

# Study on the Causes of Secondary Cracks of the Eave Wall Mural of Daxiong Hall at Fengguo Temple in Yixian, Liaoning, China

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## Research Article

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**Study on the Causes of Secondary Cracks of the Eave Wall Mural of Daxiong Hall at Fengguo Temple in Yixian, Liaoning, China**

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# **Study on the Causes of Secondary Cracks of the Eave Wall Mural of Daxiong Hall at Fengguo Temple in Yixian, Liaoning, China**

**Abstract:** Built in Kaitai nine years of Liao Dynasty (1020 A.D.), the Daxiong Hall of Fengguo Temple in Yixian County, Liaoning Province, is one of the largest existing ancient single-eave wooden structure in China. There are nearly 470m<sup>2</sup> murals of Yuan Dynasty on the four walls of the hall. Since the in-situ reinforcement and protection of the mural were carried out in the 1980s in cooperation with the maintenance and restoration project of the main hall, the seriously developed cracks have become the primary factor affecting the structural stability of the mural. In order to find out the macroscopic causes of secondary cracks, endoscope, infrared thermal imager, three-dimensional laser scanner and other equipment were applied to study the relations between cracks' attitude and structural defects of the eave wall, as well as the pathway that external environment act on the mural noumenon through comprehensive investigation, and the idea of restoring the stability of the mural by blocking the air channel and offsetting the environmental stress is put forward.

**Keywords:** Fengguo Temple; Mural; Eave wall structure; Secondary disease; Cracks

## **Introduction**

Architectural mural is one of the main types of mural in ancient China. It exists on the wall of ancient buildings and is an organic part of architectural structure. The rationality of the architectural structure, especially the wall structure, has an important influence on the stability of the mural noumenon, and the crack disease is a common manifestation of the structural instability of the mural, whose causes are mostly related to the influence of micro-vibration<sup>[1]</sup>, the deformation and settlement of building enclosure structure<sup>[2, 3]</sup>, and the extrusion of the wood column due to its expansion<sup>[4]</sup>, etc. The existing cracks of the eave wall mural of Daxiong Hall in Fengguo Temple were mostly generated after the in-situ reinforcement and protection project in the 1980s, which is a typical problem about the secondary disease caused by the protection and treatment measures. This kind

of problem has been paid more and more attention in recent years. Most of the research have focused on the failure mechanism of protective materials<sup>[5]</sup>, their direct impact on the mural noumenon<sup>[6, 7]</sup> as well as the removal methods of them<sup>[8, 9]</sup>, etc., and mostly involves the detached mural, but less attention has been paid to the systematic causes of complex secondary diseases and the architectural mural preserved in situ. In addition, studies on the mechanism of in-situ preserved mural disease from the perspective of architectural pathology have also been discussed in special papers<sup>[10, 11]</sup>, but they often focus on the corresponding relations between the coordination of multiple factors and the manifestations of multiple diseases, and the specific formation process of a single disease has not been discussed deeply.

Based on the comprehensive investigation results, this paper carried out a monographic study on the secondary crack disease of the eave wall mural of Daxiong Hall in Fengguo Temple, and interpreted the regularities of distribution of stress release as well as coupling relations between the environment and the mural noumenon, thus constructing the formation path model of secondary cracks and providing a case reference for related studies.

## **Investigation content and methods**

### ***Investigation content***

The investigation content of this study is divided into five parts:

- (1) The basic information of the mural, including its theme, size and location;
- (2) The existing structural features of the mural, including the basic structure of painting and eave wall structure;
- (3) The attitude of the mural's secondary cracks, including the developmental direction, degree of penetration, connectivity, etc. Secondary cracks refer to new

cracks generated after in-situ reinforcement and protection of the mural in the 1980s;

- (4) The deformation of the mural surface, that is, the displacement of the points on the surface of the mural over a period of time;
- (5) The environmental characteristics of the mural, including the air fluidity, the change of temperature and humidity and the heat conduction.

### ***Investigation methods***

Literature reference and filed investigation method were applied to identify the mural's theme, content and distribution; tapeline and laser rangefinder were used to measure the length and height of the mural directly or indirectly.

The in-situ reinforcement and protection process of the mural in the 1980s were known by referring to the engineering report; the basic structure of painting were recognized by observing the edge of shedding part of paint layer and mud layer; endoscope probe was inserted into the eave wall through the cracks to observe the detail features of the wall structure and the mural backing layer, the endoscope is LF42 type produced by Zhuhai Mingxiang Medical Technology Co., Ltd., its probe line has a diameter of 2.5mm and a length of 0.6m, and the activity range of the probe is -190°~150°; infrared thermal imager was applied to observe the mural surface, and the internal structure as well as the path of heat conduction can be deduced from the static infrared image of the surface, the instrument is Hawk-E384 on-line infrared thermal imager produced by Xi'an Haoke Electronics Co., Ltd., with a horizontal field Angle of 24.6° , a vertical field Angle of 18.1° , a minimum imaging distance of 0.5m, a resolution of 384×288 ppi, a thermal sensitivity of 0.065°C at 25°C and a working band of 8 ~ 14 μ m.

A full-frame digital camera was used to photograph the mural in sections, and Photoshop was used for stitching them. The secondary cracks were distinguished by comparing historical photographs with recent ones and determining the intrusion relation between cracks and their developmental layers. The vector diagram of the secondary cracks distribution of the mural was drawn with AutoCAD, and the cracks with different attitude were marked.

Three-dimensional (3D) laser scanner was applied to collect point cloud data on the wall at the northwest corner of Daxiong Hall for several times, and then the Geomagic Control 3D detection software was used to make deviation chromatogram to analyse the deviation between target point cloud and grid model, and the colour difference could represent the deformation condition of the eave wall surface. The 3D laser scanner is Faro Focus S350, with a visual field of  $360^{\circ}$  transverse /  $300^{\circ}$  longitudinal, an accuracy of  $\pm 1\text{mm}$  within a distance of 25m, a resolution of 1/4, a point cloud quality of 4x, and an average scanning time of 469s per station. The chromatogram deviation range was set to  $\pm 0.1\text{mm} \sim \pm 8\text{mm}$ .

The outdoor environment characteristics of the mural can be acquired by referring to the monitoring data of Yixian meteorological station<sup>[12]</sup>. On-line environmental monitoring equipment developed by Zhejiang University was placed in the hall to obtain continuous data of air temperature and humidity. The infrared thermal imager mentioned above is used to dynamically monitor the designated eave wall surface, and the change characteristics of the thermal image in different parts can reflect the heat conduction process that the external environment affects the mural nomenon.

## **Results and discussion**

### *Investigation results*

#### *The basic information of the mural*

Daxiong Hall in Fengguo Temple is a single-eave hip-roof building facing south, it's 9 units wide and 5 units deep (The unit means the part between two adjacent eave columns). After the maintenance and restoration project in the 1980s, the building envelope consists of partition doors and eave walls, the former includes seven units in the middle of front facade and the central unit of back facade, and the latter includes the remaining units. The murals of Yuan Dynasty were painted on the entire inner surface of the eave wall, and the content of each unit is independent. There are 5 Buddhas respectively painted on the east and west walls (E1~E5、W1~W5), 4 Bodhisattvas respectively painted on each side of the central unit on the north wall (N1~N8), and a 11-face Avalokitesvara respectively painted on the east and west ends of the south wall (S1~S2)<sup>[13]</sup>. The distribution of murals is shown in Figure 1.

According to the measurement, the length of the east and west walls is about 24.82m respectively; the length of the east and west parts of the north wall is about 21.18m respectively; the width of the east and west units of the south wall is about 3.83m respectively; the overall height of the eave wall is about 5.33m and that of the mural is about 4.76m. Large size and strong integrity are the prominent characteristics of the eave wall mural.

#### *The existing structural features of the mural*

Before the reinforcement and protection in 1980s, the structure of the eave wall mural is successively paint layer, background layer, fine mud layer with fibrilia added, coarse

mud layer with straw added, and supporting wall made of adobe bricks from surface to inside.

An in-situ scheme was adopted for the mural's reinforcement and protection project in the 1980s: the mural was temporarily supported by a wooden bracket from the front, then the adobe wall was demolished and new support structure was added from the back. The work was carried out from one unit to another, and from top to bottom section by section. The thinned mud layer was firstly reinforced with polyvinyl butyral and then adhered with two backing layers made of epoxy resin / glass fiber composite. The reinforced mural was integrally hoisted on the added red brick wall with the H-shaped fixture made of the glass fiber reinforced plastic(GFRP) material. Finally, adobe wall was still built outside the red brick wall and eave column was wrapped by them<sup>[14]</sup>.

