PAPER No. 361

Influence of Parapet Walls on the Ventilation of Roof

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Introduction

In addition to the maximum utility of space, economical planning and the introduction of attractive lines, the present-day architect is also trying to look after the thermal efficiency of buildings as far as possible. Effort is made in every layout to utilize to the maximum the environmental factors to improve the indoor comforts in a house so as to promote better and healthier living.

Unfortunately very little is known about the air flow patterns in and around the buildings. These patterns are very greatly influenced by the geometry and the surroundings of the buildings. It is the intention of the Building Research Station to study systematically the effects of various factors that govern the air flow in and around the buildings and a long range programme has, therefore, been chalked out to carry out the experimentation.

The major problem, in this country is to keep away the summer discomforts as only insignificant percentage of inhabitants of this country can afford the luxury of airconditioning. The thermal behaviour of dwellings during winter does not pose any problem but the unbearable heat during the months of April to September make the living very uncomfortable and if it is possible to modify the internal temperatures by the utility of natural ventilating factors it will improve the internal comforts to a significant extent at a much reduced cost.

The present study is restricted to the observation of air flow pattern over the surface of the roof. Roof forms a very important component of the building as it receives the highest solar load in summer and thus has a great bearing in conditioning the indoor temperature.

Distribution of Solar Load

Table 'A' given below shows the daily mean values of incident solar intensity expressed in B.T.U. per square foot/day for each month on the assumption that every day is "Clear". A clear day for the purpose of computation is defined as that day which is totally free from clouds when the atmosphere contains 15 mm of precipitable water, 2.5 mm of Ozone and 300 dust particles per cubic cm. The computations have been carried out under 760 mm of barometrical pressure. The solar constant has been assumed to be equal to

1.97 grams calories per square cm per minute. This is a figure accepted by International Meteorological Society. Variations in these values due to ellipticity of earth have been ignored.

TABLE 'A'

Table showing the Incident Solar Heat in B.T.U. per square foot/day.

Month		Roof	Eastern wall or Western wall	Southern wall	Northern wall
January	..	962	498	1457	..
February	..	1265	616	1368	..
March	..	1643	759	1088	..
April	..	2010	881	625	33
May	..	2256	944	322	148
June	..	2363	958	152	266
July	..	2322	951	210	218
August	..	2153	918	472	81
September	..	1834	826	874	7
October	..	1453	690	1254	..
November	..	1095	549	1431	..
December	..	911	475	1464	..

The table above represents the value of the solar radiation incident on clear days at latitude of 31° 30 minutes north. This is the latitude of Lahore and similar figures can also be worked out for different latitudes covering different cities.

