Indian Journal of Science and Technology http://www.indjst.org Vol.1 No 5 (Oct. 2008)

Effect of air gap on thermal performance of composite wall section

B. M. Suman* and R. K. Srivastava
Central Building Research Institute, Roorkee -247667, U. K., CSIR, India.
balmukund.s79@gmail.com*

Abstract: The property of low thermal transmission of small air gap between the constituents of combine material has been utilized to obtain energy efficient wall section. The paper describes the method to determine coefficient of overall thermal transmittance of combine materials with and without air gap. The combine section mainly consists of cement concrete, polycrete, PVC sheet, polyurethane foam, expanded polystyrene and air gap. Effect of air gap on thermal insulation of wall has been determined. Results of the study show that 38 mm air gap between polycrete slabs gives the lower value of over all thermal transmittance which satisfies the minimum requirement of wall to maintain indoor temperature between 2-16^{0}C in a room as per code IS: 661.

K*ey words*: Air gap, Concrete building, Combine material, Energy efficient multilayer section, Thermal resistance, Transmittance.

Introduction

Generally, the combine material is prepared with two or more different constituents. These constituent materials are the resultant mixture of either homogeneous or heterogeneous combination. They can also be obtained in multilayer composite form. The present study deals with multilayered combine material with or without air gap between the layers.

A number of studies are available on thermal performance of composite material but a very few references are available on thermal performance of composite with air gap. Keeping this in view we attempted to evaluate thermal performance of combined material with air gap and compare with a composite without air gap and with conventional thermal insulation.

Determination of U- value

The method described (Building Digest, 1980) for computing coefficient of overall thermal transmittance of a composite section consisting layers of different material are used for determining U- value.

The U-value of composites may also be determined by using the Guarded Hot Box Apparatus as per IS: 9403 (1980).In short of this facility, we measured thermal conductivity of the constituent materials with Guarded Hot Plate Apparatus as per IS: 3346 (1980), U – value of the combine section is determined. Thermal resistance/conductance value of air gap has been taken form ASHRAE Hand book (1981) to compute U – Value of a combine material consisting air gap. In a study made by the author (Suman & Saxena, 1992) on thermal design of composite roofs of buildings comprising thermal insulation EPS, Foam concrete, Mudphuska and lime concrete suggests that thermal behavior of a building may improve by using suitable thickness of the insulating materials. Thickness of different insulation varies depending on their respective thermal properties. Ottmar *et al.*, (1970) described the composites roof by using up to date thermal insulation on original layer system of the skin to reduce heat ingress. Thermal insulation has been placed outside in order to minimize thermal stresses and flow of heat into the building. Studies on use of air gap in building are in paucity. Kuetin and Maldonanda (1984) determined transient heat flow through composite wood frame walls. The study provides accurate results that agree with measurements when appropriate thermo-physical property was used. For this purpose, thermo physical properties of air gap have been utilized to get advantage of better insulation value of dry air. It also states that with no air gap in the combine wall section, internal radiation and natural convection are neglected and incorporated into effective conductivities. It was assumed in the study that each layer is made up of homogeneous isotropic material having constant properties. Different layer of materials are imperfect thermal contact that is no thermal contact exists between the layers. Moisture migration and wind driven infiltration have negligible effects on over all heat transfer and that there are no heat source within the wall. In previous study, the author (Suman & Panchal, 2005) has determined the time lag and decrement factor of composite walls. The composites wall consisted of perlite concrete with different ratio of expanded loose perlite with a fix ratio of cement concrete. Perlite concrete was used as lining material of the wall. The investigation centered on the effect of perlite concrete with different ratio of expanded perlite with cement used in wall and roof with reference to maximum time lag and minimum decrement factor. The other characteristic parameters used in the study were overall thermal transmittance and thermal resistance. Results of the study show that as the ratio of perlite and cement in perlite concrete is increased from 1:1 to 4:1, the U-Value of the section is reduced and as a result reduction in heat gain through the section was recorded from 32% to 22%. Evaluation of thermal performance of a cavity wall by conducting experiment in the field was also investigated by the author (Suman, 1993). According to the study, air-ventilated wall helps to reduce the peak indoor temperature by 2^0C to 3^0C. It is understood from the literature that utilization of low thermal transmission of optimum air gap is very few. In the absence of air gap in a combine section, internal radiation and natural convection are neglected but conduction of heat cannot be neglected, whereas the heat conduction is also reduced to improve thermal behavior of a combine section having a suitable air gap.

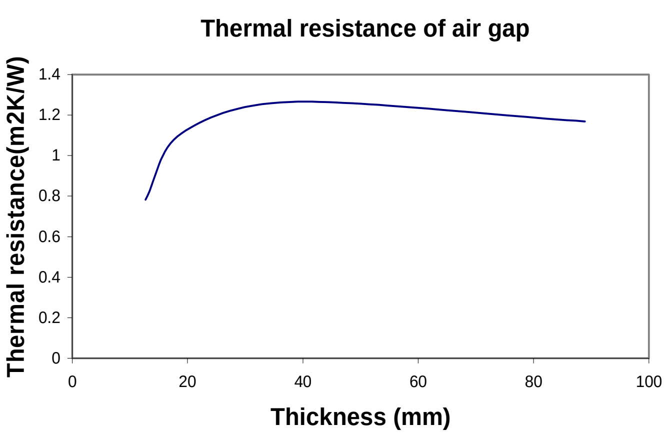
Table 1. Thermal resistance (m^2 K/W) of air gap (emissive of the enclosed surfaces-0.03).

Air gap (mm)	12.7	19.0	38.0	88.9
Vertical surfaces (wall)	0.783	1.11	1.265	1.169
Sloped surfaces (sloped roof)	0.786	1.119	1.607	1.524

Thermal properties of air gap and other materials

Thermal resistance (Suman, 1993) of air space in a composite/ combine material depends upon temperature difference of its both boundary surface and mean temperature of the air space. Table 1 shows thermal resistance (m^2 K/W) of vertical surface (wall) and sloped surface (roof) for different air gap when emissivity is as low as 0.03. A curve between thickness of air gap and its thermal resistance has been shown in Fig.1. From this figure, it is found that maximum thermal resistance exists for 38 mm air gap. In most of the cases the R -values apply only to air spaces of uniform thickness bounded by plane, smooth, parallel surfaces with no leakages of air to or from the space. These conditions are not normally present in the standard building construction. For determination of accurate value of U of all types of multiple constructions with or without air space, the use of Guarded Hot Box Apparatus is essentially recommended.

Fig. 1. Thermal resistance of air gap with its thickness.



For the criteria to develop energy efficient combine section, it is important to select its constituent materials with low thermal conductivity, low density and specific heat with adequate strength. Thermophysical properties of constituent materials used in combined section are given in Table 2. A small air gap is used between two layers of a combine section to make it high thermal resistant.

Overall thermal transmittance

The coefficient of overall thermal transmittance is the heat flow through unit square area of the material when temperature difference of the fluid across the material is maintained one degree Celsius under steady state condition. Heat flow through combine section with and without air gap has been determined by computing U- value. Maximum advantage of thermal resistance of air gap is observed for optimum gap of about 38 mm air for vertical surfaces. The U-value of combine section with Expanded Poly Styrene, Poly Urethane Foam and air gap used as thermal insulation, and without insulation is determined and reported in Table 3. The process of computation of U- value is adopted from (Building Digest, 1980) for the combine section. The inside and outside surface heat transfer coefficient has been taken as 8 W/m^2K and 20 W/m^2K respectively for the computation of the U- value. In order to compute overall thermal coefficient of combine section, thermal conductivity of the constituent materials has been taken from the Table 2. The overall thermal transmittance value (U-value) of combine wall section with and without air gap is given below in Table 3. The air gap is used as sandwich between two layers of the multilayered wall section but placing of thermal insulation may be kept as per convenience as shown in Fig. 2. The effect of placing of thermal insulation in the combined slabs on U-value is found to be negligible.

