —3·5 | —10·0 | —10·5 | —10·0 | —7·0 | —3·0 | —55·8 |
| 3·0 | 11·5 | —4·5 | —2·5 | —10·0 | —11·0 | —10·5 | —7·5 | —3·5 | —52·7 |
| 2·0 | 10·5 | —5·5 | —3·0 | —10·5 | —12·0 | —11·5 | —8·5 | —4·5 | —61·0 |
| 2·5 | 6·5 | —6·0 | —4·0 | —10·0 | —11·0 | —8·5 | —6·5 | —3·5 | —64·0 |
| 3·5 | 4·5 | —7·5 | —6·0 | —12·5 | —13·0 | —12·0 | —8·5 | —4·5 | —84·1 |

| No. of room. | Roofing material. | Cost of roof per hundred square feet laid in position. | Last 10 days of September 1913 | | | |
|---|---|---|---|---|---|---|
| | | | *Maximum* | *Minimum.* | *8 A.M.* | 8 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | | Rs. a. p. | | | | |
| 1 | Red eternit F pattern tiles on battens with an eternit ceiling fixed below the rafters. | 42 4 0 Add for ceiling. 45 6 0 | —6 | 15·9 | 1·5 | 3 |
| 2 | Gray eternit F pattern tiles on battens ... ... ... ... | 40 14 3 | —8·7 | 12·6 | —1·6 | |
| 3 | Gray eternit F pattern tiles on $\frac{3}{4}''$ boards ... ... ... ... | 53 12 0 | —9·2 | 14·6 | — 0 6 | 1 |
| 4 | Asbestone sheets on battens ... | 32 5 0 | — 9·3 | 11·6 | — 2·1 | —0 |
| 5 | Asbestos corrugated sheets on battens ... ... ... ... | 65 1 6 | —10·7 | 9·1 | —3·7 | —3 |
| 6 | 22 B. W. G. corrugated iron sheets laid directly on $\frac{3}{4}''$ boards with 3/16″ fibro cement ceiling below the rafters... ... ... ... | 84 13 11 | —11·3 | 13·1 | —1·6 | —0 |
| 7 | 22 B. W. G. corrugated iron sheets laid directly on $\frac{3}{4}''$ boards ... | 46 5 3 | —10·3 | 14·1 | —1·7 | —0 |
| 8 | 22 B. W. G. corrugated iron sheets on 2″ battens over $\frac{3}{4}''$ boards ... ... ... | 50 2 3 | —11·1 | 12·7 | —2·2 | —0 |
| 9 | 22 B. W. G. corrugated iron sheets on battens, sheets painted two coats of white corrugal paint ... | 31 6 3 | —9·4 | 9·4 | —1·9 | —1 |
| 10 | 22 B. W. G. corrugated iron sheets on battens... ... ... ... | 28 6 3 | —8·5 | 9·9 | —2·1 | —1 |
| 11 | (Gate Lodge) second class mud roof consisting of 6″ mud on $1\frac{1}{4}''$ tiles | ... | —5·8 | 15·1 | 1·3 | 4 |
| 12 | In open verandah ... ... ... | ... | ... | ... | ... | ... |
| 13 | Three ply Genasco on $\frac{3}{4}''$ boards ... | 36 7 3 | ... | ... | ... | ... |
| 14 | Three ply Malthoid on felt on $\frac{3}{4}''$ boards ... ... ... ... | 56 7 0 | ... | ... | ... | ... |
| 15 | Red poilite tiles on battens with $\frac{1}{2}''$ pine ceiling ... ... ... | 40 1 3 Add for ceiling. 14 4 3 | ... | ... | ... | ... |
| 16 | Roman tiles on battens ... ... | 50 7 0 | ... | ... | ... | ... |
| 17 | Single Allahabad tiles on battens... | 22 0 0 | ... | ... | ... | ... |

# Tabulated Statement.

THERMOMETER READINGS.

| | 27th September 1913. | | | | | | | Total of columns 4 to 14. | Last 10 days of M 1914. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12 | 13 | 14 | 15 | 16 | 17 | 18 | | *Maximum.* | *Minimum.* | 8 A |
| | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| ·0 | —7·0 | —11·5 | —9·0 | —7·5 | —3 0 | 1·0 | 2·5 | —20·1 | —11·8 | 8·4 | —5 |
| c | —9·0 | —13·0 | —10 0 | —9·0 | —6·0 | —2·0 | —1·0 | —47·7 | —10·3 | 5·5 | —4 |
| ·0 | —9·0 | —13·5 | —11·0 | —10·0 | —6·0 | —0·5 | 1·0 | —43·2 | —10·6 | 3·8 | —4· |
| ·5 | —9·5 | —13·5 | —11·0 | —9·5 | —6 0 | —2·5 | —1·0 | —53·3 | —11·3 | 6·3 | —5· |
| ·0 | —11·0 | —15·0 | —12·0 | —11·0 | —7·0 | —3 | —2·5 | —69·8 | —11·3 | 3·5 | —5· |
| ·5 | —10·5 | —15·0 | —13·0 | —11·5 | —8·0 | —3·5 | —2·0 | —63·8 | —13·5 | 8·8 | —3 |
| ·5 | —10·0 | —14·5 | —12·5 | —11·0 | —7 0 | —2·5 | —1·0 | —56·9 | —13·6 | 6·1 | —5· |
| ·5 | —11·5 | —15·5 | —12·5 | —11·5 | —7·5 | —3·5 | —2·0 | —65·1 | —13·8 | 5·3 | —5· |
| ·0 | —9·0 | —13·0 | —11·0 | —10·0 | —6·0 | —2 5 | —1·0 | —55·4 | —11·9 | 4·8 | —5· |
| ·0 | —9·0 | —13·0 | —11·0 | —10·0 | —6 0 | —2·5 | —1·5 | —54·7 | —9·9 | 5·5 | —3· |
| 0 | —10 0 | —14·0 | —12·0 | —10·0 | —5·0 | —0·5 | 1·5 | —35·4 | —12·8 | 9·4 | —2·1 |
| | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | ... | ... | ... | ... | ... | ... | ... | ... | —10·2 | 9·3 | —2·9 |
| | ... | ... | ... | ... | ... | ... | ... | ... | —9·1 | 9·9 | —2· |
| | ... | ... | ... | ... | ... | ... | ... | ... | —10·6 | 9·6 | —3· |
| | ... | ... | ... | ... | ... | ... | ... | ... | —10·0 | 5·5 | —4· |
| | ... | ... | ... | ... | ... | ... | ... | ... | —10·2 | 4·7 | —5·6 |