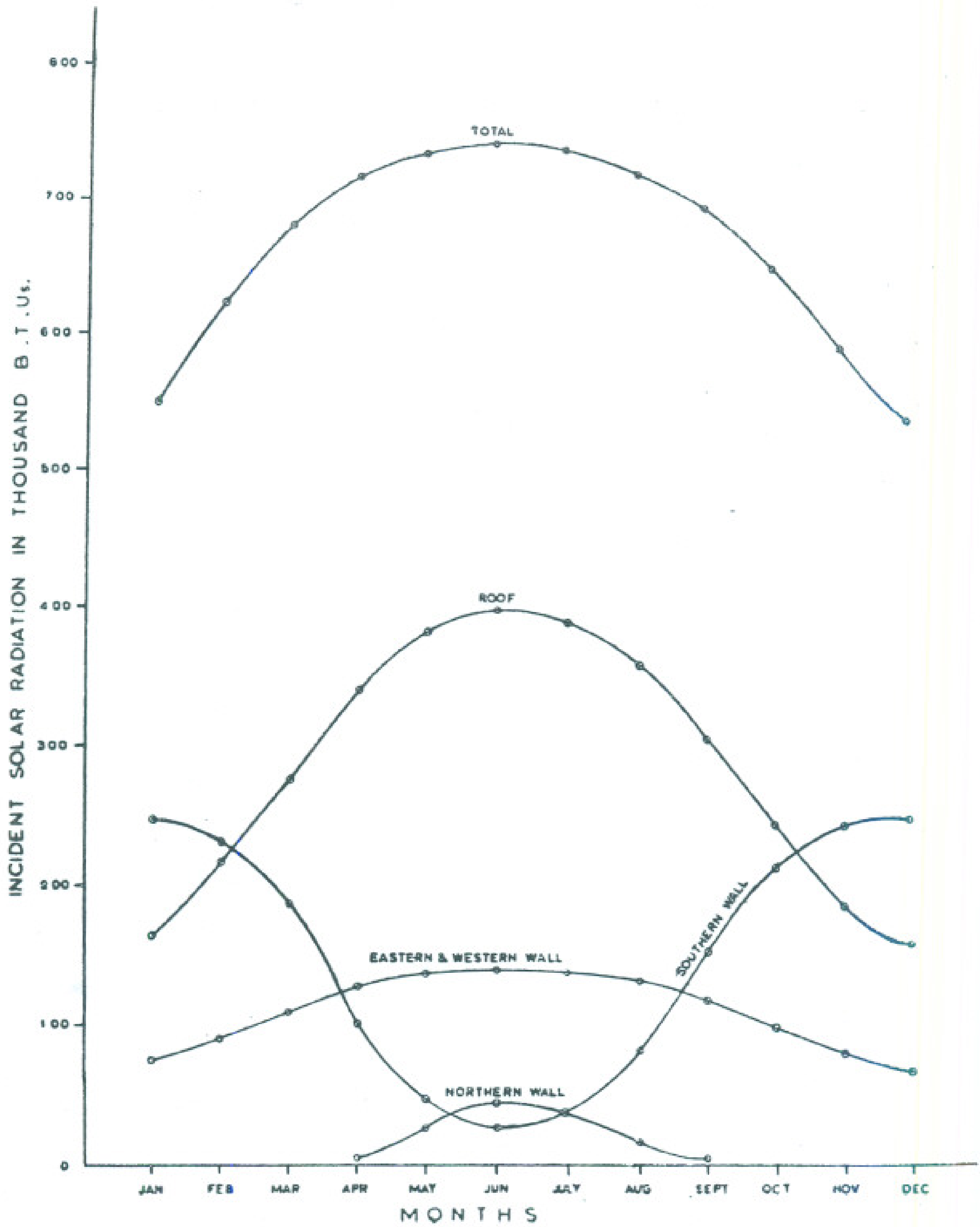
Table 'B' shows the incident solar heat, percentage load on each component and comparative solar load of a room 12′×14′ with a height of 12′. The room has been supposed to be orientated in such a way that the 14′ length of the room is facing north. From table 'B' it can be observed that the amount of direct solar radiation incident on a clear day on a roof varies from 44 to 53% of the total during the months of April to September. During the summer

TABLE 'B'

Table showing the incident Solar Radiation in thousand B.T.Us; Percentage load on each component and Comparative solar load on roof

Month.	1. Roof	1. Eastern / Western wall	1. Southern wall	1. Northern wall	1. Total	2. Percentage of total. Roof	2. Percentage of total. Eastern / Western wall	2. Percentage of total. Southern wall	2. Percentage of total. Northern wall	3. Ratio of solar loads Roof. / Eastern / Western wall	3. Ratio of solar loads Roof / Southen wall
January ..	162	72	245	..	551	29.4	13.6	44.4	..	2.2	0.7
February ..	213	89	230	..	621	34.3	14.3	37.0	..	2.4	0.9
March ..	276	109	183	..	677	40.7	16.1	27.0	..	2.5	1.5
April ..	338	127	105	6	703	48.1	18.1	14.9	0.9	2.7	3.2
May ..	379	136	54	25	730	51.9	18.6	7.4	3.5	2.8	7.0
June ..	396	138	26	45	743	53.3	18.4	3.5	6.1	2.9	15.2
July ..	390	137	35	37	736	52.9	18.6	4.7	5.0	2.8	11.1
August ..	362	132	79	14	719	50.3	18.3	10.9	1.9	2.7	4.5
September ..	308	119	147	1	694	44.3	17.1	21.1	..	2.6	2.1
October ..	244	99	210	..	652	37.4	15.2	32.2	..	2.5	1.1
November ..	184	79	240	..	582	81.6	13.5	41.2	..	2.3	0.8
December ..	153	68	246	..	535	28.6	12.9	45.9	..	2.2	0.6

Graph Showing Distribution of Solar Radiation during the Year on a Room Size 12′×14′×12′ at Lahore. (Lat. 31°-31′)



season the loads of solar intensity on the northern and southern walls are minimum and the maximum intensity is found on the western and western walls.