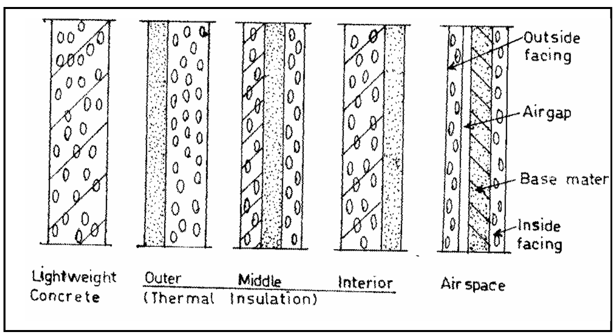
Discussion

Indoor thermal environment may be improved by judicious utilization of good thermal insulation or placing of optimum air

Table 2. Thermo-physical properties of building and insulating materials used in combine section.

S.no.	Materials	Density (kg/m^3)	Thermal conductivity (W/mK)
i.	Plastocreat	1675	1.18
ii.	Cement concrete	2223	1.44
iii.	PVC (Flexible) (Rigid)	1200 1390	0.14 0.17
iv.	Expanded Polystyrene	28	0.032
v.	Brick	1820	0.808
vi.	Cement Plaster	1762	0.720
vii.	Poly urethane foam	18	0.028

Fig.2. Position of insulation in various kinds of walls.



gap between two layers of combine wall section. The use of air gap in vertical surface (wall) of building gives better perspective to utilize their efficient thermal performance. Thermal conductivity and density of the constituent basic and insulating materials are given in Table 2 which has been utilized to determine thermal performance of the wall section. The 38 mm air gap was found to be optimum to give maximum thermal resistance as it can be seen from the depicted curve in Fig. 1. By increasing air gap, the convective heat transfer takes place within the air gap and as a result to reduce thermal resistance.

The computation of over all thermal transmittance of the wall section with and without air gap was made and given in Table 3. From the table, it is observed that U- value of combine wall section with air gap always satisfy the minimum standard of a wall of a room to maintain indoor temperature between 2 – 16 ^oC as per IS:661. The aspects of the design of thermal efficient wall to minimize the flow of solar heat and to reduce inside surface temperature of the wall have been fulfilled. The sloped roof or wall of a building may also be designed by providing a suitable air gap(38 mm) to get maximum thermal resistance (1.265m^2 K/W)as described in Fundamental Handbook, ASHRAE (1981).

In the present investigation, the basic materials i.e., PVC sheet, polycreat, cement concrete are taken as constituent materials and air gap, expanded polystyrene and polyurethane foam are used as insulation material of combined wall section. There are twelve sections in all considered for evaluating thermal performance which gives the impact of EPS thermal insulation and air gap over a section with no insulation. It is found from the result of section (viii) and (x) that 6mm PVC sheet has equal performance of 25 mm plastocreat as the U- value of both the sections are approximately same. In other sections thickness of EPS thermal insulation and air gap are same to study the effect of air gap over the EPS. It may be observed from sections (i) with (iii), (iv) with (vi) and (vii) with (ix) that the effect of air gap gives 80 % reduced U- value over the sections without air gap. Similarly from the sections (i) and (ii), (iv) and (v) and (vii) and (viii), it is found that thermal insulation EPS has the lower U- value by 75% over a wall section with no insulation. Thus a net 5% lower U-value is observed with air gap insulation over EPS insulation in a combine wall section. In order to maintain indoor temperature below 2 ^oC of a fruit storage room further lower U- value of wall section is required as it is found from section (xii) that by replacing 25 mm of plastocreat with PUF panel a further 38% lower U - value is obtained (from 0.701 to 0.413 W/ m^2 K). Similar approach may be adopted to get a lower U-value of sloped roof by utilizing suitable air gap or polyurethane foam insulation as sandwich between two layers.

Conclusion

The advantage of high thermal resistance of air gap should be utilized to get energy efficient combine section. Results of the study show that about 80% of U- value is reduced by providing 38 mm air gap between two layers of a combined wall section. If we use Expanded Polystyrene thermal insulation in place of air gap, it gives 75 % reduced U- value approximately. It means that by replacing EPS thermal insulation with same thickness of air gap, 5% further lower U-value is achieved for combine wall section. If situation arise to get a further lower U- value, both the air gap as well as PUF thermal insulation may be used. As it is found from section (xii) of Table 3 that by replacing 25

Table 3. Overall thermal transmittance value of combine wall section with and without air gap.

S.no.	Specification of Wall section	U-value W/m^2K
i	10 mm Cement Concrete + 25 mm Plastocreat	4.930
ii	10 mm Cement Concrete + 38 mm EPS + 25 mm Plastocreat	0.719
iii	10 mm Cement Concrete + 38 mm air gap + 25 mm Plastocreat	0.681
iv	10 mm PVC + 25 mm Plastocreat	3.745
v	10 mm PVC + 38 mm EPS + 25 mm Plastocreat	0.688
vi	10 mm Cement Concrete + 38 mm air gap + 25 mm Plastocreat	0.652
vii	6 mm PVC + 25 mm Plastocreat	4.180
viii	6 mm PVC + 38 mm EPS + 25 mm Plastocreat	0.701
ix	6 mm PVC + 38 mm air gap + 25 mm Plastocreat	0.670
x	25 mm Plastocreat + 38 mm EPS + 25 mm Plastocreat	0.712
xi	25 mm Plastocreat + 38 mm air gap + 25 mm Plastocreat	0.671
xii	25 mm PUF panel with PVC + 38 mm air gap + 25 mm Plastocreat	0.413

mm of plastocreat with PUF panel and air gap, further 38% lower U – value is obtained. This study may also be utilized to design energy efficient sloped roof as thermal resistance of sloped roof with air gap is quite high which can be observed from Table 2. Thermal insulation may be used at any place i.e. inside, outside or at middle as sandwich but air gap can be used only between two layers of constituent materials of a combine section. Insulation material can be placed anywhere as per convenience as shown in Fig.2.

Acknowledgment

This study forms part of regular R & D work done at Central Building Research Institute Roorkee. The paper is communicated for publication with permission of the Director of the Institute. The author wish to acknowledge Mr. Iqbal Ahmad for preparing the drawing required for the study.

References

1. Building Digest 138 (1980) Thermal performance of wall and roof section. CBRI Publication.
2. IS: 9403 (1980) Method of test for thermal conductance and transmittance of built up sections by means of Guarded Hot Box.
3. IS: 3346 (1980) Method for the determination of thermal conductivity of thermal insulation materials by two slab, Guarded Hot Plate method.
4. ASHRAE (1981) Handbook of Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, USA .
5. Suman BM and Saxena BK (1992) Role of roof treatment in thermal design of buildings, *Architectural Science Review*, 35 (4), 111-114.
6. Ottmar B, Pattantyus AA and Petro B (1970) Up to date thermal insulation and damp proofing system, *Building Science*, 4 (4) 225-228.
7. Kuehn TH and Maldonado EAB (1984) Two dimensional transient heat transfer through composite wood frame walls- field measurements and modeling, *Energy and Buildings*, 6, 55-66.
8. Suman BM and Panchal P (2005) Effect of perlite ratio in perlite concrete on time lag and decrement factor of building section, *Architectural Science Review*, 48 (4) 239-244.
9. Suman BM (1993) Thermal performance of air ventilated cavity wall. Proceedings: *National Solar Energy convention on Role of renewable energy in energy policy*, held at Vadodara (GEDA), pp:119-122, Dec. (1993).