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Research Article

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Research on the thermal performance of southern Anhui traditional dwellings' cavity wall

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ABSTRACT

The pros and cons of the thermal performance of the external wall not only affect indoor thermal environment in dwellings, but also affect the energy consumption of the building. In this paper, take Southern Anhui Traditional dwellings' Cavity Wall which have different masonry methods and interlayer as the research object, using theoretical calculations and software simulations to comparative analysis of the thermal performance on Cavity Wall, providing a reference for thermal design of modern wall.

Key words: Cavity Wall; Thermal Calculation; Infrared Testing

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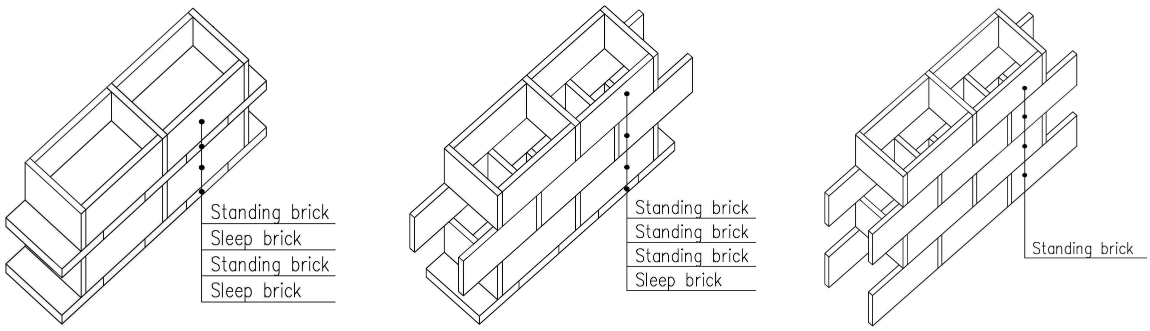
INTRODUCTION

1. THE CONSTRUCTION FEATURES OF CAVITY WALL

External wall of the Southern Anhui traditional dwellings are mostly build by clay bricks. Depending on masonry methods, mainly divided into two categories: One kind is the solid wall, the bricks are all laid flat masonry; The other kind is Cavity Wall which is the most outstanding feature in southern Anhui traditional dwellings. Some inhabitant with better economic conditions, they build the exterior walls with wooden planks inner surface. Not only does it plays a decorative role, but also improves the thermal performance of the wall. There are single-sided and double-sided wooden planks two approaches, between the wooden planks and the exterior left 100 ~ 200mm thick cavity. Wood reinforcement is used between the wooden planks and the exterior well, internal wall, corners to increase the stability.



(a) one sleep one standing **(b) one sleep three standing** **(c) all standing no sleep**

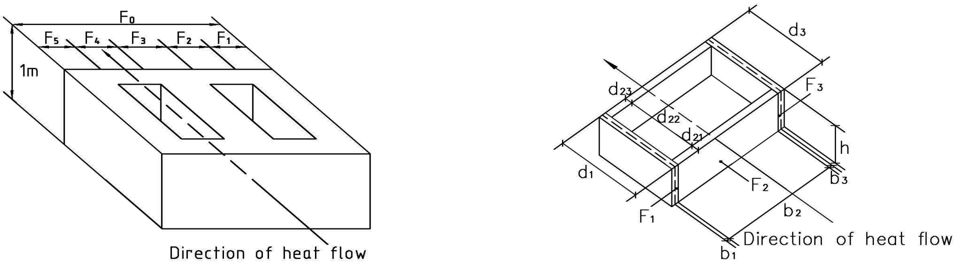
Fig.1: The masonry method of cavity Wall

Cavity Wall is built by flat wise bricks and vertical bricks in different permutations regular patterns .The flat wise brick is called "sleep brick", and the vertical brick is called "standing brick". There are three kinds of masonry methods about Cavity Wall: one sleep one standing, one sleep three standing and all standing no sleep (Fig.1).Although there is a pattern masonry method, but specific to each one dwelling the wall, its masonry law is not unified. Usually less than one meter in Cavity Wall used the more sleep brick masonry method such as one sleep one standing, one sleep three standing and so on. Higher than one meter in Cavity Wall used the more standing brick masonry method, even the all standing brick masonry method. It will not only save material, the structure is also reflected by the light weight, high stability characteristics. There is also some Cavity Wall is filled with yellow mud in its empty bucket, which have better thermal performance compared to Cavity Wall just only filled with air in its empty bucket. Therefore, the study will be conducted in accordance with each masonry method for filling different Cavity Wall.