Figures given in table 'B' have also been represented graphically for immediate grasp of the distribution of incident solar radiation. From the graph a difference of 2,56,000 B.T.U. for a room of $12' \times 14'$ can be seen between the hottest wall and the roof. Incidentally the graph also gives an interesting study of the various components of a room and can also be utilised for the proper orientation of a house. It may be observed that during the summer season the eastern and western walls have the maximum solar load and it will, therefore, be desirable to have unimportant rooms on the eastern and western sides. The solar intensity graph for the southern wall shows the compromising attitude of the nature. The load on the southern phase is minimum during the summer season and maximum during the winter season, when the heat actually is required. Although the subject of orientation is not a part of this paper but a passing reference has been made as a matter of general interest. Column 3 of table 'B' also shows that the amount of solar load on the roof varies from 2 to 3 times than that on the eastern or western wall during the months of March to September and is as high as 16 times when compared to the southern phase of the room.

From these figures one can conclude that the amount of solar load on the roof is maximum. This high intensity although welcome in winter is most undesirable during the summer, as it raises the internal temperature of the room considerably. Consequently the amount of heat conducted into the room through roof is maximum depending upon the type of construction of the roof. For this study the type of the roof construction has been omitted and only the solar load on different parts of the room has been taken as a criteria for gauging the intensity of heat that flows in from different sides of the room.

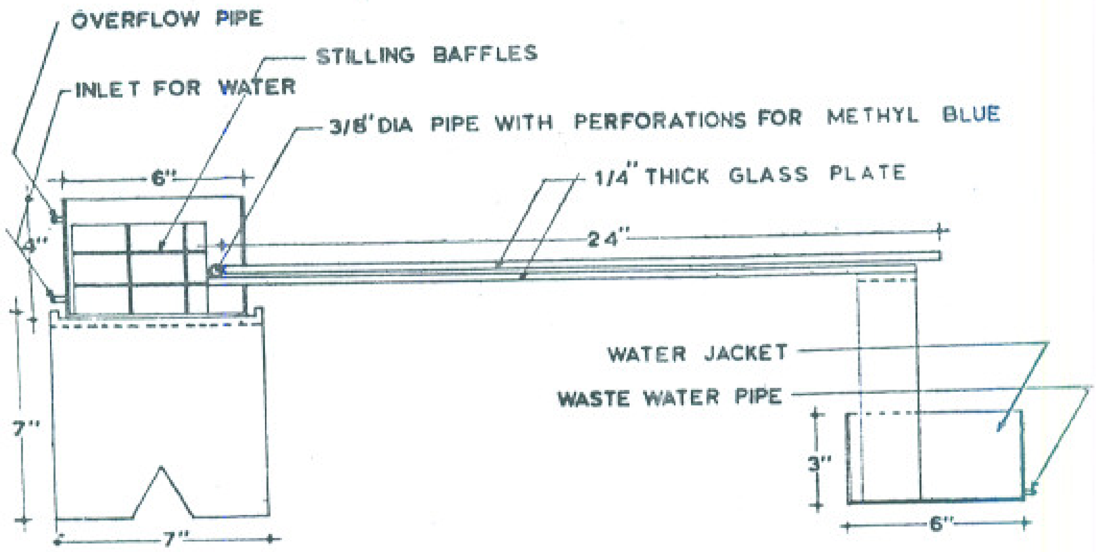
From the above, the problem comes out to that if some methods are adopted to ventilate the roof of a room, which has the maximum solar load, it should be possible to improve the inside thermal comfort of a dwelling. With this idea the first item which has been experimented upon is the parapet walls which are usually constructed on the roof and the present study restricts itself to the influence of parapet walls on the ventilation of the roofs.