The filed investigation results(As shown in Figure 2 and Figure 3) show that there is a cavity with a thickness of 2 ~ 10cm between the GFRP backing and the red brick wall in addition to the structure mentioned in the engineering report. The red brick wall was built roughly and the brick joints are relatively large. Furthermore, there are 5~6 rows of horizontal wood keels adhered to the GFRP backing, which are parallel to each other. Their thickness is about 3cm, height is about 10cm, and length is basically equal to the width of a unit. However, there is no physical connection between the wood keels and the red brick wall, and some of the wood keels split near the bonding surface due to the deformation of the material. The wood keels of the two adjacent units are discontinuous and their upper and lower positions are staggered to a certain extent. The ends of some wood keels are covered by the upturned fiberglass cloth of the adjacent units, which is consistent with the description in the engineering report that the reinforcement was carried out unit by unit. The combination of "wood keels + GFRP backing" was commonly used as the support for the detached mural in China in the



1970s and 1980s<sup>[15]</sup>. The wood keels were generally arranged into a horizontal and vertical grid frame to improve the strength of the support and enhance the integrity of the mural. But it is difficult to apply the grid frame of wood keels in the in-situ reinforcement project in Fengguo Temple due to the mural's large size. Therefore, only the horizontal wood keels were applied in the order of top-down reinforcement, instead of the vertical wood keels.

The structure of the wall at the junction of the two adjacent units, where is the joint part of wood keels and GFRP backing with a weak strength, is somewhat different from the wall in the unit due to the existence of inner columns. In order to protect against corrosion and buffer the expansion stress, two layers of reeds and flat tiles are wrapped around the wooden column, and a vent is arranged at the position of the column root on the external wall. The loose reeds form a ring of air channel about 5cm thick around the wooden column, which is connected to the cavity through the red brick wall joints. The existing basic structure of the eave wall mural is shown in Figure 4.

#### *The attitude of the mural's secondary cracks*

In the 1930s, the Japanese scholar Sekino Tadashi took a group of black-and-white photos of the eave wall mural of Daxiong Hall during his investigation in Fengguo Temple<sup>[16]</sup>. After comparing them with the existing murals, it is found that most of the initial cracks at that time have been filled with the same material (Figure 5), and it is one of the coordination measures of the reinforcement and protection project in the 1980s. Then the secondary cracks can be basically distinguished after eliminating very few initial cracks which have not been filled. In addition, some cracks obviously penetrate through the FRP backing layer, and can be directly judged as secondary cracks by the intrusion relation.

Figure 6 shows the planar distribution of secondary cracks on the surface of eave walls, which can be divided into three categories according to their attitude. The first category are the long longitudinal cracks at the eave column position, which are developed vertically and generally run through the whole wall from top to bottom, dividing the mural into units. Some of them are developed into upper and lower sections but have not yet been connected with each other. Most of these cracks have caused the tear of the GFRP backing, and the wall on both sides of them often has the phenomenon of dislocation due to shear failure. In terms of the orientation, the cracks in the north wall are obviously more serious than those in the east and west wall, especially the crack at the junction of N1 and N2, whose widest point can even reach 5cm. And the ends of horizontal wood keels are arranged on both sides of this kind of cracks. The second category are the general cracks in the unit. In addition to the long transverse cracks that intersect with the longitudinal ones at some locations, others mostly form transverse development trends in the form of short cracks groups. Several rows of parallel distribution are formed among different short cracks groups in the same unit, and their development locations are mostly near the edge of the horizontal wood keels. The third category are the new cracks at the edge of the repaired places, which are mainly the results of the release of internal stress along the weak part of the repaired edge.

#### *The deformation of the mural's surface*

The 3D scanning point cloud data of the north wall (N1) at 11:00 on December 2, 2018 and the west wall (W5) at 14:00 on December 2, 2018 were respectively packed into a grid model as a reference, and the other three 3D scanning point cloud data of the corresponding wall from December 2018 to April 2019 were compared with it, and the deviation chromatogram was made as shown in Figure 7. It can be seen that the surface

deformation of the eave wall mural has the characteristics of both integrity and locality. Among them, the deformation of the area near the longitudinal and transverse long cracks is different from that of the next adjacent area, while the deformation of the transverse short cracks groups in the unit are not obvious. There are stripe areas parallel to each other in the unit, which are basically consistent with the position of the horizontal wood keels. The deformation degree in the stripe areas is obviously smaller than that in other areas, which should be caused by the restriction of the horizontal wood keels and the GFRP fixture. In the figure, the deformation phenomenon of some block areas is different from that of other parts, which can be interpreted as the non-uniform deformation restriction conditions inside the eave wall. On the whole, the surface deformation of the mural in the two stages before and after January 2019 has a reverse trend, which corresponds to the temperature change trend, reflecting that the deformation may be a cyclical process of reciprocating fluctuation with the temperature change.

#### *The environmental characteristics of the mural*

Yixian County is located in the zone between Songling Mountain and Yiwulu Mountain, only 70km to the Bohai Sea. Affected by the monsoon climate and the topographic narrow pipe effect, it is windy all the year round, especially in spring<sup>[17]</sup>. The terrain around the main hall of Fengguo Temple is open, and the outside air is easy to enter the wall through the vents at eave columns, which has a continuous impact on the murals. It is measured that when the external wind is strong, the wind can also be obviously felt at the longitudinal cracks in the inner wall, and the maximum wind speed can reach 1.4m/s. The north wall of the hall is close to the Daling River and there are few barriers, together with the air pressure difference between the direct sunlight area and the shadow area, so the wind force here is stronger than that at the wall in other directions.

Figure 8 shows the changes of near-surface atmospheric temperature and relative humidity in Yixian from 2008 to 2017. The maximum fluctuation range of atmospheric temperature during the decade is  $-27.3^{\circ}\text{C} \sim 41.3^{\circ}\text{C}$ , and the time when the maximum temperature was below  $0^{\circ}\text{C}$  and the minimum temperature was above  $20^{\circ}\text{C}$  accounted for 16% and 9%, respectively. the maximum fluctuation range of the average daily relative humidity of the atmosphere is 11% ~ 99%, and the time when the relative humidity is higher than 70% reaches 33%. Figure 9 shows the hourly changes of air temperature and relative humidity in the main hall from May 2019 to January 2021, with the fluctuation range of  $-11.28^{\circ}\text{C} \sim 30.52^{\circ}\text{C}$  and 24.49% ~ 83.12%, respectively, which are slightly less volatile than the outdoor atmospheric environment.

Figure 10 shows the infrared thermal images of the N1 surface of the north wall at different time in a sunny day, which visually reflects the influence process that the external environment act on the mural from the perspective of heat transfer theory.

### ***Analysis and discussion***

#### *Relations between structural defects and attitude of secondary cracks*

According to the investigation results, there are strong correspondences between the existing structure of the mural and the attitude of secondary cracks, which are realized through the wall deformation and stress distribution. Since the red brick wall and adobe wall are intact, the stress causing the crack should be generated from the GFRP backing and its outer structure layers. It has been studied that the epoxy resins composing the GFRP backing will undergo significant curing shrinkage deformation and environmental deformation during the shaping and keeping stages, respectively<sup>[18]</sup>. With the aging of the material, its flexibility will become worse, and the bending strength will also significantly reduce. In the case of uneven distribution of restriction intensity,

deformation will produce stress at the edge of the region where the restriction intensity is greatly different. When the stress exceeds the mechanical limit of the material itself, it will cause brittle fracture of the material and further lead to cracks. The GFRP material is anisotropic in mechanical strength and the mechanical strength along the fiber direction is much better than that perpendicular to the fiber direction<sup>[19]</sup>. This determines that the release of stress will give priority to shear failure in the direction of thickness, so that both sides of the crack appear to be anterior and posterior dislocation, and the existence of cavity structure provides space conditions for the deformation and stress release.

The position of the eave column, as the junction of two adjacent units of the mural, lacks the overall reinforcing effect of transverse wood keels, and is relatively weak in structure. As the murals of adjacent units are respectively strengthened, the different installation conditions of fixtures and wood keels such as their position and tightness will cause the difference of restriction strength, thus generating the overall stress at the eave column, that is, at the junction of two adjacent units. The concentration and superposition of stress and the weakness of structure constitute the two potential internal causes for the formation of longitudinal cracks. The existence of transverse cracks in the unit shows that the horizontal wood keel only plays a unidirectional reinforcing role, and the stress is confined to the horizontal direction and released in a concentrated way. Since there is no physical connection between the wood keels and the red brick wall behind them, when the GFRP backing is overall deformed or displaced, the wood keels will move along with it, thus offsetting part of the overall stress and making the local stress at the edge of the reinforced parts by wood keels play a decisive role. Therefore, the transverse cracks in the unit are generally less serious than the longitudinal cracks at the eave column.

### *The pathway that environmental factors act on the mural noumenon*

From the changes of temperature and humidity, the climate in Yixian County is characterized by cold and desiccation of winter, torridity and moist of summer, rapid change rate of temperature and humidity in spring and autumn, and large annual fluctuation range of temperature and humidity. Although the main hall plays a certain role in cushioning the external environment, the effect is very limited. The good air fluidity further promotes the influence process that temperature and humidity conditions act on the mural noumenon. When the epoxy GFRP backing material is aged in the humid and hot environment, the crosslinking structure of the resin matrix is destroyed, then the interface bonding of "matrix-fiber" fails<sup>[20]</sup>, and thermal stress damage occurs, resulting in a significant decrease in the mechanical properties of the material. At the same time, the fluctuation of temperature and humidity leads to the generation of moist and hot expansion stress and steam pressure in the epoxy GFRP backing and the mud layer, which leads to the deformation and cracking of the materials.

