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18 Application of GRC Curved Sandwich Panels with EPS Core and Exterior Finish

Jiang Yonghai
Nanjing Beilida, China

Summary: GRC curved sandwich panels, which mainly consist of GRC facing layer, GRC rear layer, EPS core, steel joist, exterior finish etc were used as exterior walls on the concrete frame structure buildings in Huhhot city. These panels incorporate the functions of enclosure, thermal insulation and surface decoration together. They have characteristics of lightweight, fireproof, good appearance and easier installation. In this paper the design, manufacture and installation processes of these panels are described.

Key words: GRC; sandwich panel; concrete frame construction

INTRODUCTION

The Youth Centre, being constructed in the capital city Huhhot of the Inner Mongolia Autonomous Region of China, covers an area of 3.6 hectares and its total building area is more than 38,000m^2. The construction concludes three main parts: a complex building, a theater and a gymnasium. Fig.1 shows the design effect drawing of the project. According to the requirements of the owner, the construction project should reflect not only the feature of the culture and custom of the Mongolia nationality, but also the modern architectural design concepts. For meeting the above first requirement, the color of all the buildings should be white and all window openings should be irregular triangular. For meeting the above second requirement, it should be considered in design such as the use of lightweight and high strength construction materials, energy conservation in use and elegant appearance.

In consideration of the owner's requirements and by comparing the performance of different construction materials, it was decided to use GRC sandwich panels, which mainly consist of GRC facings, EPS core as thermal insulation material, steel joist and exterior finish, for constructing all exterior walls of the buildings of the Youth Centre.

Because various shape for GRC elements could be fabricated by using the spray-up process, the shape of most GRC sandwich panels was designed as curved rhombus. In most panels there are preformed irregular triangular openings for installing glass windows. The typical dimension of the panels is as follows: width—2400 mm, height—4200 mm, thickness—250 mm. The average area and

average weight of the panels is about 10m^2 and 1.6t, respectively. Among them the largest area of the individual panel is about 30 m2. The total areas of the panels to be used are 26,000 m^2.
The contour of the external facade of the buildings was designed to have cured shape. Especially its most parts are with irregular curved surfaces. For these reasons there were some difficulties for designing, production and installation of the GRC sandwich panels used in this construction.

DESIGN OF THE GRC PANELS

The design task for the construction was entrusted by the Design Institute of the Inner Mongolia University of Technology. According to the design scheme, the panels to be used for constructing the exterior walls of the buildings should correspond with the following criterions:

(1) The exterior finish of the panels gives the decorative effect of white concave-convex surface.
(2) The shape of the panels must be curved rhombus.
(3) Irregular triangular openings must be preformed in the panels.
(4) The panels have the functions of enclosure, thermal insulation and surface decoration.

In consideration of these requirements combining with the budget of the construction cost, the technological difficulty and other factors, the expected purpose could not be attained if the conventional construction materials such as building stone, metal, glass etc were used. Finally GRC has been selected as a result of overall comparing the production technology, the properties and application reliability for some construction materials.
The main design contents for GRC sandwich panels are as follows.

Structural design

The conventional GRC decorative panel is a single-skin sheet with thickness of 10-30mm, which does not have the functions of enclosure and thermal insulation. For this construction project it is required that the GRC panel should have the functions of enclosure, thermal insulation and decoration, therefore the construction form of the panel to be used in this construction would be more complicated in comparison with the conventional single-skin panel.
According to the above requirements, the panel used in this project was designed as a cased beam, which consists of finishing layer, GRC facing layer, EPS core, GRC reinforcing web, GRC rear layer, steel truss, connecting fittings and crack-resistant material (see Fig.3). Based on mechanical calculation and thermal engineering calculation, it has been confirmed that the thickness of EPS core, that of GRC facing layer (including the finishing layer) and that of GRC rear layer shall be taken as 223mm, 15mm and12mm, respectively. In general the prefabricated reinforced concrete wall panel is very heavy. In order to decrease the load applied to the construction structure and reducing the difficulties in handling and installation, the designer has designed to decrease the dead weight of the

panel as much as possible. The weight of unit area of GRC is only the third of that of the prefabricated reinforced concrete wall panel. Because the GRC layer is very thin, it is necessary to set steel truss embedded in it in order to increase the bending strength and the stiffness of the product, ensuring the safety of the overall panel construction. Considering the water tightness of the panels after installation, tongued- and grooved edge connecting of the panels was designed. For ensuring the fire resistance of the panel, EPS core should be fully enclosed in GRC material. Under this circumstance, even any panel might be damaged inducing the burning of EPS core, it could not influence on the others.

