THERMAL PERFORMANCE OF HALF BRICK WALL MASONRY IN HOT DRY CLIMATES

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Reprinted from April 1978 issue of

THE INDIAN ARCHITECT

A-15 Pamposh Enclave, New Delhi-48.

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Abstract: In order to economise the cost of construction, the practising architects and engineers strongly emphasize the need to reduce the wall thickness to half that of 23.0 cm thick conventional solid brick wall. Field tests were therefore conducted on 11.5 and 23.0 cm thick solid brick wall enclosures, to compare their thermal behaviour under different exposure conditions. Results clearly show their relative thermal performance in quantitative terms under different exposure conditions. 11.5 cm thick solid brick wall in exposed west direction contributes maximum discomfort indoors.

Introduction:—The challenge before building engineers is to evolve ways and means of economising in housing construction so that the maximum number of houses can be built from the available resources. In conventional building, both external and internal walls upto roof level are built with 25.0 cm brick masonry. From strength considerations, use of 25.0 cm thick brick wall upto two storey building is unnecessary and results in wastage of building material and also involves greater expenditure on the sub-structure. In frame structures even brick-on-edge may be utilised without any structural problems. In view of all this the practising architects and engineers strongly feel the need to reduce the thickness of conventional wall to a bare minimum value without much detriment to the indoor thermal environment.

A preliminary study [2] to indicate the effect of thickness on thermal performance of solid brick wall panels has already been published recently but it is not enough to illustrate the effect on indoor thermal conditions due to a complex convective and radiative exchange phenomenon between the various elements of an enclosure. However, this study showed clearly that thermal performance of a 7.6 cm thick solid brick wall is exceptionally poor as compared to a 23.0 cm solid brick wall; therefore it was decided to obtain comprehensive thermal performance data for a 11.5 cm thick solid brick wall enclosure as compared to that of a 23.0 cm thick brick wall enclosure under different exposure conditions.

Experimental procedure:

The study was conducted in two specially designed full size (3.5 x 2.9 x 3.2 m) test rooms Photo (1) 13 metres apart in the fields so as to have unobstructed wind and solar exposure. The test rooms and the experimental set up were described in detail in the earlier thermal studies[3] carried out at this institute. However it would be relevant to describe the specific design feature of the test rooms used for this study. The test rooms had similar roofs (10.5 cm R.C.C. slab with 1.3 cm cement plaster inside) but with walls of different thicknesses. In each of these two test rooms the three exposed walls towards east, west and south were constructed with 11.5 and 23.0 cm solid brick wall masonry, respectively, with common 1.3 cm thick cement plaster inside and cement pointing outside. These rooms were not provided with any window or ventilator so as to exclusively examine the effect of only the materials and to exclude the effect of any other agency like ventilation etc. which might interact with the two thicknesses differently. These tests were conducted as per I.S. guide [4] for Heat Insulation of Non-Industrial Buildings.

In order to maintain a high order of similarity, these walls were constructed in two thicknesses with similar bricks and cement mortar within the same time period. This was done to avoid any possible difference due to non-uniformity of materials, construction technique etc.

TEST CONDITIONS:— In the first set of observation, the study was conducted to see the effect of wall thickness under the worst exposure condition i.e. when all the three sunlit walls were fully exposed to outside weather. The second and third set of observations were taken by exposing two and one wall respectively at a time to study different situations. This has been achieved by shading walls Photo (2) with heavy tarpaulins to ensure absence of solar radiation and unrestricted air movement over the wall. Although such an arrangement did not simulate actual shading but being a relative study, the discrepancy remained common to both the test cases.