Apparatus

It may be realised that full scale field study of this problem will involve many variables and many complex problems culminating in great difficulties. To cope with this difficulty a small inexpensive apparatus has been set up in the Building Research Station Lahore to carry out the model studies on the analogy of flow of water. The principle involved in this instrumentation is that the laminar flow of air can be simulated by an analogous flow of water, if air is considered incompressible.

A drawing showing a view of the apparatus is given below:

Hydraulic Analogue Apparatus



Drawing No. 1

The apparatus consists of two $\frac{1}{4}''$ thick glass plates of size $24'' \times 16''$ separated from each other by a gap of 1/16 of an inch which is provided by a strip of graphite paper of the same thickness at each side. The two plates with the graphite paper are kept pressed against each other with the help of clamps. One end of the two plates is inserted in a small chamber containing a constant head of water. A pipe 3/8″ internal dia is placed at the junction of the plates inside the water chamber. This pipe contains a number of pin-point perforations spaced equally at intervals of $\frac{1}{4}''$ and is connected to a supply of methyl blue. Colours like that of Potassium Permanganate and Niger Black can also be used. Water is allowed to enter in the tank and the eddies produced in the tank are damped by the provision of baffles so as to ensure a steady and smooth flow of water through 1/16″ gap between the two plates. All leaks are stopped with plasticine. The air flow pattern around any model can be picturized by allowing the methyl blue lines accompanying the water flowing into 1/16″ gap.

Experimentation.

Graphite paper was used to prepare two dimensional models to a scale of 1/24′. Various sizes of rooms were studied but the study on a typical room of size $12' \times 14'$ with varying heights of parapets is reported here as the observations with other sizes are similar. The models were slipped in the 1/16″ gap between two glass plates. Water flowing in the gap carried the blue coloured lines which represented the air-flow patterns around the model under study.

The air-flow patterns as indicated by the coloured lines were photographed and are discussed in the ensuing passages.

Observations.

Parapets $7\frac{1}{2}''$ high

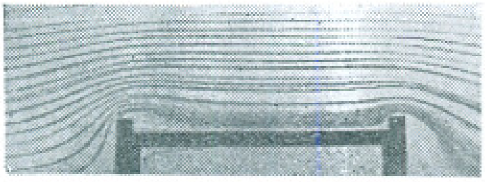


Photo No. 1

Parapets $10\frac{1}{2}''$ high

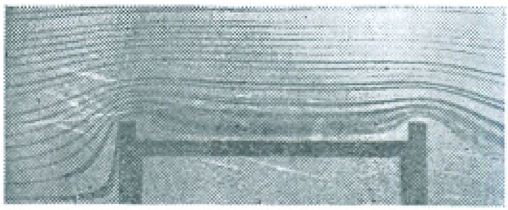


Photo No. 2

Parapets $13\frac{1}{2}''$ high

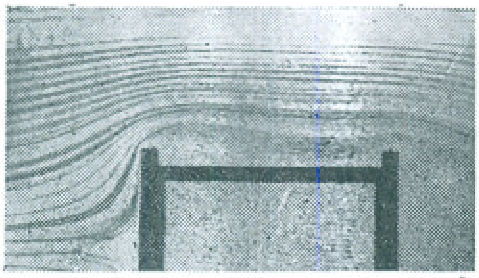


Photo No. 3

Parapets 18″ high

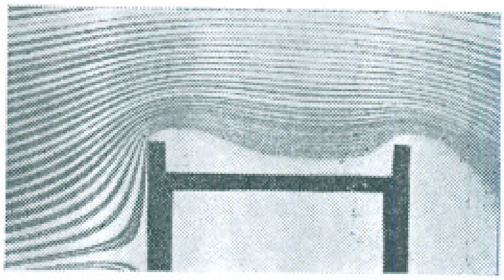


Photo No. 4

Photographs No. 1 to 5 represent the flow pattern of air around the roof of a room of size $12' \times 14'$ with parapets height varying from $7\frac{1}{2}''$ to 2′—6″. Photograph No. 4 represents a room with parapets 18″ on both sides. This photograph vividly brings out the fact that in the presence of the parapets the moving air has a tendency to keep away from the roof surface. This tendency goes on increasing with the increasing heights of the parapets. This pattern of air flow is undesirable as, otherwise, the breeze while passing over the roof can carry away heat of the roof thus reducing its solar load.