In order to attain the monolithic finishing effect, the designer should consider that how to ensuring the leveling and integrality of the panels after installation. Because the external façade of the buildings is irregular cured, the designer had to divide the façade into many panels with different dimensions and curves. For this construction project there were more than 1000 panels in different dimensions and curves designed and produced. The total number of panels used was 3000.

Fig.2 shows the construction site of the Huhhot Youth Centre.

Design of installation joints

The total thickness of one GRC sandwich panel was 250mm. Though the panel was filled with EPS core, its weight of unit area was still greater than that of single-skin GRC panel. Therefore, it was very necessary to consider by the designer that which installation technique should be used for ensuring the safety of the panels in use. The designer took the following factors for comprehensive considerations, such as strength, stiffness, ductility, volume deformation, durability and fire resistance etc. for ensuring that the fittings could bear and transfer the stresses induced by the dead weight and the volume change of the sandwich panel, the wind load , seismic load etc. The panels were designed to connect with concrete frame construction by using L-type steel angles. It can be seen from Fig.4, that there are 3 installation connecting points set on upper edge and bottom edge of the panel, respectively. Each connecting point is welded with the steel truss embedded in GRC material in order to transfer the stress from the connecting point to the truss. Taking this important technical measure, the stresses can be dissipated effectively avoiding the damage of the panel due to the higher local stress. For ensuring the 50 year service life of the panels, all fittings were made with hot galvanizing or stainless steel. According to the mechanical calculation, the GRC material on the installation connecting point could subject horizontal shear stress of 0.76 MPa and perpendicular shear stress of 0.64 MPa, so all these stresses were less than the designed standard stress of 1.0 MPa. For further verifying the safety of the installation connecting points, the pull-out failure testing was carried out. The test results showed that the average value of single point can reach more than 18 KN, which is obviously much higher than the design value of 6.25 KN.

Fig.4 is a sectional drawing of upper and bottom supporting points for installing the panel.

Mechanical calculation

For ensuring the safe coefficient of above than 1.5 for the GRC panels, the structural design engineer performed strict calculation according to the relevant design codes and took the following factors into consideration, such as the local geographical environment and weather conditions, material performance, panel construction etc.

The highest installation point of the GRC exterior wall for the Huhhot Youth Centre is 39.3 m. According to the codes for curtain wall and the relevant loads, the designer took the following data for calculation:

Dead weight of GRC panel = 2000 Kg/m3;

Basic wind pressure = 0.55 KPa (only once in 50 years);

Dead load of (15 mm GRC face layer + 12 mm GRC rear layer + EPS core + GRC web) = 1.1 KPa

Overhaul live load = 1.0 KPa;

Seismic load applied to (15 mm GRC face layer +12 mm GRC rear layer +EPS core + GRC web) = 0.44 KPa.

Based on the above load values, the designer performed calculation for the sandwich panels with different constructions. The calculations contents included monolithic bending strength and deformation, local bending strength (for embedded beams between windows), shear strength on installation connecting point of GRC, shear stress of stay bolts and welding seams etc. All testing results for the sandwich panels including pulling force, shear force, loading capacity and stiffness showed that the measured strengths of the panels could meet the design values or were even higher. The design and the measured stress values for GRC sandwich panel are given in Table1 1. Fig. 5 shows the field testing for a GRC panel.