Table (1) gives the exposure conditions in the three sets of observations

Table 1:

Set No. 1.	Exposure Conditions
1.	All the Three walls (east, south and west) exposed.
2.	T walls (East and South) Exposed. (West wall shaded)
3.	One wall (South) Exposed (East and West wall shaded)

Measurements: —

Temperature measurements were made by 30 SWG calibrated copper-constantan thermocouples connected to a precision self-balancing potentiometer through a gang of rotatory switches, located in a central instrument room. The temperatures are correct to 0.15°C. Half hourly observations of external and internal surface temperature of walls and roofs and of the inside air (dry bulb, wet bulb and globe thermometers) were recorded on relatively calm, dry and clear sunny days in the summer of 1977. Outside dry and wet bulb temperatures were also recorded in the Stevensen screen. Each set of observation was repeated to check the reproducibility of result. Half hourly readings were plotted and used to determine temperatures at any desired instant and location. Table (2) shows the outdoor dry bulb temperature (maxima and minima) on hot days for the three tests.

Results and Discussion:

In tropics much stress is laid on summer conditions while designing buildings and so this study was concentrated on summer conditions only. Further the critical period of optimum indoor discomfort lies during the day time when windows and doors have to be necessarily kept closed to prevent hot air entering from outside. Also the usage period (day, night or both) of a building dictates for considering the period of performance. Therefore it becomes essential to examine the performance during periods of usage or at the time of critical indoor thermal conditions, as the case may be. Therefore, the results of this study have been mainly discussed on the basis of discomfort in the critical periods; however, discomfort position for any other usage periods can also be obtained from the various curves of round the clock observations given in this paper.

Inside Surface Temperatures

The first parameter which governs the indoor thermal conditions of an enclosure is the variation of inside surface temperatures of building components. For thermal comfort the corresponding section should ensure lower internal surface temperatures to minimise the radiation heat load to the occupants. Higher inside surface temperatures also contribute indirectly in raising the indoor air temperatures.

TABLE 2

Outdoor Dry Bulb Temperatures on Hot Days of Three Tests

	(East South & West Three Wall Exposed	(East & South) Two walls exposed (West wall shaded)	(South) One wall Exposed (East and West wall shaded)
Maxima	43.6°C	41.1°C	41.9°C
Minima	22.6°O	23.1°C	23.9°O

Figures 1, 2 and 3 show comparison of inside surface temperatures variation under the three test conditions of exposure at different hours of hot summer days for 11.5 cm and 23.0 cm solid brick wall enclosures. The difference in thermal capacity of two walls accounts for lower temperatures during night and higher temperatures during day time for 11.5 cm thick wall as compared to the 23.0 cm solid brick wall, but the temperature difference between the two walls during the heating period is more than that during the cooling one. These differences in temperatures for the three test conditions gradually decrease as the number of exposed walls decreases.

Discomfort Degree Hour Rating (5): Based on the outside and inside surface maximum and minimum temperatures, thermal damping is often used to compare the overall thermal performance of building sections and enclosures, but it does not exclusively indicate the performance for such critical periods of the day when protective measures from severe heat stress inside a building are essentially required. The concept of Degree-Hour-Rating gives a more realistic comparison of the intensity and duration of discomfort conditions inside during the critical or usage period. For this integrated effect of duration and intensity of peak temperatures is computed from the observed data and in this calculation the peak temperatures above 30°C at each hour are added together leading to the integrated discomfort degree hours.

Table (3) gives the comparison of integrated discomfort degree hours during 1000 to 1900 hours on a hot summer day for the two solid brick wall enclosures of 11.5 and 23.0 cm thickness under the three test exposure conditions. It can be observed that the intensity of integrated discomfort for the inside surface temperatures of the two thicknesses of wall, differs from 66 to 98% when all the three walls were exposed, but when two or one wall were exposed the corresponding differences were reduced to (57 to 70%) and (43 to 56%, respectively. Thermal discomfort in both the cases in the three exposure conditions was found to prevail for 24 hours on hot summer days, i.e., the temperatures remained above 30 degrees centigrade throughout the day and night.

Tropical Summer Index (T.S.I.)

T.S.I. has also been recently developed[6] to correlate the thermal sensations of human being with the environmental parameters and it can be calculated from the measured values of wet bulb, globe temperatures and wind speed indoors. Wind speed indoors is considered here as zero. Fig. 4 shows the comparison of hourly variation of T.S.I. on hot summer days under the three test conditions of exposure for the two thicknesses of walls. A difference upto the order of 2.3, 1.4 and 0.8°C can be observed between the two cases in the three test conditions respectively. On comparing the integrated discomfort degree hours of T.S.I. above 30°C it was observed that the values differed by 37, 28 and 15% respectively in the three test conditions.