Parapets 30″ high

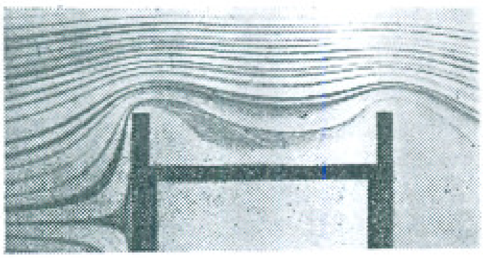


Photo No. 5

Oneside Parapet

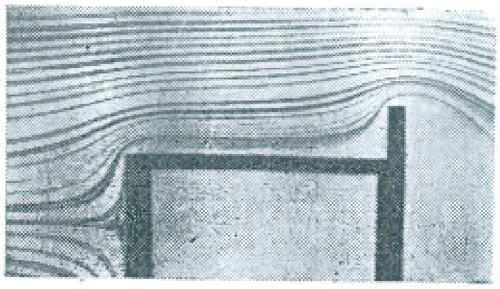


Photo No. 6

Photograph No. 6 shows the effect of removing one side parapet. Although this is not a practical case but the observations have been taken only with acedamic interest. From this photograph it can, however, be clearly

Detail of Various Experimental Roof Projections:

FIG NO. 1

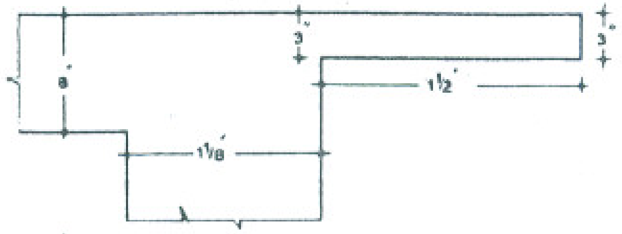


FIG NO. 2

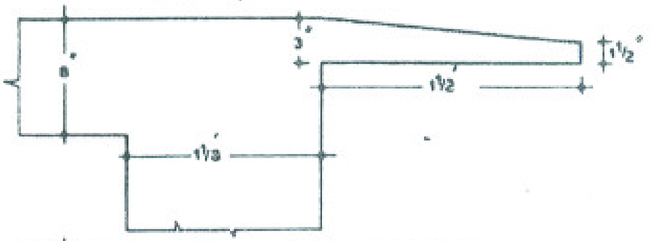


FIG NO. 3

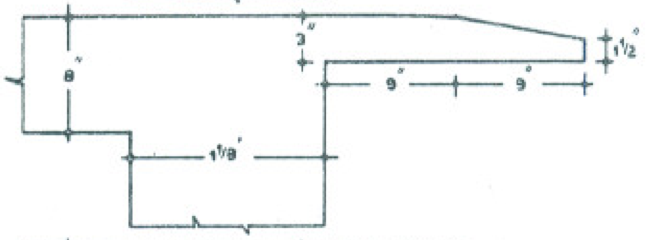


FIG NO. 4

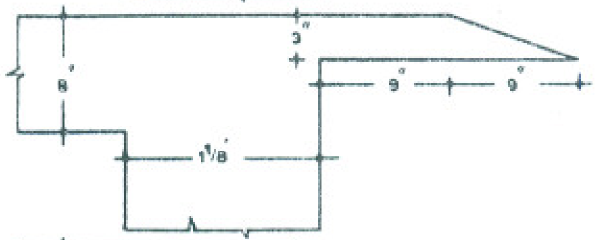


FIG NO. 5

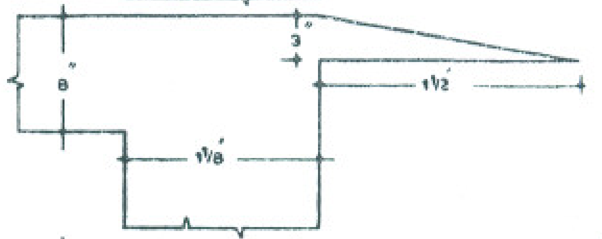
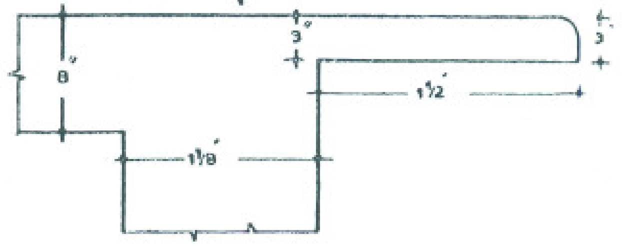