The changes of infrared thermal images of the mural surface show that the temperature changes at the longitudinal cracks are more responsive to the diurnal changes of air temperature compared with other areas, which proves that the longitudinal crack has good connectivity with the outside atmosphere, and the heated or cooled outside air can reach the crack site through the air channel, causing a lasting impact on the mural there. The thermal image of the transverse wood keels gradually appeared synchronously after noon, which reflects that the influence of the external environment on the mural is not only realized through the air channel at the eave column, but also the heat conduction of the wall (As shown in Figure 11). Just because of the good buffering effect of the 1.2m thick eave wall, the influence of this heat conduction pathway is mild and slow. In addition, the thermal image of the longitudinal

crack tends to become coarser and diffuse over time, which means that the mural noumenon and wood keels near the crack are significantly heated up due to the continuous conduction of the external air, which proves that the external air entering through the channel at the eave column can also cause a certain degree of influence on the mural inside the unit.

#### *Causes and treatment thinking of secondary cracks*

Based on the above discussion, two major models of the pathway that external environment promote the formation of secondary cracks of the eave wall mural through its structural defects can be summarized:

- (1) The effects of atmospheric temperature and humidity levels as well as fluctuations can reach to the GFRP backing layer through the air channel at the eave column with the help of good air fluidity, resulting in aging and deformation of the GFRP backing, making the stress release along the end and edge of the wood keel in a directional way under the restriction of it so that the transverse and longitudinal long cracks near the eave column are finally generated.
- (2) The external environment takes the eave wall as the medium to exchange heat with the mural noumenon, generating overall temperature stress inside the unit as well as local temperature stress on the edge of the wood keel. The former further promotes the shear failure near the eave column, while the latter induces the formation of the parallel short cracks group between the horizontal wood keel.

It can be seen that the deep influence of external environment and the non-uniformity of material reinforcement are the two major causes of secondary cracks,

which should be avoided in the subsequent protection treatment. On the one hand, the air channel should be blocked or changed, and the insulation layer should be added to reduce the impact of the external environment on the mural noumenon. On the other hand, the backing and supporting materials should be replaced with ones who have smaller expansion and contraction, and the connection between layers should be strengthened to offset the stress caused by the difference of restriction conditions.

## **Conclusions**

This study is a case study on the causes of secondary diseases of the architectural mural preserved in situ. Through the comprehensive investigation and analysis of the location and distribution, noumenon structure, disease conditions, deformation dynamics and storage environment of the research object, the following conclusions can be drawn:

- (1) Most of the existing cracks in the eave wall murals of Daxiong Hall in Fengguo Temple are secondary cracks, which are related to the changes of the eave wall structure after the in-situ reinforcement and protection project in the 1980s.
- (2) In essence, secondary cracks are environmental stress cracks, which are caused by the directionally released stress along the weak parts due to the aging and deformation of GFRP backing under the effect of temperature and humidity.
- (3) The external environment can contribute to the formation of cracks through two pathways: air channel and heat conduction via eave walls. The influence of the former is more intense and deeper than that of the latter.
- (4) To restore the stability of the mural, the deep influence of external environment should be avoided and the structure of the mural should be strengthened. On the one hand, the air channel should be blocked of changed; On the other hand, the



backing and supporting materials must be replaced with ones who have stronger weather fastness.

### **List of abbreviations**

3D: Three dimensional

GFRP: Glass fiber reinforced plastic

### **Declarations**

#### *Availability of data and materials*

More photographs of the mural (Including the appearance photographs, endoscopic photographs and infrared thermal images, etc.) generated during the current study are available from the corresponding author on reasonable request.

The datasets of 3D scanning point cloud as well as air temperature and humidity in Daxiong hall generated during the current study are not publicly available due to the use in other unpublished studies, but are available from the corresponding author on reasonable request.

The datasets of near-surface atmospheric temperature and humidity in Yixian County analyzed during the current study are available in the repository of Resources and Environmental Science and Data Center of Chinese Academy of Sciences, <https://www.resdc.cn/data.aspx?DATAID=230>.

#### *Competing interests*

The authors declare that they have no competing interests.

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### ***Authors' contributions***

CL presided over the whole research work and designed the overall framework of the manuscript. YH carried out field investigation and data analysis, and was a major contributor in writing the manuscript. QL systematically analyzed the causes of secondary crack disease. FW collected and organized relevant historical documents. All authors read and approved the final manuscript.

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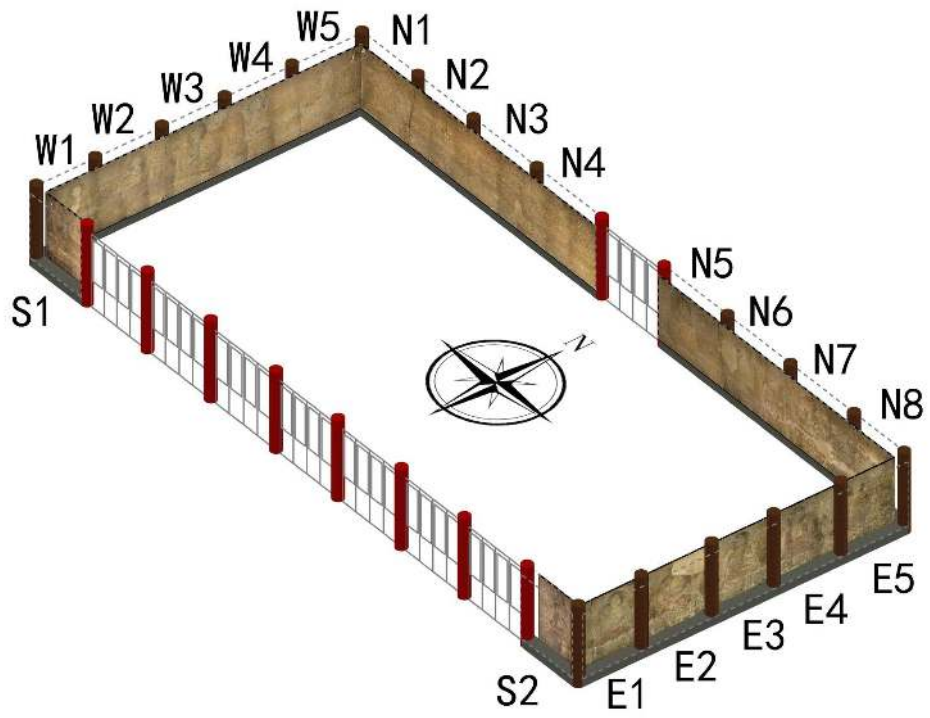