TABLE 3

Comparison of Integrated Discomfort Degree Hours during 1000 to 1900 hours on a Hot Summer Day

	(East, South & West) Three walls exposed				(East & South) Two walls exposed (w-wall shaded)				(South) One wall exposed (E & W walls shaded)			
	23.0 cm solid brick wall	11.5 cm solid brick wall	Diff	Diff. in per-cent	23 0 cm. solid brick wall	11.5 cm. solid brick wall	Diff	Diff in per-cent	23.0 cm. solid brick wall	11.5 cm. solid brick wall	Diff	Diff in percent
East wall inside surface	71.6	118.6	47.0	66	64.8	101.6	36.8	57	55.1	81.0	25.9	47
South wall inside surface	44.6	79.7	35.1	79	44.4	75.4	31.0	70	46.7	72.7	26.0	56
West wall inside surface	50.3	99.6	49.3	98	42.5	70.3	27.8	65	48.8	69.6	20.8	43
T.S.I. at 1.2 meter above uoor centre	61.3	83.8	22.5	37	58.0	74.2	16.2	28	57.5	66.4	8.9	15

Note: 1.3 cm thick cement plaster was applied at the inside surface of all the walls.

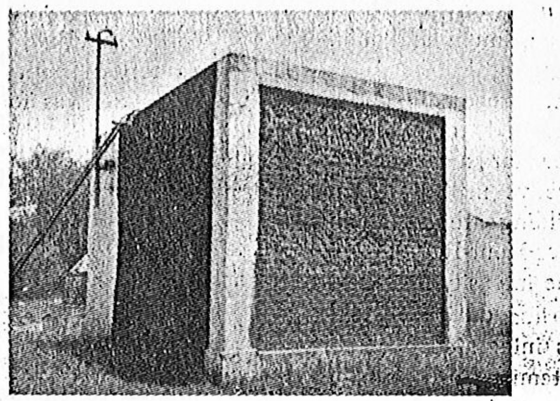

Photo-II

11.5 Cm. Thick solid Brick Wall Test-room (West Wall, Shaded with tarpaulin)

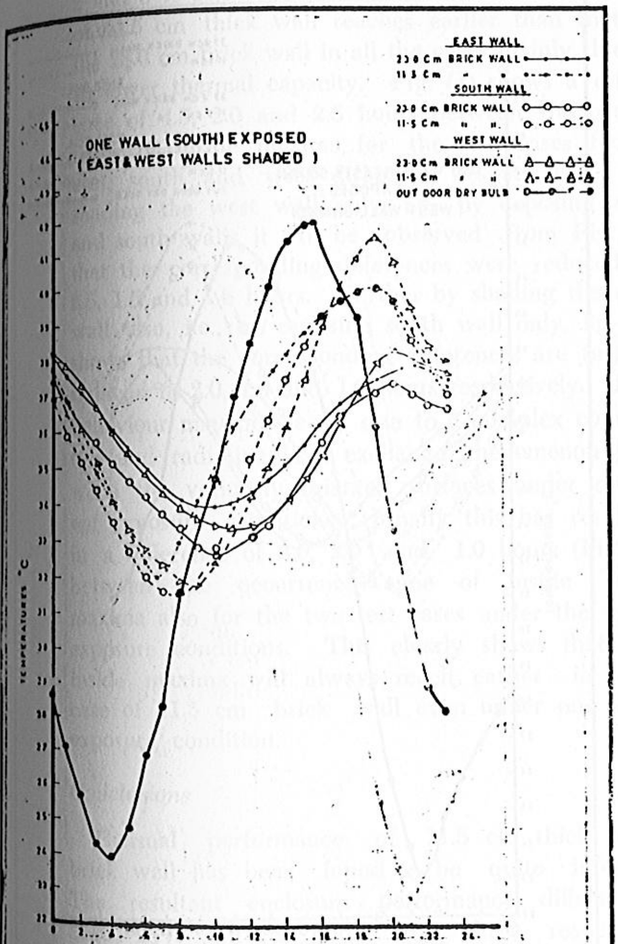

FIG. 3. COMPARISON OF HOURLY VARIATION OF INSIDE WALL SURFACE TEMPERATURES OF 11·5 Cm AND 23·0 Cm SOLID BRICK WALL ENCLOSURES.