FIG NO. 6



Drawing No. 2

seen that the parapet has a very pronounced tendency to lift up the air current and obstruct ventilation, thus preventing the flowing air to come in contact with the roof.

Photograph No. 7 shows the air-flow patterns in a case when both the parapet walls have been removed. This arrangement encourages the air streams to come nearer the roof but the wall corners have a tendency to lift the air stream.

No Parapets

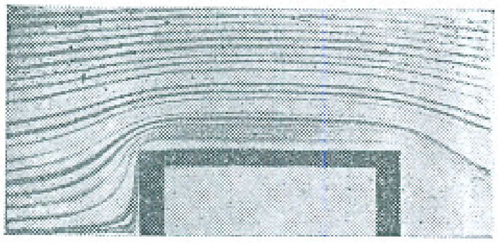


Photo No. 7

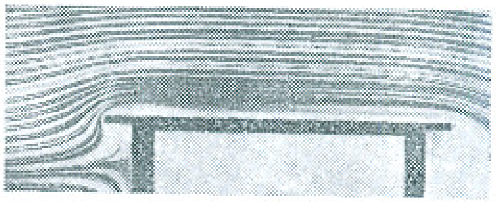


Photo No. 8

To overcome this tendency six different alternatives were tried in which a projection of $1\frac{1}{2}'$ beyond the wall was provided. The thickness of this projection was kept as 3″. Diagram No. 2 shows the details of various types of projections tried to improve the air-flow pattern. The different types of air-flow patterns obtained with each type are discussed below:

Model of Fig. No. 1 as shown in photograph No. 8 was tried and from the air-flow pattern it can be observed that the sharp edges of the projection have a great tendency to lift the air streams in a detrimental fashion.

The air-flow pattern corresponding to figure No. 2 is represented in photograph No. 9. The light improvement in the sense that the air steam has a tendency to come nearer to the roof is observed but it is still far away from the ideal condition.

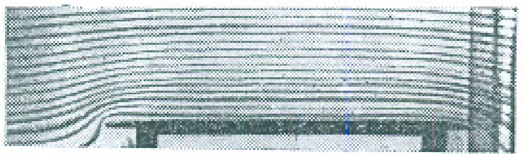


Photo No. 9

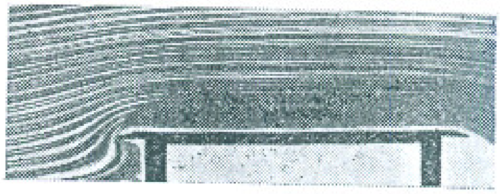


Photo No. 10

Fig. No. 3 represented by Photograph No. 10 does not give satisfactory results as the air does not come in contact with the roof.

TABLE "C"

Table showing the Velocity of Wind at Lahore during the year

Month	Velocity of Wind in Knots/Hr.							Mean Velocity in Knots/hr.	Mean Velocity in ft./Sec.
	1947	1948	1950	1951	1952	1953	1954		
January ..	..	2.0	2.1	2.3	1.8	..	..	2.05	3.48
February ..	..	2.6	2.3	3.0	1.9	2.3	2.8	2.48	4.21
March ..	..	3.5	3.0	3.0	3.0	..	..	3.13	5.32
April ..	..	4.0	3.4	2.7	2.8	..	2.4	3.06	5.20
May ..	..	4.1	3.0	3.6	2.9	..	..	3.40	5.78
June ..	..	2.8	2.6	3.9	3.8	..	..	3.28	5.57
July ..	..	..	2.9	3.4	3.1	..	..	3.13	5.32
August ..	4.1	..	2.4	2.7	2.9	..	..	3.03	5.15
September ..	2.9	..	2.7	1.8	1.9	..	..	2.33	3.96
October ..	2.0	..	1.3	1.7	..	..	..	1.67	2.84
November ..	1.2	..	1.4	1.7	1.1	..	..	1.35	2.29
December ..	2.2	..	1.0	1.0	1.4	..	..	1.40	2.38

Fig. No. 4 represented by Photograph No. 11 gives better results but the ideal conditions yet remain to be achieved.