Figure 1. Distribution diagram of the eave wall mural in Daxiong Hall



(a) The end of the wood keel



(b) The wood keel bonded to the GFRP backing



(c) The wood keel covered by the GFRP backing



(d) The GFRP fixture

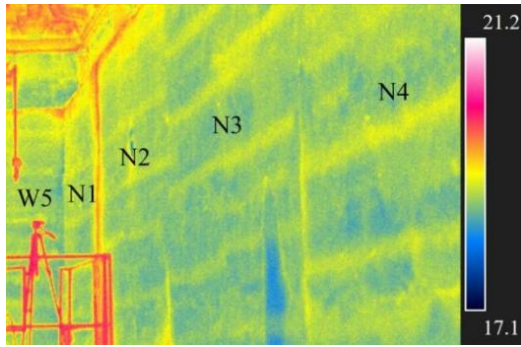


(e) Rough red brick wall

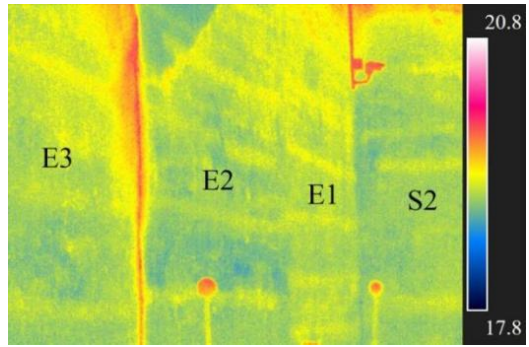


(f) Splitting of the wood keel

Figure 2. Endoscopic photographs of internal structure details of the eave wall



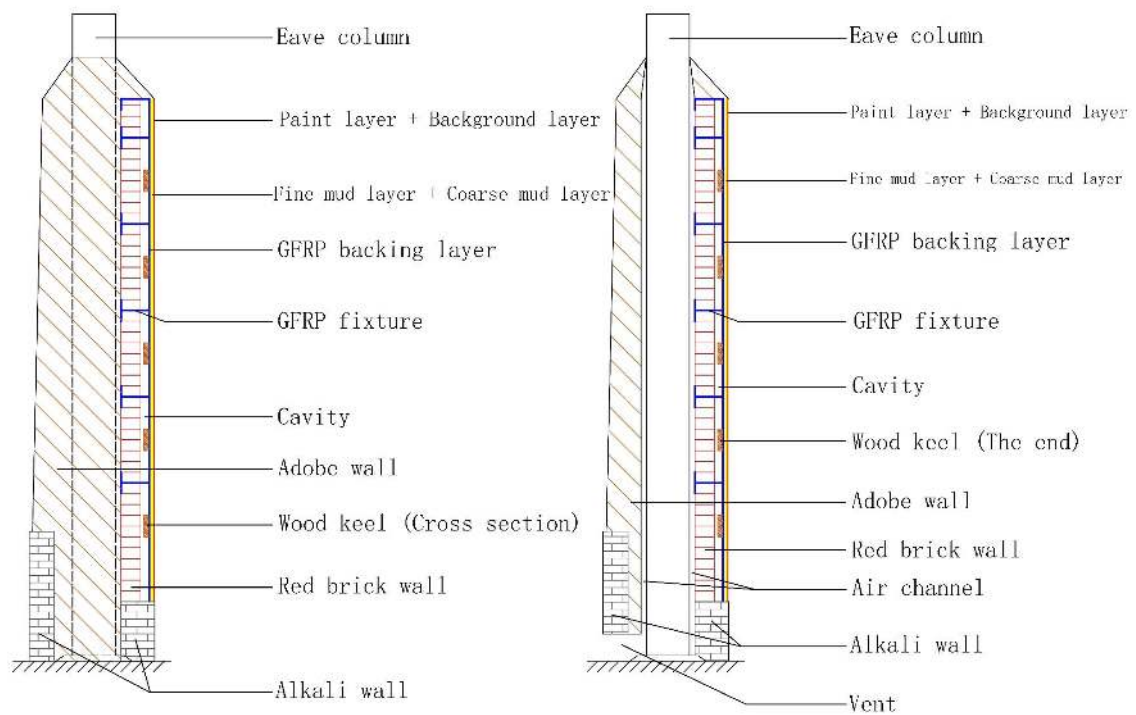
(a) The northwest corner



(b) The southeast corner

Figure 3. Infrared thermal images of the arrangement of wood keels behind the mural backing





(a) Mural structure in the unit (b) Mural structure at the eave column

Figure 4. Cross-section of the eave wall mural's existing structure



Figure 5. Comparison of the eave wall mural in Daxiong Hall between the present and the past (East wall E4)

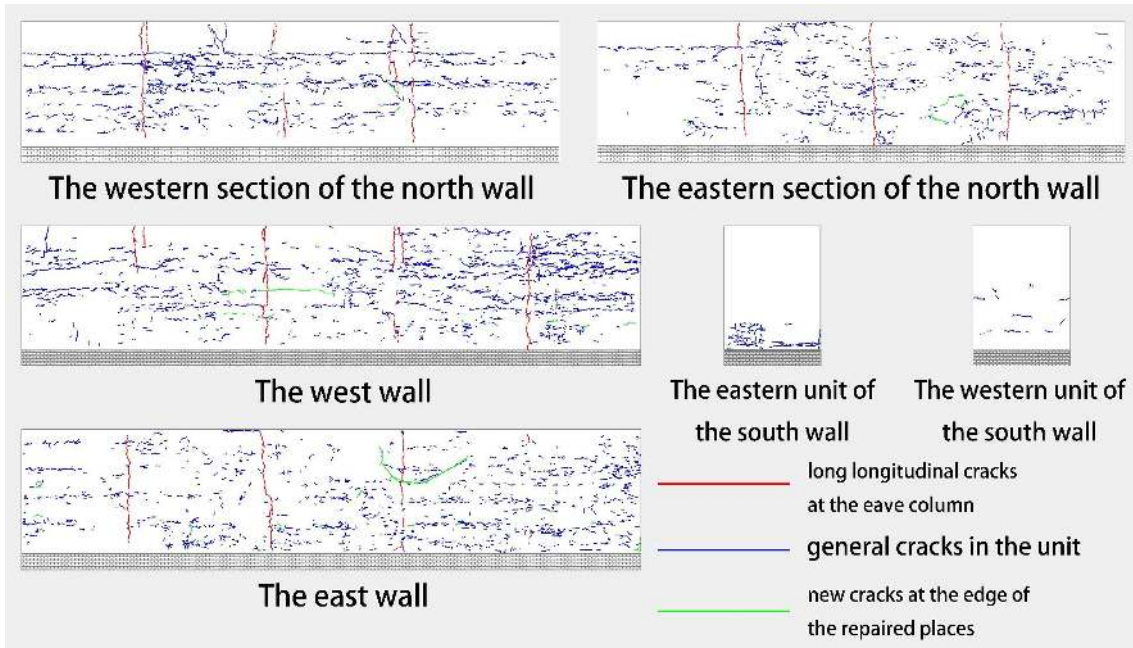


Figure 6. The vector diagram of the distribution of secondary cracks of the eave wall mural

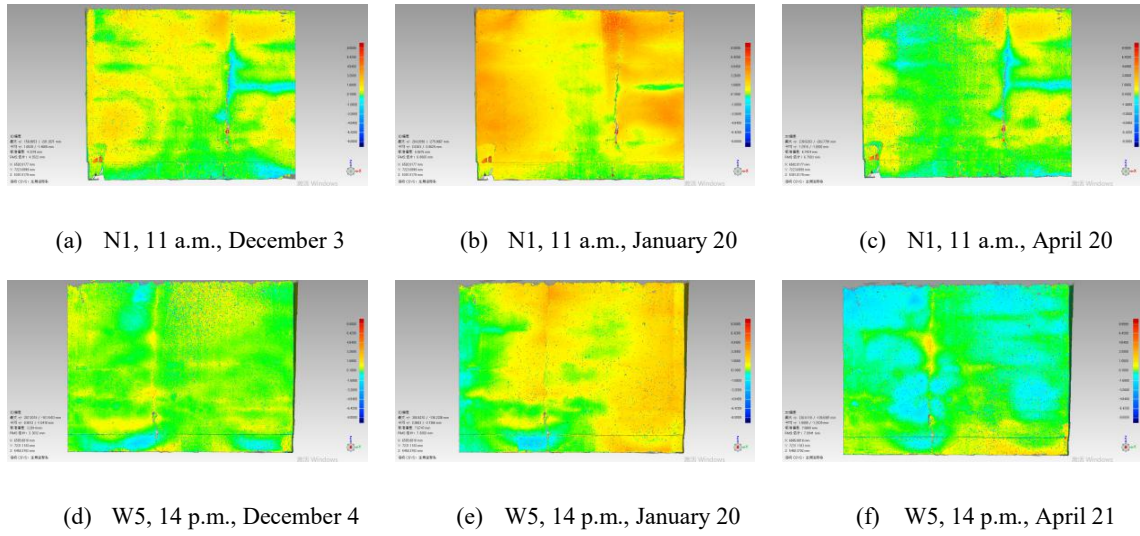


Figure 7. Deviation chromatogram of surface deformation of the eave wall mural in the northwest corner of Daxiong Hall

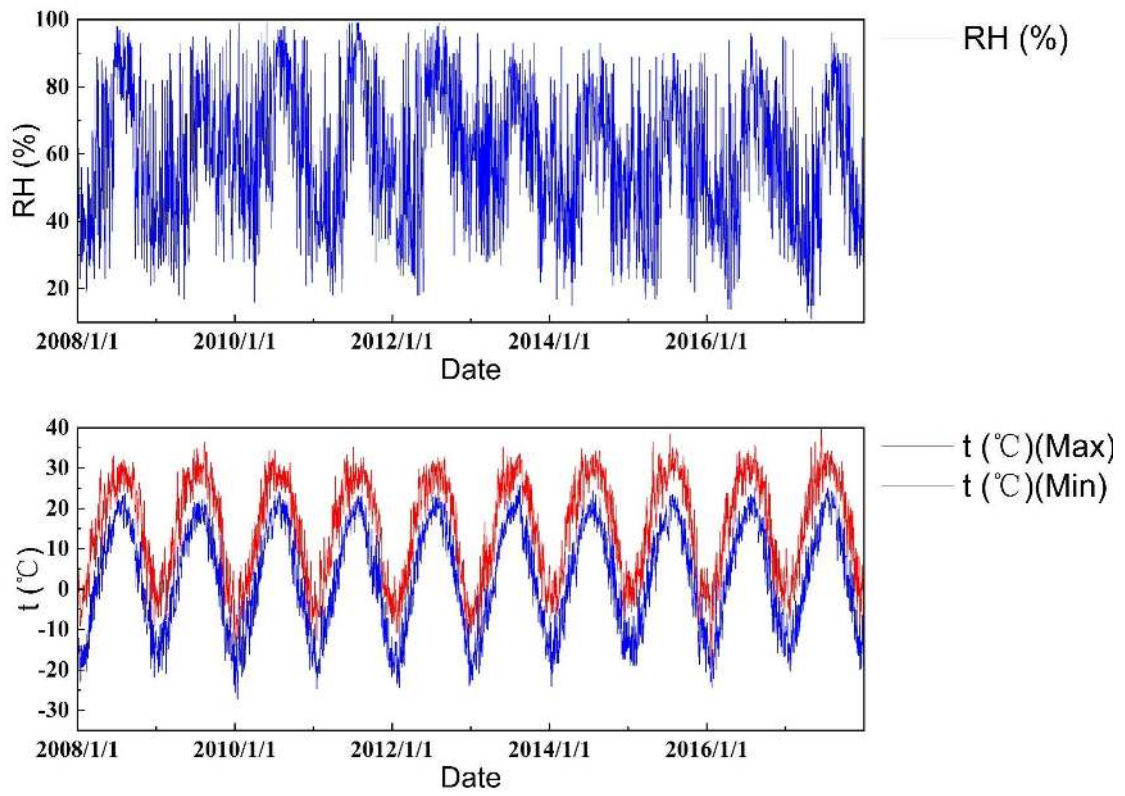


Figure 8. Diurnal variation curve of near-surface atmospheric temperature and humidity in Yixian County from 2008 to 2017