2. AVERAGE HEAT TRANSFER COEFFICIENT CALCULATION

2.1 Modeling computation problems

The direction of heat flow in Cavity Wall is perpendicular to standing brick and the air space. But it is parallel to sleep brick. Thus, different masonry method Cavity Wall average heat transfer coefficient calculation model is mainly divided into two categories (Fig.2): wall with no lying brick and wall with lying brick. All standing no sleep masonry method don't need to consider the direction of sleep brick, formula 1 can be directly used to calculate; Cavity Wall with lying brick need to calculate the thermal resistance of sleep brick at first. Then calculate the thermal resistance of standing brick and the air space. Finally, use formula 2 to calculate average thermal transmittance of Cavity Wall.



(a) Wall with no lying brick **(b) Wall with lying brick**

Fig.2: Calculation model of average thermal resistance of Cavity Wall

$$\bar{\lambda} = 1/\left\{\left[\frac{F_o}{\frac{F_1}{R_{o.1}}+\frac{F_2}{R_{o.2}}+\cdots\frac{F_n}{R_{o.n}}} - (R_i + R_e)\right]\varphi\right\} \text{(Formula 1[1])}$$

The meaning of each symbol in the formula:

$\bar{\lambda}$ …… Average thermal transmittance ,W/(m·K)
F_O …… Perpendicular to the direction of heat flow total heat transfer area ,m^2
F_n …… Parallel to the direction of heat flow each heat transfer area,m^2
$R_{0.1}$ …… Overall thermal resistance of various parts,m^2·K/W
R_i …… The inner surface exchanging thermal resistance ,0.11,m^2·K/W
R_e …… The outer surface exchanging thermal resistance,0.04,m^2·K/W
φ …… Correction factor

$$\bar{\lambda} = \frac{\lambda_1 F_1+\lambda_2 F_2+\cdots+\lambda_n F_n}{F_1+F_2+\cdots+F_n} \text{ (Formula 2)}$$

The meaning of each symbol in the formula:

$\bar{\lambda}$ …… Average thermal transmittance ,W/(m·K)
F_n …… Parallel to the direction of heat flow each heat transfer area, m^2
λ_n …… Thermal transmittance of each heat transfer area, W/(m·K)

2.2 The calculation results analysis

According to the above average heat transfer model, calculate the average thermal conductivity of Cavity Wall which are built by different masonry methods, such as one sleep one standing, one sleep three standing, all standing no sleep. Due to the different choice of brick size, therefore wall thickness different. Unified control variables to compare the differences between materials and construction. In this study, the choice of a brick in Cavity Wall size is 350x150x30 (mm), thickness of the wall is 350mm, and ignore the exterior painting layer thickness in the calculation. Since the air at different temperature and humidity conditions, the thermal transmittance of it is different(For the general air interstratifications: the vertical air space height greater than 60mm, winter thermal resistance is 0.18m2·K/W, summer thermal resistance is 0.150.15m2·K/W). Therefore, with no filler Cavity Wall used the air as an interlayer, in winter and summer exhibit different heat transfer coefficient. For such Cavity Wall calculation should be divided in summer (Table 1) and winter (Table 2).

Although the average heat transfer coefficient of Cavity Wall in winter generally lower than in summer, but the two tables are calculated to reflect the same regular pattern: the average heat transfer coefficient “all standing no sleep”>“one sleep three standing” > “one sleep one standing”. Thus it can be seen, the larger the share of the air interlayer between the ratio of the wall portion, the smaller the thermal resistance, the greater the heat transfer coefficient. When the distance of closed air interlayer increase, radiation heat transfer of air in the interlayer is too large, air interlayer not only could not achieve the effect of increased thermal resistance, but raise the average heat transfer coefficient of the wall. In the follow-up study, the rational use of characteristic of Cavity Wall in the winter and summer show different characteristics of the heat transfer coefficient, maybe received the excellent research achievements.

Table 1: Average heat transfer coefficient of Cavity Wall used air interlayer (summer)

masonry law	total area (m^2)	average thermal resistance ($m^2 \cdot K/W$)	mean heat transfer coefficient[$W/(m^2 \cdot K)$]
all standing no sleep	0.057	0.085	11.782
one sleep three standing	0.182	0.085/0.461	11.181
one sleep one standing	0.068	0.085/0.461	10.180

Table 2: Average heat transfer coefficient of Cavity Wall used air interlayer (winter)

masonry law	total area (m^2)	average thermal resistance ($m^2 \cdot K/W$)	mean heat transfer coefficient[$W/(m^2 \cdot K)$]
all standing no sleep	0.057	0.113	8.812
one sleep three standing	0.182	0.113/0.461	8.396
one sleep one standing	0.068	0.113/0.461	7.705

Table 3: Average heat transfer coefficient of Cavity Wall used yellow mud interlayer

masonry law	total area (m^2)	average thermal resistance ($m^2 \cdot K/W$)	mean heat transfer coefficient[$W/(m^2 \cdot K)$]
all standing no sleep	0.057	0.498	11.782
one sleep three standing	0.182	0.498/0.461	11.181
one sleep one standing	0.068	0.498/0.461	10.180

Although builders in southern Anhui cannot reduce radiant heat transfer of air between the interlayer by using other effective methods in the limited time, in order to reduce the average heat transfer coefficient of Cavity Wall. But they improved Cavity Wall thermal performance by another method that used yellow mud to fill the air interlayer. Yellow mud this material is not only easy to get, easy construction, heat resistant, light weight, and environmentally friendly. The research indicates that, Cavity Wall after filling yellow mud under the same conditions, the average heat transfer coefficient of the wall significantly decreased (Table 3). Showing the opposite regular pattern with air interlayer: the average heat transfer coefficient “one sleep one standing”>“one sleep three standing”>“all standing no sleep”. It is obvious that the average heat transfer coefficient of Cavity Wall not only with an interlayer proportion related to the size and the type of material inside the interlayer is also closely related. Materials used in Cavity Wall is simple and easy to get ,but the structural of it is varied and abundant, reflecting the amazing construction wisdom of craftsmen in southern Anhui. Especial, the construction technology that used other materials to fill the interlayer in Cavity Wall, to improve the overall thermal performance of the wall, it is worth learning by modern architects.

3. UNFRARED TESTING OF CAVITY WALL THERMAL

To select two Cavity Walls respectively used the infrared thermal imager for comparison testing, the one is used air interlayer, the other one is used yellow mud interlayer, they are both used the same masonry law. Testing time was about 3:00 pm, the weather was sunny, no significant wind direction. By comparing the temperature difference between the inner and outer surface, to analyzing the thermal performance of the Cavity Wall. Test result of Cavity Wall used air interlayer is that the average temperature of the outer surface is 31.0℃, and the highest value is 33.8℃; the average temperature of the inner surface is 28.5℃,and the highest value is 29.8℃ (Fig.3).The average temperature difference between the inner and outer surfaces is 2.5℃.Test result of Cavity Wall used yellow mud interlayer is that the average temperature of the outer surface is 33.6℃, and the highest value is 34.7℃; the average temperature of the inner surface is 29.1℃,and the highest value is 30℃ (Fig.4).The average temperature difference between the inner and outer surfaces is 4.5℃.