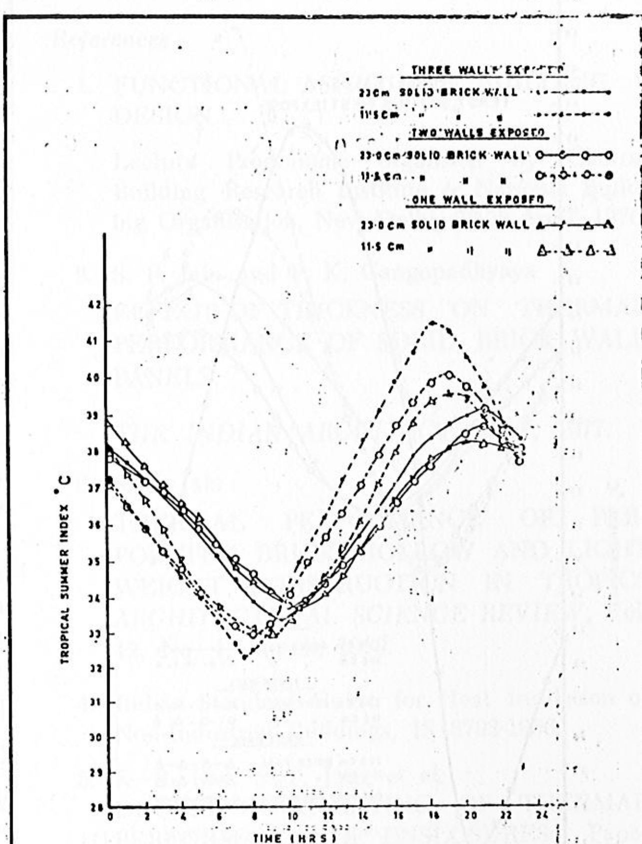

FIG. 4. COMPARISON OF HOURLY VARIATION OF TROPICAL SUMMER-INDEX OF 11·5 Cm AND 23·0 Cm. SOLID BRICK WALL ENCLOSURES.

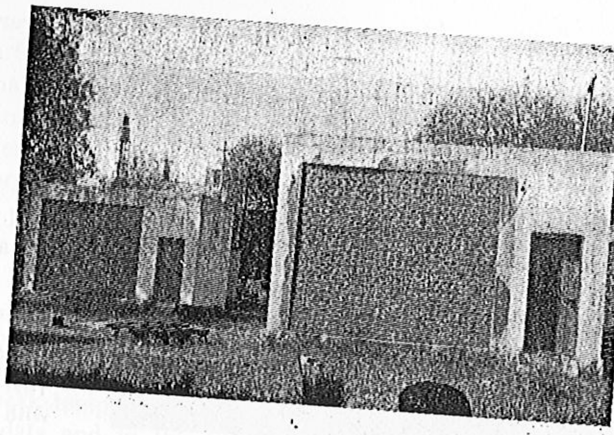

Photo-I

11.5 and 23.0 cm. Thick solid Brick Wall Test rooms.

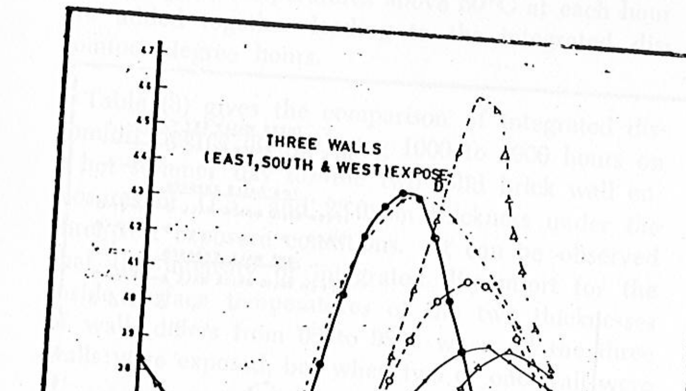

FIG.1. COMPARISON OF HOURLY VARIATION OF INSIDE WALL SURFACE TEMPERATURES OF 11.5Cm AND 23·0Cm SOLID BRICK WALL ENCLOSURES.

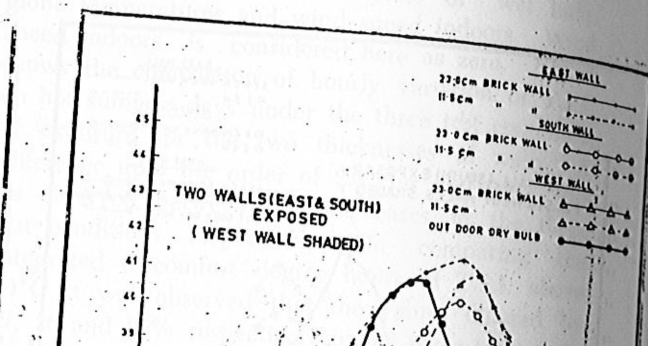

FIG.2. COMPARISON OF HOURLY VARIATION OF INSIDE WALL SURFACE TEMPERATURES OF 11·5 Cm AND 23·0 Cm. SOLID BRICK WALL ENCLOSURES.

Time Lag

In hot dry climates another fundamental and important parameter for thin sections is the time lag in attaining indoor temperature maxima with respect to the outdoor temperature maxima. Time lag depends mainly on the heat storage capacity of the structure. When indoor maxima reaches before the time of opening of windows and ventilators in the evening hours it considerably enhances heat stress to the occupants. It is always desirable if indoor temperature maxima reach late in the evening so that the windows and ventilators can be kept open for taking advantage of natural ventilation. From the various curves drawn in Figures 1, 2 and 3 it can be observed that the inside maxima of 11.5 cm thick wall reaches earlier than that of the 23.0 cm brick wall in all the cases mainly due to its lower thermal capacity. Fig. (1) shows a difference of 4.5, 2.0 and 2.5 hours between the occurrence of inside maxima for the two cases facing east, south and west directions respectively. On shading the west wall only, i.e., by exposing east and south walls it can be observed from Fig. (2) that the corresponding differences were reduced to 2.5, 1.5 and 1.5 hours. Further by shading the east wall also, i.e., by exposing south wall only, fig. (3) shows that the corresponding differences are further reduced to 2.0, 1.0 and 1.0 hours respectively. This behaviour may be clearly due to a complex convective and radiative heat exchange phenomenon between the variously oriented surfaces under different exposure conditions. Finally this has resulted in a difference of 3.0, 2.0 and 1.0 hours (Fig. 4) between the occurrence time of inside T.S.I. maxima also for the two test cases under the three exposure conditions. This clearly shows that the inside maxima will always reach earlier in the case of 11.5 cm brick wall even under one wall exposure condition.

Conclusions

Thermal performance of 11.5 cm thick solid brick wall has been found to be quite inferior. The resultant enclosure performance differs by 37%, 28%, and 15% under the three respective exposure conditions when three, two and one wall at a time were exposed to outside weather. However, in causing this resultant difference and radiant heat stress the east, south and west oriented walls contribute upto 66%, 79% and 98% respectively and as such in no case it should be advised to use exposed 11.5 cm thick solid brick wall towards the west direction in normal buildings.

Acknowledgements

Authors are grateful to Prof. Dinesh Mohan, Director, Dr. N. K. D. Choudhury and Mr. R. D. Srivatsava, Scientist Coordinator for suggesting this work and helpful discussions. Thanks are also due to Mr. Vinod Kumar, S.S.A., for assisting in the instrumentation work, and Shri T. C. Agarwal, Shift Operator, for taking observations. This paper forms part of the research programme of the Central Building Research Institute, Roorkee (U.P.), India, and is published with the permission of the Director.

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6. TROPICAL SUMMER INDEX

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