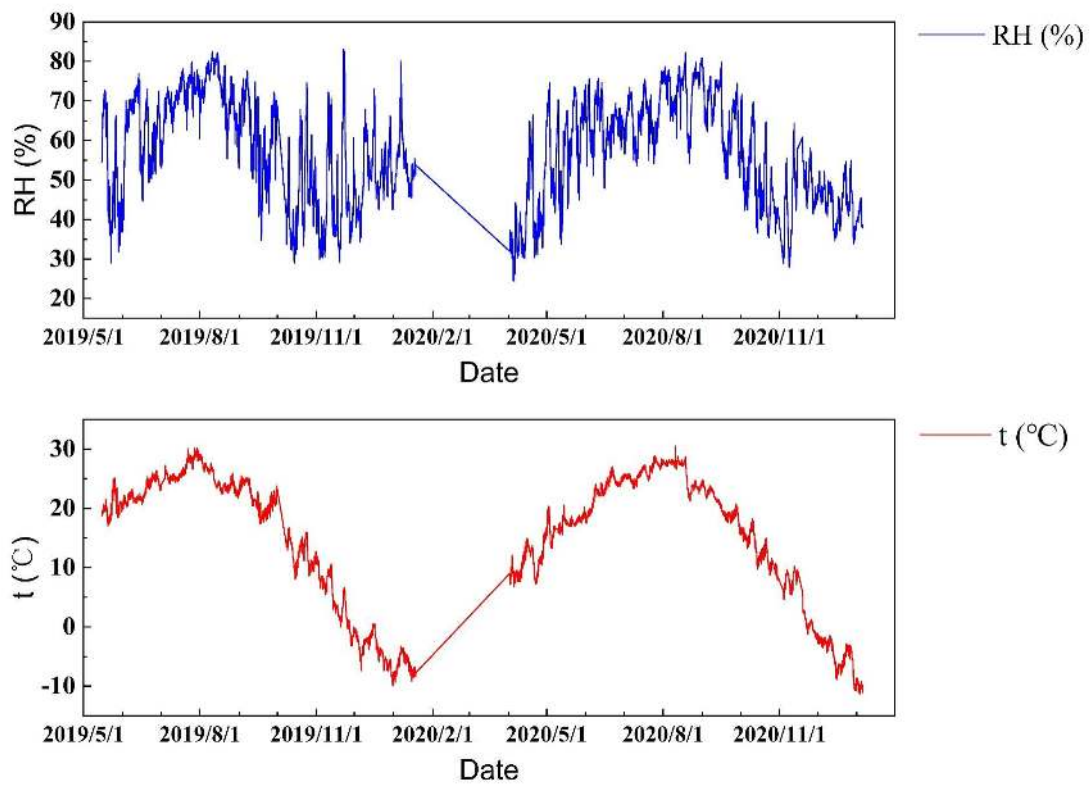
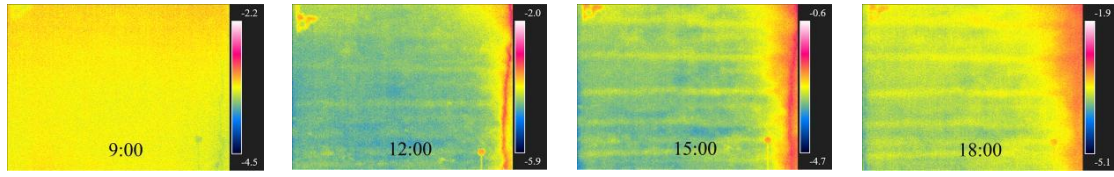


Figure 9. Hourly change curve of air temperature and humidity in Daxiong Hall from May 2019 to January 2021



(a) 9:00 a.m.

(b) 12:00 p.m.

(c) 15:00 p.m.

(d) 18:00 p.m.

Figure 10. The change process of infrared thermal image on surface of the north wall N1 during a sunny day

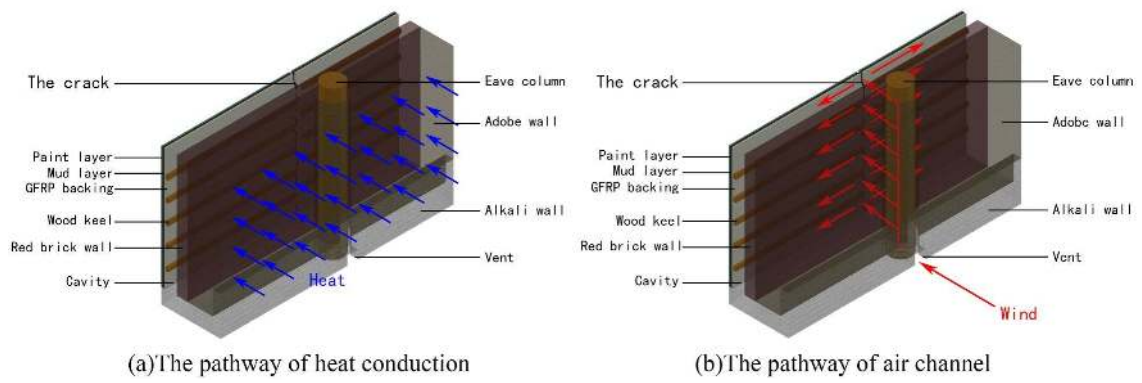


Figure 11. The pathway of external environment acting on the mural noumenon



# Figures

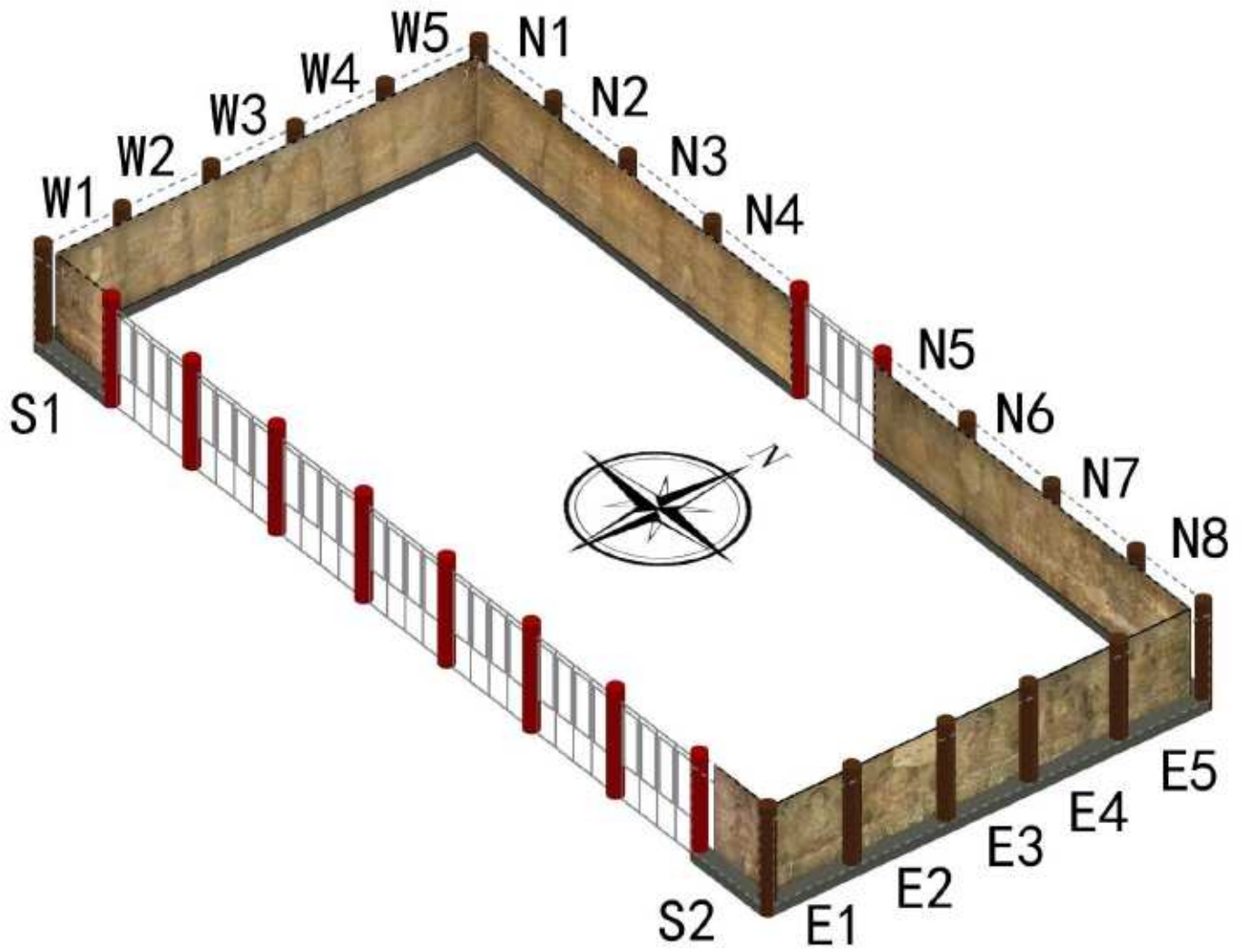


Figure 1

Distribution diagram of the eave wall mural in Daxiong Hall



(a) The end of the wood keel



(b) The wood keel bonded to the GFRP backing



(c) The wood keel covered by the GFRP backing



(d) The GFRP fixture



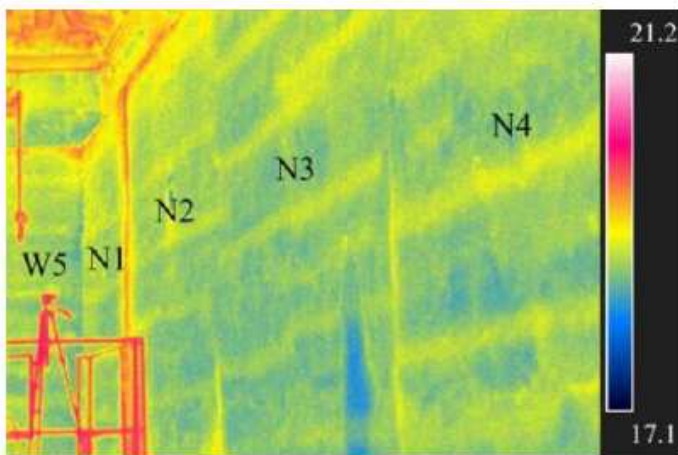
(e) Rough red brick wall



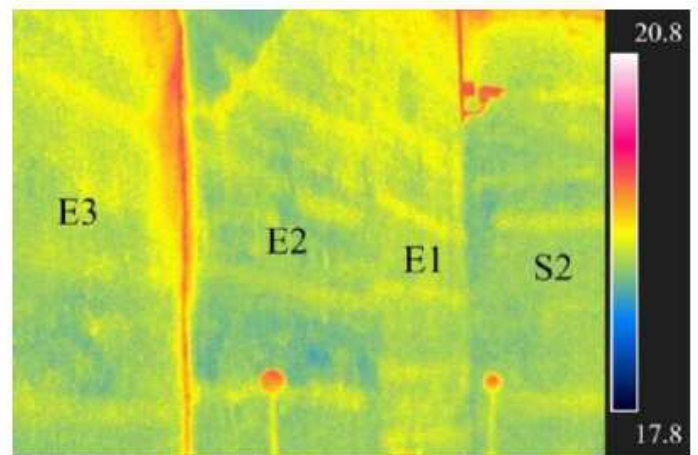
(f) Splitting of the wood keel

**Figure 2**

Endoscopic photographs of internal structure details of the eave wall



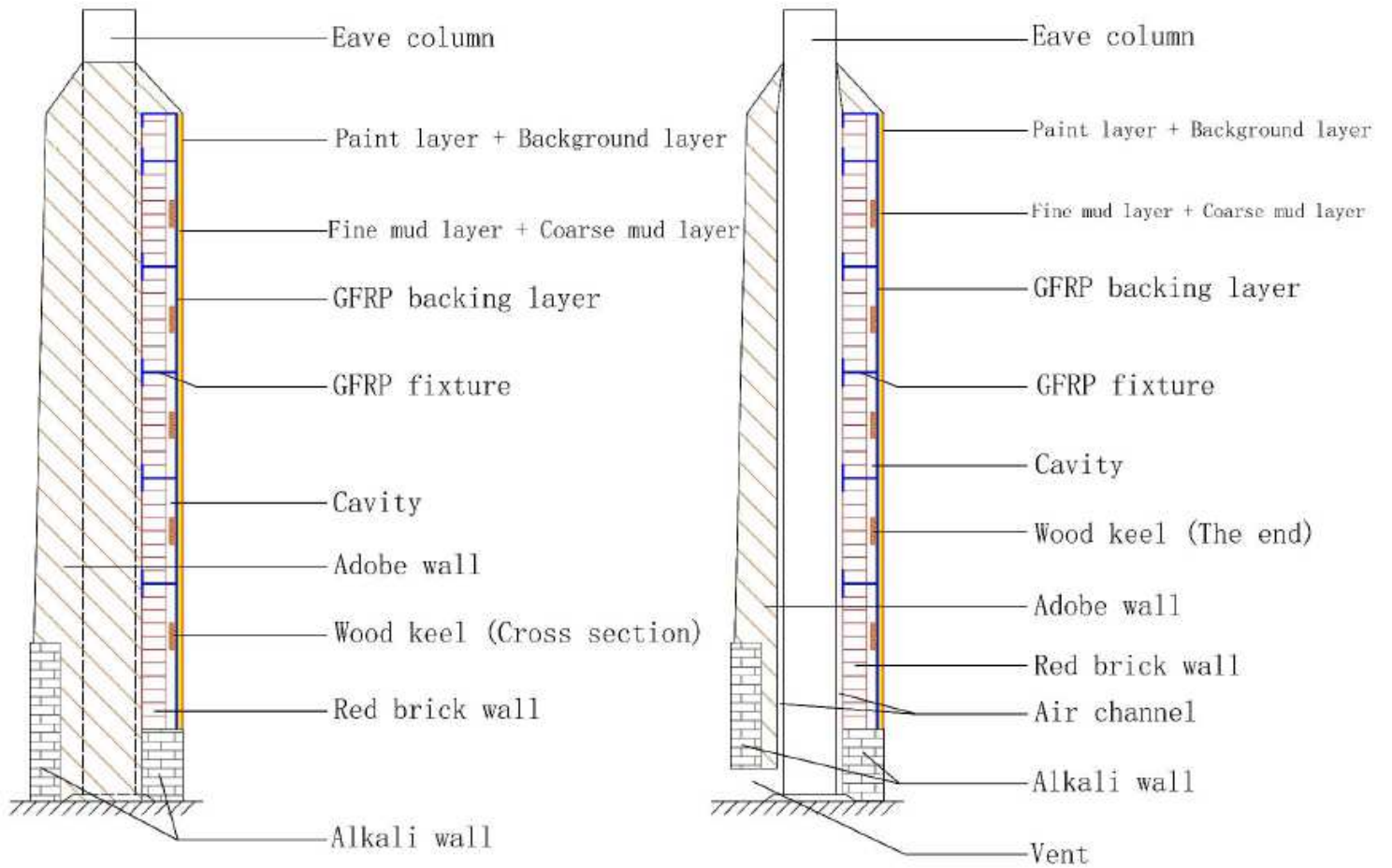
(a) The northwest corner



(b) The southeast corner

**Figure 3**

Infrared thermal images of the arrangement of wood keels behind the mural backing



(a) Mural structure in the unit (b) Mural structure at the eave column

**Figure 4**

Cross-section of the eave wall mural's existing structure



**Figure 5**

Comparison of the eave wall mural in Daxiong Hall between the present and the past (East wall E4)

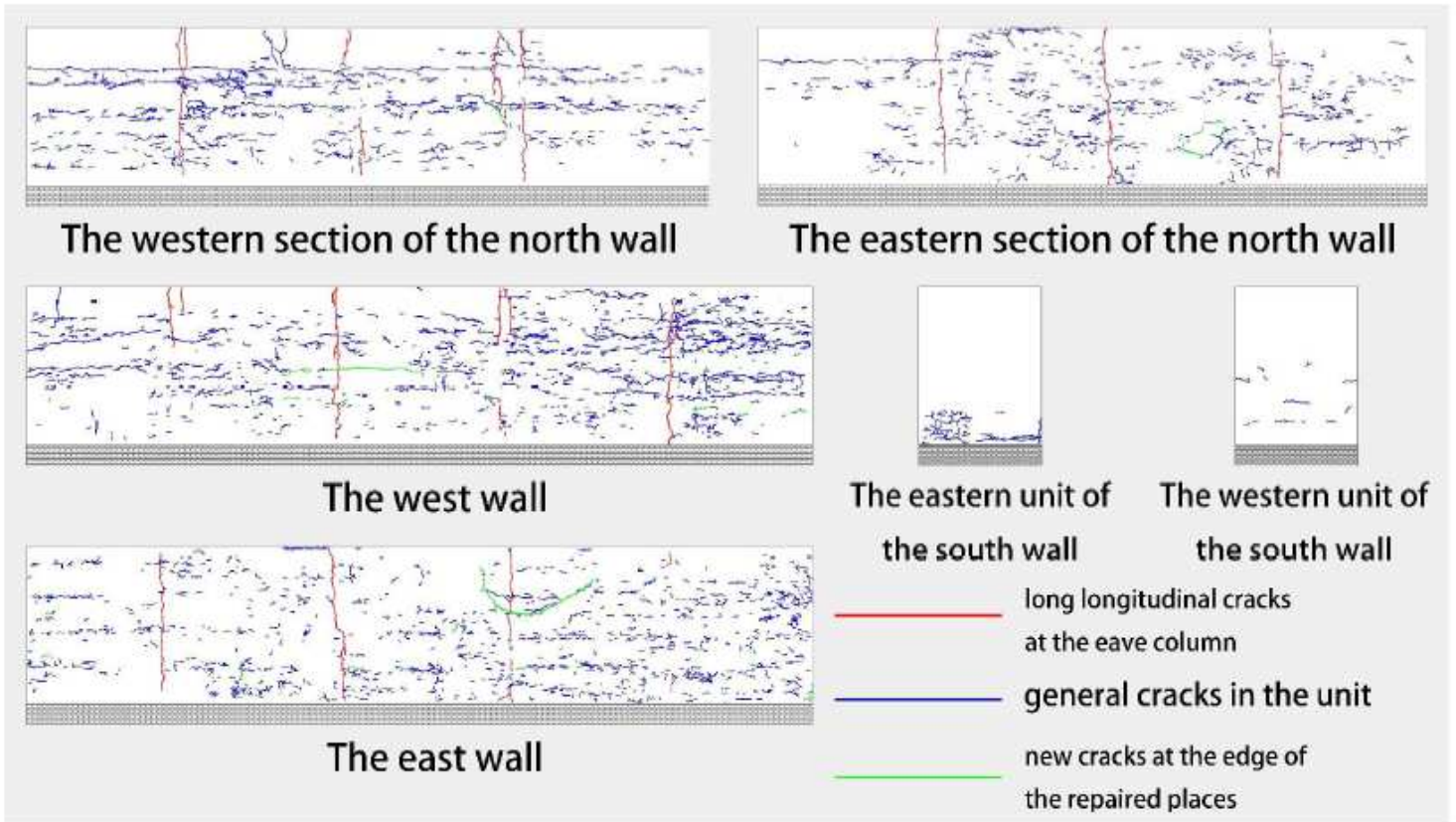


Figure 6

The vector diagram of the distribution of secondary cracks of the eave wall mural

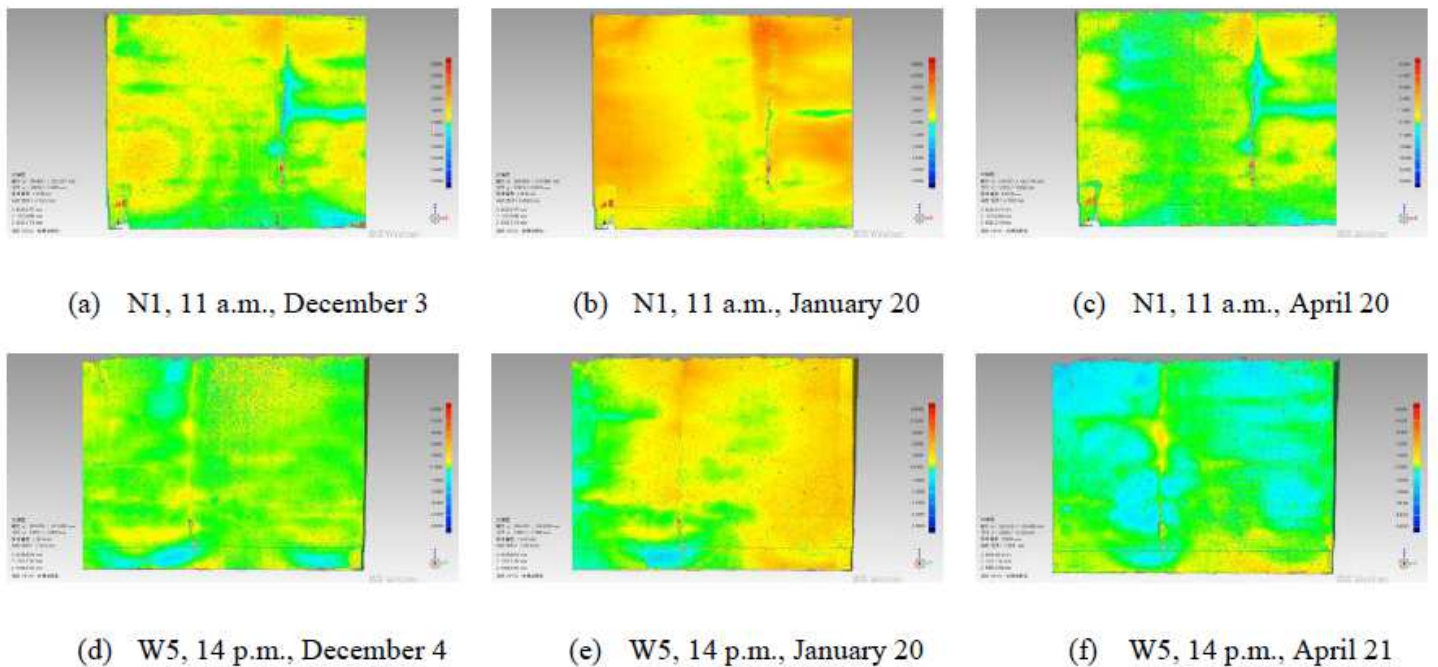


Figure 7

Deviation chromatogram of surface deformation of the eave wall mural in the northwest corner of Daxiong Hall

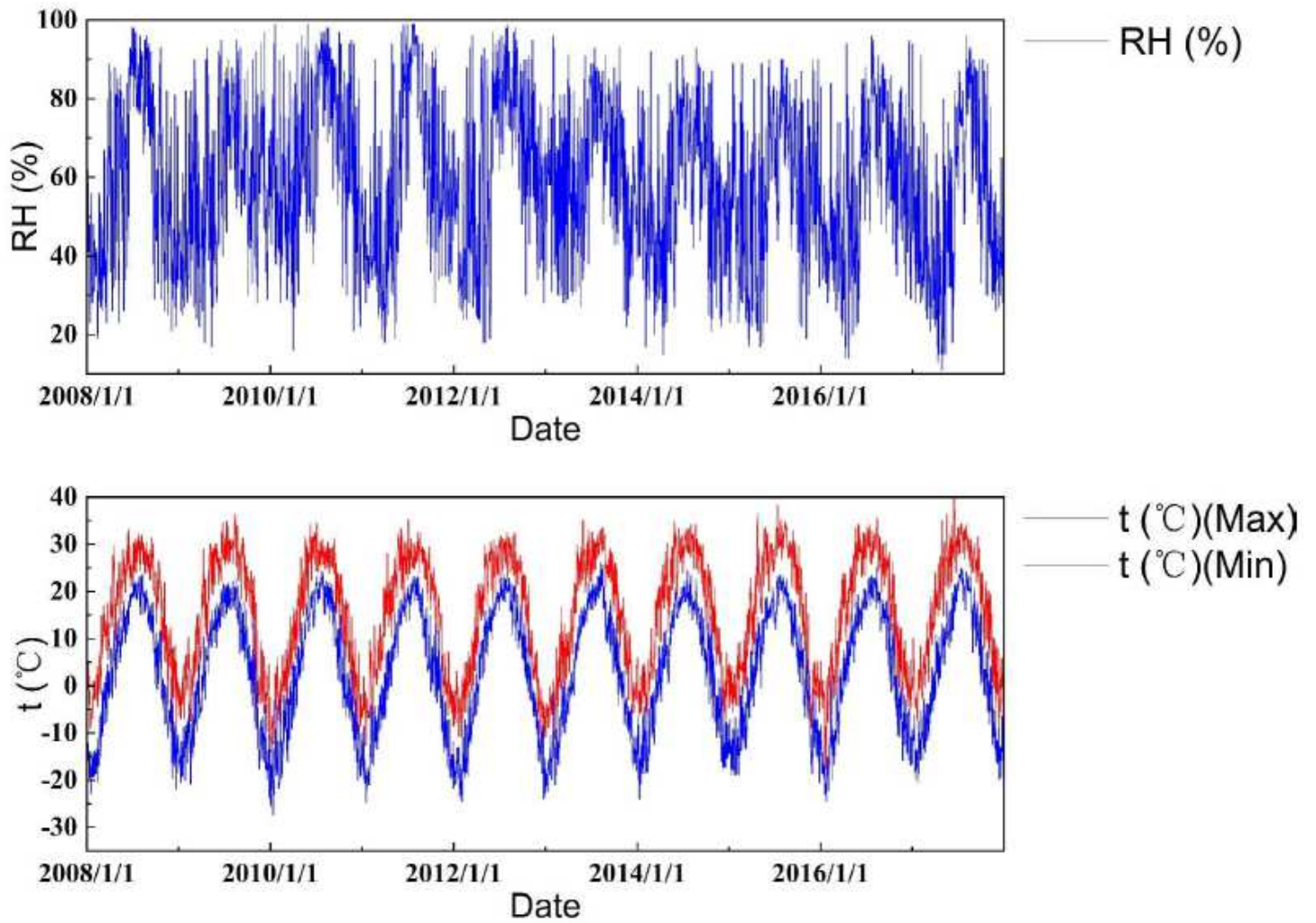


Figure 8

Diurnal variation curve of near-surface atmospheric temperature and humidity in Yixian County from 2008 to 2017

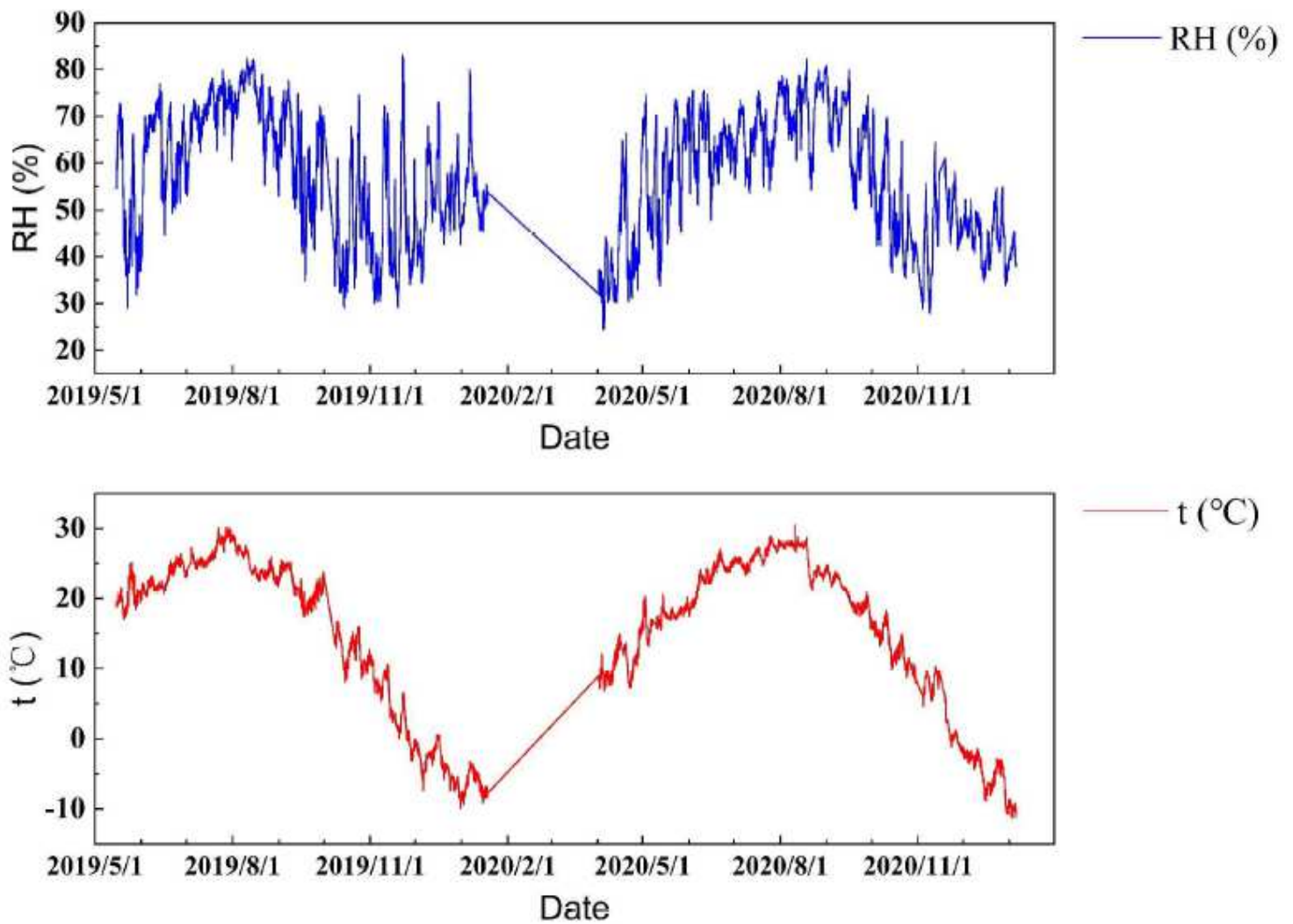
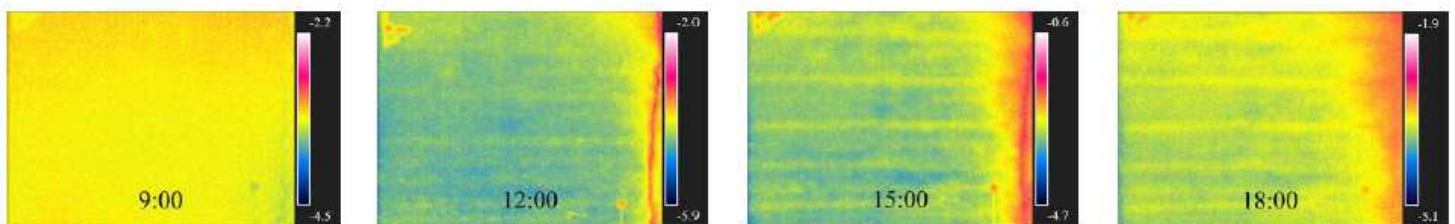


Figure 9

Hourly change curve of air temperature and humidity in Daxiong Hall from May 2019 to January 2021



(a) 9:00 a.m.

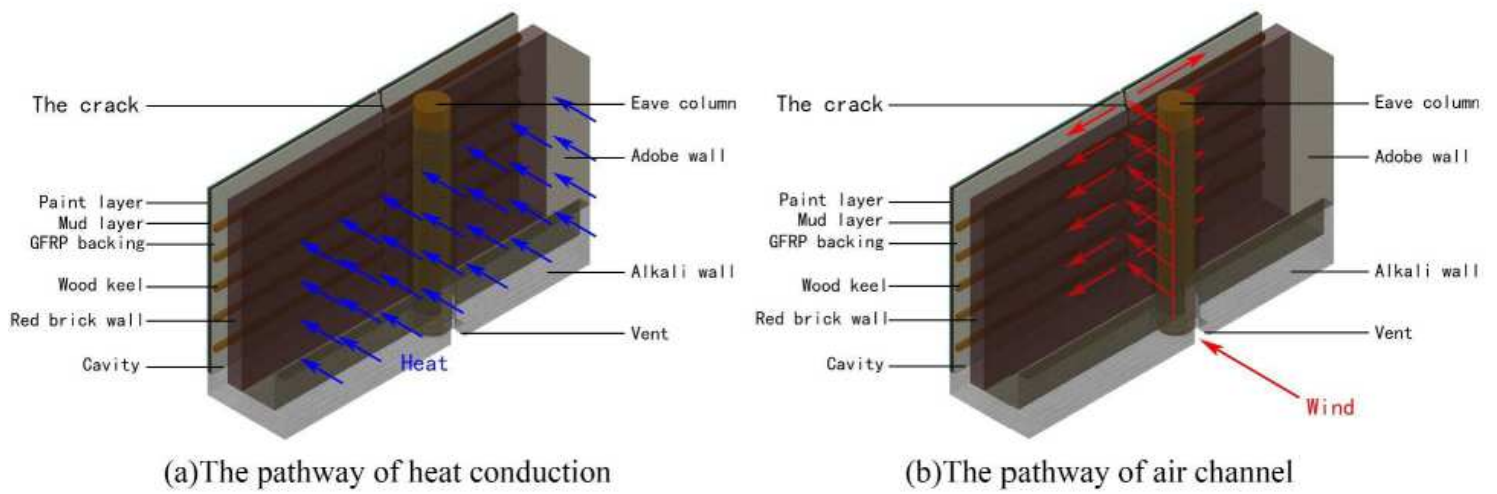
(b) 12:00 p.m.

(c) 15:00 p.m.

(d) 18:00 p.m.

Figure 10

The change process of infrared thermal image on surface of the north wall N1 during a sunny day



**Figure 11**

The pathway of external environment acting on the mural noumenon