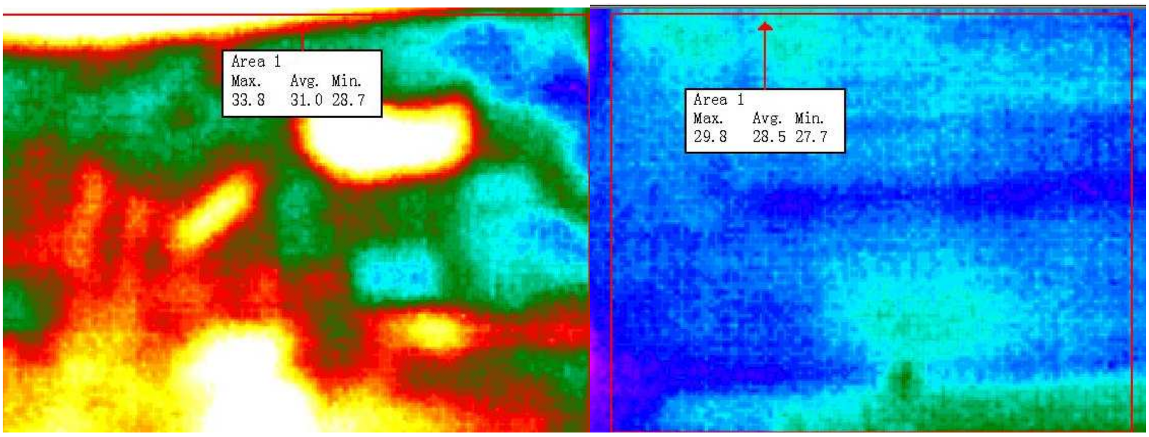


Fig. 3: The infrared test icon of Cavity Wall with yellow mud interlayer

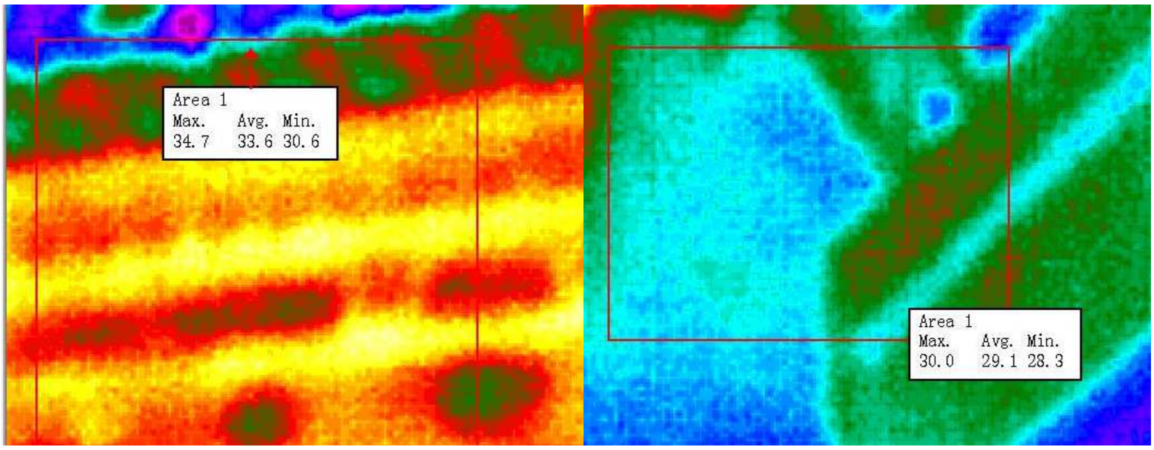


Fig. 4: The infrared test icon of Cavity Wall with air interlayer

Experimental results show that the effect of air interlayer is poor in cutting off the indoor and outdoor heat transfer, consistent with the theoretical calculation results. The test areas on inside and outside surfaces of the wall temperature fluctuations little, have shown uniform heat and heat transfer. Consolidated study results, the heat transfer coefficients of Cavity Wall significantly reducing after used yellow mud. Reserved Cavity Wall traditional masonry methods, choose the right material for the filling interlayer,is an effective way to improve the thermal performance of the wall.

CONCLUSION

Cavity Wall in southern Anhui has more advantages than solid wall. On the one hand, solid wall used more material, its own large weight, long construction period. On the other hand, Cavity Wall has more transform conditions. Such as maintained the appearance of Cavity Wall unchanged, filling other materials in interlayer to improve thermal resistance. Or keeping air interlayer unchanged, reducing the radiation heat transfer of air by other ways. Provided both beautiful and meet thermal specification requires techniques for the dwellings which required to maintain the traditional appearance in modern time. The construction skills of southern Anhui traditional dwellings' Cavity Wall to inspire contemporary architects use simple materials to create maximum thermal performance in the design.

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