Table 1 Design and measured stress values for GRC sandwich panel

Kind of stress	Actual load	Design stress (MPa)	Measured stress (MPa)
Compressive	Compression force	12	27.6
Bending	Bending force on GRC surface	6	14.5
Bending	Bending load on GRC web	4	9.6
Shear on supporting point	Shear load on supporting point	1	2.1

Thermal engineering calculation

According to the China National Standard “GB 50189 Energy Saving Design Standard for Public Buildings”, Huhhot city belongs to region B of the cold regions in China, therefore heat transfer

coefficient of the exterior enclosure construction for this construction project shall be 0.45 W/㎡·K or less than it. The thermal engineering calculation of the exterior wall was performed according to the above standard and the standard "GB 50176-95 Code of thermal engineering Design for Civil Architecture". For meeting the energy saving requirement prescribed in the standards, it was confirmed that 223mm thick EPS board with thermal conductivity of 0.040 W/m·K should be filled in the cavity of the panel. After installing the panel, a 20 mm thick air layer, a 15 mm thick calcium silicate board and a 20 mm thick mortar layer are set on the panel rear side. Taking the above mentioned measures, the overall thermal resistance of the exterior enclosure construction could reach 2.8 m^2·K /W and its average heat transfer coefficient was less than W/㎡·K, so that its thermal insulation effect is much better than that of 300mm thick ceramsite concrete thermally insulated with 70 mm thick EPS.

In the position, where the panel connected with the beam and column of the concrete frame construction, the panel was designed to have thinner perimeter parts covering the beam and column. For avoiding the formation of cold bridge on this position, the beam and column should be adhered with foamed thermal insulation material.

INSTALLATION AND AFTERTREAMENT

It is very necessary to set lift hooks used for demoulding, handling, transporting and installing for the large-sized GRC sandwich panels.

The GRC sandwich panel was hoisted to the floor for installing by a crane. After fixing it by the electric hoist as a first step, the position of the panel should be adjusted and calibrated, and then it was set on the connecting angle as a fixed position. After leaving from the lift hooks, the panel was connected with the concrete frame by using expansion and plastic bolts. Finally the connecting fittings of the panel were welded with the angles. The joint seams between the panels were sealed with foamed strips and elastic adhesive glues. Fig.6 shows installation of GRC sandwich panels on the site.

For ensuring the aesthetic effect of the buildings, it is very necessary to keep the consistence for the surface colour of all panels, the contour and the joints of the walls. Because the GRC sandwich panels were curved and very thick, it was the most important to control the quality of the production and installation processes for the panels. Otherwise, if some panels with greater dimension or contour deviation were be used, there would be very trouble and puzzled in construction works.

It is possible that the panels may be polluted by rainwater, dust, sludge, iron rust etc. In fact the pollution problem of building products can not be avoided on construction sites; therefore the panel manufacturer should provide suitable protective measures to the construction organization. The following protective measures may be used: such as covering the products with plastic films or spraying certain permeable stain-resisting agent on the product surfaces. For this construction

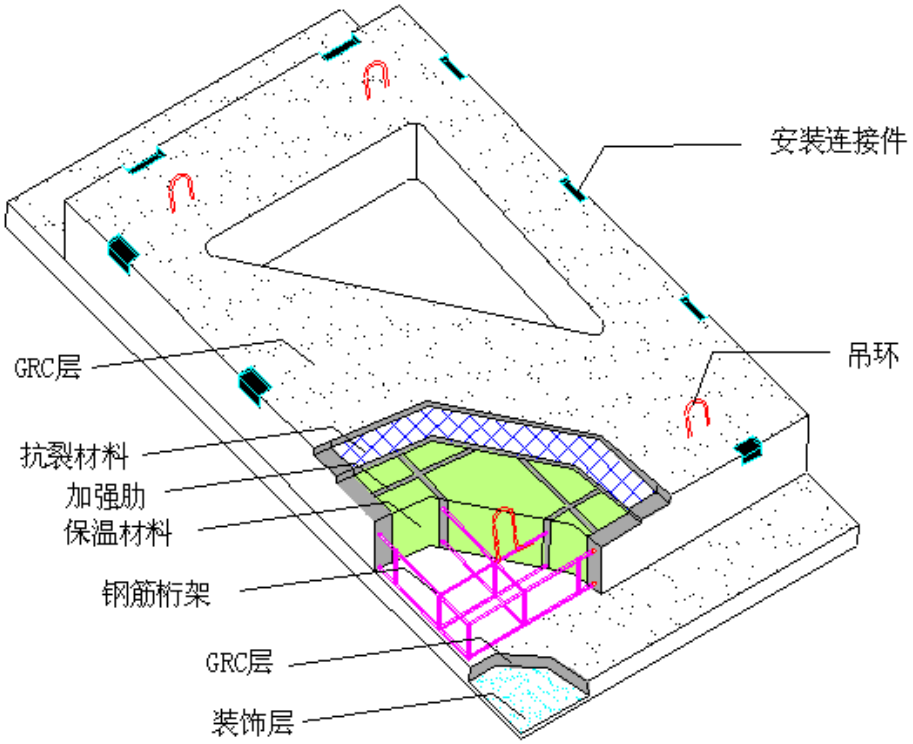
project mainly the second measure mentioned above was used more effectively.