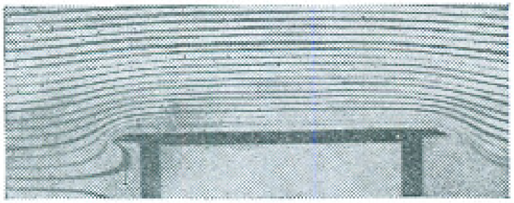


Photo No. 11

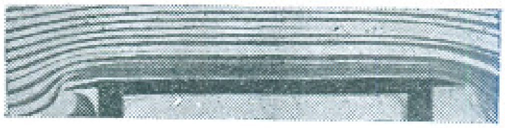


Photo No. 12

Fig. No. 5 which is a modification of Fig. No. 4 and is represented by Photograph No. 12 does not give the desired air-flow patterns.

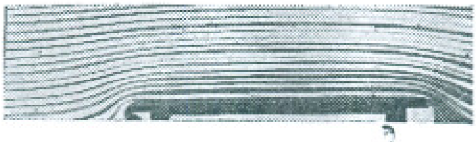


Photo No. 13

The air-flow pattern of Fig. 6 represented by Photograph No. 13 gives the most satisfactory results. In this case the air stream completely flows hugging over the roof. This is an ideal condition in which the moving air takes away some of the heat load on the roof which is naturally reflected in the reduction of heat conducted through the roof thus improving the indoor climate.

Comparison of Hydraulic Characteristics of Prototype and Model

Before arriving at any conclusion on the basis of the experience reported heretofore, it is essential to compare the hydraulic characteristics of the prototype with the model employed in the Laboratory. The magnitude of the Reynolds Number, a dimentionless parameter involving the product of velocity and the characteristic length divided by kinematic viscosity of the fluid is the well-known and well-recognised measure of dynamic similarity as well as the nature of flow.

Computation of Reynolds Number

$$\text{Reynolds Number } R = \frac{V \times L}{\nu}$$

Where V = Velocity in feet/sec.

L = Characteristic length *i.e.*, height.

ν = Kinematic Viscosity of the fluid.

Reynolds Number for Prototype.

For finding out the Reynolds Number for Prototype help has been taken of the Meteorological data for the wind velocity. Table 'C' shows the velocity of the wind at Lahore during different months of year. The mean velocity of the wind has been taken for the months of March to August which are hot months during the year. The average velocity for these months works out to be 5.4 fee/sec. The average temperature of the air has been taken as 80°F.

So the Reynolds Number

$$R_p = \frac{5.4 \times 12}{1.69 \times 10^{-4}}$$

$=38.3 \times 10^4$. Where 12 ft. is the height of the room.

Reynolds Number for the Model

Form the actual observations the velocity of water in the model has been found to be 0.28 feet/sec. The viscosity of water at 70°F has been taken as 1.05×10^{-5}. Therefore, the Reynolds Number

$$R_m = \frac{0.28 \times \frac{1}{16 \times 12}}{1.05 \times 10^{-5}}$$

$= 140$

From the magnitude of Reynolds Number in the model as well as from the Photographs Nos. 1 to 13 it will be observed that the flow in the model is laminar.

From the magnitude of Reynolds number in the prototype it is clear that it is much higher than the known limits of R, where laminar flow in real case is possible and thus it is fair to conclude that the flow in prototype will almost always be turbulent. For having a Reynolds Number 140 the velocity of the air in the Prototype works out to be 0.002 ft./sec.

It is well known that higher the magnitude of the Reynolds Number the greater is the mixing in a flow. Heat removal from surface being directly depending upon the rate of mixing, it may be concluded that for this flow in prototype the rate of heat removal *i.e.* ventilation of the roof will be much greater.

It is not difficult to see that the absence of the parapet will be conducive to the removal of points of stagnation *i.e.* the points where ventilation is difficult, in the same manner in turbulent flow as in laminar flow.

Absence of parapets, therefore, helps in mixing of the heated layers next to the roof with those layers of live stream of air which are carried away from the roof.

Conclusions

(1) From the above study it is clear that the parapet walls over the roof obstruct the ventilation of the roof and should, therefore, be omitted.

(2) It is desirable that the slab of the roof should be projected about 1½ foot beyond the wall with a little curvature at the end which makes the air stream to flow completely hugging over the roof. The moving air takes away solar heat thus influencing the internal temperature.

(3) The present practice of providing railing will not hinder the ventilation of the roof and may be adopted where considered necessary without detriment to ventilation. But in houses where the inhabitants usually do not go upstairs, even the railing can be avoided.

Advantages of Projected Roof

(1) The overhanging roofs have the additional advantage of protecting from the sun a significant portion of the wall which will remain under the shade.

(2) It helps in reducing leakage of water through the junction of slabs and parapet.

(3) It throws rain water off the building face and protects a large portion from rain splashes.

(4) It allows full bearing of roof on the walls thus stopping rain penetration through joints.

Economics of the Suggested Roof Projection

Lest it should be thought that the cost of the proposed projection of the roof will be an abnormal burden on the cost of the house, Appendix 'A' shows the analysis of rates for a parapet wall 9″ thick and 13½″ high and a corresponding rate for the recommended R.C.C. roof projection. It can be seen that the new recommendation increases the cost by about 1½ times. For a house with a plinth area of 2,000 square feet the approximate increase in the total cost will be about Rs. 700 but the extra advantage of improving the indoor comforts for the whole house on this reduced cost should not invite any criticism. The improvement in the architectural features of the house should not escape the attention which increases the property value.

Acknowledgment

The author is indebted to Mr. Ashfaq Hasan, P.S.E. (I)., Director, Building Research for his abundantly available guidance and useful suggestions during the course of this stduy. The author is also thankful to Dr. Mubashar Hasan for the improvements suggested by him.

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(2) Climatological & Solar Data for India C.B.R.I., Roorkee, India.

APPENDIX "A"

I. ANALYSIS OF RATE FOR PARAPET WALL 9″ THICK AND 13½″ HIGH IN 1: 6 CEMENT MORTAR.

1. B. B. in cement in super-structure.

(*i*) Parapet walls $1 \times 10 \times 3/4 \times 1\text{-}1/8 = 8.5$ cft.

Brick Masonry against slab $1 \times 10 \times 3/4 \times 1/4 = 1.9$ cft.

= 10.4 cft. at Rs. 31/-% cft. =Rs. 3.22

(*ii*) Drip Course. = 10 Rft. at Rs. -/1/6 Rft. =Rs. 0.94

(*iii*) Cement Plaster (1:3)$=10 \times 1 = 10$ sft. at Rs. 6/-% =Rs. 0.60

(*iv*) Cement Pointing (1: 2) Struck Joints on wall

$=10 \times 5/2 = 25$ sft. at Rs. 5/-% sft. =Rs. 1.25

(*v*) 2 Coats of Bitumen$=10 \times 1 = 10$ sft. at Rs. 3/-% sft. =Rs. 0.30

Total: Rs. 6.31

Add 300 % premium..................... =Rs. 18.93

Total: Rs. 25.24

Rate per Rft.$=\frac{25.24}{10}=$Rs. 2.52

II. ANALYSIS OF RATE FOR R.C.C. ROOF PROJECTION 3″ THICK AND 1½ FOOT PROJECTED OUTSIDE.

1. R.C.C. Projection $1 \times 10 \times 2 \times 1/4 = 5.0$cft. at Rs. 2/- cft. =Rs. 10.00

Add 300 % premium .... =Rs. 30.00

Total: =Rs. 40.00

Rate per Rft$=\frac{40.00}{10}=$Rs. 4.00

Ratio of cost of Projection and parapet wall$=\frac{4.00}{2.52}=1.62$