CONCLUSION

GRC curved sandwich panels, which incorporate the functions of enclosure, thermal insulation and surface decoration together, have been used as exterior walls in concrete frame construction of the Huhhot Youth Centre. The production and application of these panels were for the first time in China. In comparison with the traditional enclosure construction, especially the prefabricated concrete sandwich panel thermally insulated, the main features of the GRC sandwich panel are lightweight, fireproof, good decorative effect and easier installation. Certainly, it could be anticipated that the GRC industry in China might make new contributions for developing new type energy saving buildings.

Fig.1 The design effect drawing for the Huhhot Youth Centre

Fig.2 The construction site of the Huhhot Youth Centre



饰面层(decorative layer)、GRC 层(GRC layer)、保温层(EPS core)、GRC 加强肋(GRC reinforcing web)、GRC 层(GRC layer)、钢筋桁架(steel truss)、安装连接件(connecting fitting)、抗裂材料(crack resistant material)、吊环(lift hook)

Fig.3 Schematic drawing of the GRC sandwich panel

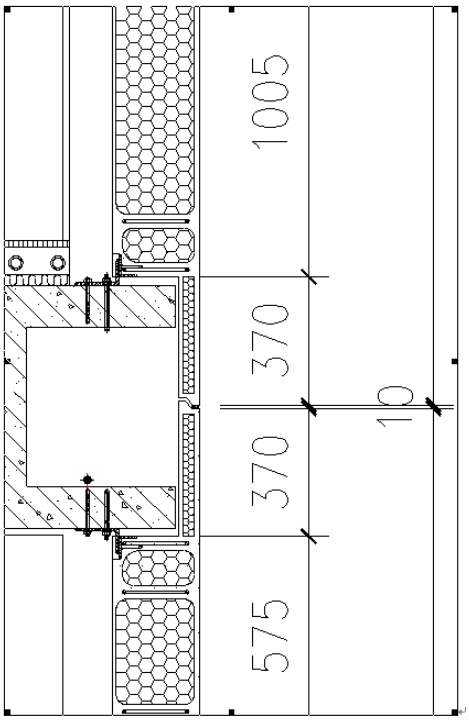
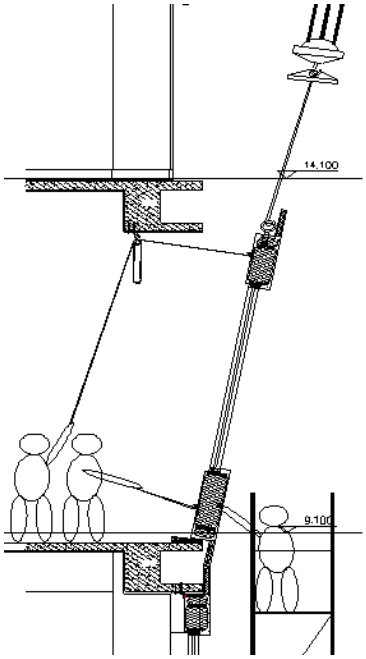


Fig.4 Sectional drawing of upper and bottom supporting points

Fig.5 Field testing of a GRC sandwich panel



(a) Schematic drawing (b) Panel installation on construction site

Fig.6 Installation of GRC sandwich panels: