



31 Recent Development in China GRC Industry and Development and Application of Diversified GRC Products

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Abstract: The first part of this paper describes the outline of the development of the China GRC industry, including organization of the China GRC industry and its business activities, recent development of GRC raw materials, development of GRC products and establishment of standards. The second part presents the development and application of diversified GRC products, emphasis is laid on several typical products, for example, GRC wall panel and ceiling used in prestigious buildings, GRC hollow core formwork used in large area roof or floor, GRC box-room used in electrical and telecom engineering, GRC partition wall panel and GRC exhaust port used in residential buildings etc.

1. Outline of the development of China GRC industry

1.1 Organization of China GRC industry and its business activities

China GRC industry is organised by the China GRC Association (GRCA) which is an affiliation of the China Building Materials Federation registered under the Ministry of Civil Affairs of the People's Republic of China.

Founded in 1985, China GRCA has 160 members now. Main business activities of the association are: organising conferences and technical seminars, establishing technical guides and standards, editing technical information, providing technical consultant and organizing members to attend related events etc.

China GRCA organises national congress biennially and a different theme is set at every congress. Themes of recent three congressed are "GRC cladding panels and review of 20 years' development of the China GRC industry" in 2006, "GRC products and Olympic projects" in 2008 and "GRC product and



customised building” in 2010. Through exchange of first-hand experiences and new technologies, introduction of typical GRC products and projects, studying new standards, discussing common problems, GRCA congresses provide opportunities for members to publicize themselves and learn from each other.

1.2 Recent development in GRC raw materials

1.2.1 Recent development of alkali-resistant (AR) glassfibre

Quality of AR glassfibre products shall comply with JC/T 572 - AR glassfibre roving and JC/T 841 - AR glassfibre mesh. While continuing improving the quality and performance of AR glassfibre roving and AR glassfibre mesh, Xiangfan Huierjie Glassfibre Co. Ltd. has successfully developed AR glassfibre mat (Figure 1) in 2008. This product is manufactured by cutting glassfibre strand (filament diameter: 9-11 μ m) into 50mm length then bonded by adhesives and flattened. The specially developed adhesives dissolve rapidly in cement slurry when meet with water, enabling chopped strands disperse and combine with cement slurry closely, and hence the performance of GRC products is improved. So far, AR glassfibre mats have been applied in many projects and showed good effect.



Figure 1 AR glassfibre mat

1.2.2 Recent development of sulphoaluminate cement (CSA)

Because the pH value of liquid phase in hydration products of CSA cement is lower than that of OPC, it is beneficial to maintain original properties of AR-glassfibres. Another advantage of this cement is the setting and hardening is very fast, which helps improve the production efficiency. For those

reasons, this cement is widely used in China GRC industry. Quality criterion of CSA cements is GB 20472 - sulphoaluminate cement. In recent years, demand on coloured GRC products is increasing, this normally needs to add inorganic pigments into very light colour cement. Wanglou Cement Industry Co., Ltd. has successfully developed a white CSA cement to meet this demand in 2010. Systematic experiments are undergoing to enable mass production. Figure 2 shows the colour difference of samples made from traditional and white CSA cements.



Figure 2 Comparison of sample colours

1.3 Quality standards for GRC products

Since 1983, dozens of different GRC products have been developed in China. As time goes by and a deeper understanding of GRC technologies, some products have gradually disappeared on the market, whilst new products have emerged with considerable influence to draw designers' and government authorities' attention. For quality assurance purpose, China GRCA has organised members to establish a series of GRC product standards including JC/T 854-2008 - Glassfibre reinforced cement exhaust port, JC/T 567-2008 - Glassfibre reinforced cement corrugated sheet and ridge tile, JC/T 1057-2007 - Glassfibre reinforced cement panel for exterior wall, GB/T 19631-2005 - Glassfibre reinforced cement lightweight hollow panel for partition wall, JC/T 952-2005 - Glassfibre reinforced cement permanent tube-shaped core formwork, JC/T 940-2004 - Glassfibre reinforced cement decorative products and JC/T 893-2001 - Glassfibre reinforced cement inside insulation panel for the exterior wall. These standards play an important role in guarantee product quality and progress the China GRC industry.

2 Development and application of GRC products

As mentioned above, GRC products in China are diversified. Only products gained wide popularity in

recent years in construction industry and building material industry are presented here, including GRC wall panel and ceiling used in prestigious buildings, GRC hollow core formwork used in large area roof or floor, GRC box-room used in electrical and telecom engineering, GRC partition wall panel and GRC exhaust port used in residential buildings.

2.1 GRC wall panel and ceiling used in prestigious buildings

In China, GRC products have been well accepted by architects when designing prestigious buildings, for example, Olympic projects, World Expo projects, commemorative architectures, museums, national or local landmark buildings etc.

Figure 3 is a photograph of the music hall of the National Grand Theatre. Inside the hall, GRC ceilings and GRC wall boards were used. Ceilings were manufactured by Beijing Baogui StoneArt Co. Ltd. Total area of ceiling was about 1300m², individual ceiling board was 3420mm long, 2260mm wide and 24mm thick. The surface of ceiling was corrugated, the maximum convexo-concave was 480 mm. Wall boards were manufactured by GRC Building Materials Industry Co. Ltd. Total area was around 2000 m² with a standard board size 3.3×1.1m. The whole wall surface was shaped into sea waves.



Figure 3 GRC used in the music hall of the National Grand Theatre

Figure 4 shows the GRC lamp pool and ceiling in the Opera House of the National Grand Theatre. Total GRC use is about 500 m². The lamp pool was built into an arc shape. GRC surface is painted in golden colour. Round holes were evenly distributed in the arc board to enable light pass through. These products were manufactured by GRC Building Materials Industry Co. Ltd.



Figure 4 GRC in the opera house of the National Grand Theatre

Figure 5 shows the GRC and concrete hybrid wall panels used in Xi'an Daming Palace.



Figure 5 Hybrid panels of GRC and concrete in Xi'an Daming Palace

Figure 6 is a photograph of Beijing Guo'ao Gallery, which was presented at Shanghai World Expo. External wall were made of GRC.



Figure 6 GRC external wall in Beijing Guo'ao Gallery

Projects in Figure 5 and Figure 6 were undertaken by Beijing Baogui StoneArt Co. Ltd.

Figure 7 shows Shanghai Music Square. The corrugated roof, the dome, the S-shape ornament and the arc-shape strips were all made of GRC.



Figure 7 Shanghai Music Square

Figure 8 is a photograph of Zhengzhou International Convention and Exhibition Centre. GRC were used in the eastward and westward wall, the secondary entrance and cornices. Total GRC area was about 10,000m². The dimension of the largest panel was 4×2 m.



Figure 8 Zhengzhou International Convention and Exhibition Centre

Figure 9 is a photograph of Beijing CR Land Plaza. About 12,000m² GRC cladding panels were used, colour is light gray or dark gray, surface was sand blasted to achieve a granite effect.



Figure 9 Beijing CR Land Plaza

Projects in Figure 7 - Figure 9 were all completed by GRC Building Materials Industry Co. Ltd.

Figure 10 shows GRC panels used as exterior wall of an elevator room, which is part of the reconstructing and extending project for National Olympic Athletics Centre. There were six elevators in this project. Due to the elliptical shape of the Athletics Centre, the outward side of these elevator rooms had to follow the elliptical curve. Most GRC panels were made into irregular shape, for example, L-shape panels to enclose doors and windows and U-shape panels to cover columns. Most corners were not right-angled. Ribbed GRC panels were designed at maximum dimension of 2×3.2m. Typical panel thickness and rib depth was 15 mm and 140mm respectively.



Figure 10 GRC panel used in elevator rooms in the National Olympic Athletics Centre

Figure 11 shows GRC double curved ceiling used in the corridor of a shopping centre in Beijing. The ceiling is 200m long and 15m wide. The cross section of the ceiling was an arc shape and the ceiling required smooth connection in the width direction, i.e. no obvious joint should be observed in 15m

width range. The ceiling panel was ribbed and stud frame hybrid construction. Maximum size was 3000mm×2000mm. Thickness of panel was 15mm and depth of rib was 150mm.



Figure 11 Double curved ceiling used in a shopping centre in Beijing

Figure 12 shows the entrance of a subway station of Line 15 in Beijing. Totally 3000m² precast GRC grid panel were used. Standard panel size was 2×2m with thickness of 100mm.



Figure 12 Entrance of subway station

Figure 13 shows a project in Shenyang, in which artificial copper decorative column and wall panel were used. The width of column was 0.5m and the height was 12m. Each column consisted of four U-type ribbed panels, and hence the height of individual panel was 6m. The artificial copper wall consisted five U-type stud frame panels, the height of each panel was 1.5m and the width 5.4m with

0.5m edge return.



Figure 13 Artificial copper columns and wall panels

Another project using artificial copper panels was the Army Exhibiting Hall in Zhengzhou Virescence Exposition shown in Figure 14. Due to the irregular 3-D profiling of the structure, panel dimension and fixing types were diversified. Individual panel was ribbed U-type. The total area is about 3000m².



Figure 14 Army Exhibiting Hall in Zhengzhou Virescence Exposition

Projects shown in Figure 10 - Figure 14 were all undertaken by Beijing Leinuo Light Panel Co. Ltd.

2.2 GRC hollow core formwork used in large area roof and floor

The use of GRC core formwork in cast-in-place reinforced concrete hollow floors and roofs can solve technical problems occurred in traditional cast-in-place hollow construction and increase the span the space of the structure. Another advantage is that this technique can improve the sound and thermal insulation performance. The current standard regarding this application, JC/T952-2005 - Glassfibre reinforced cement permanent tube-shaped core formwork, is under revising in order to

expand its application scope. GRC hollow core formwork can be categorised into box-type, column-type and trapezium-type. Figure 15 shows an example of the application of GRC thin-walled hollow core formworks..



Figure 15 Application of GRC thin-walled hollow core formwork

2.3 GRC box-room used in electrical and telecom engineering

In recent years, transformer boxes and telecommunication houses (Figure 16) made of GRC have found wide application in China. Six sides of the box-room are all made of GRC. Wall panels are usually sandwich type to stabilize the temperature inside. Due to the absence of steel reinforcement in this product, it has notable advantages in electricity and telecommunication filed.



4400mm×2200mm×2400mm

11800mm×4800mm×2500mm

Figure 16 GRC transformer box and telecommunication house

2.4 GRC partition wall panel and GRC exhaust port used in residential building

GRC partition wall panel is one of the few standard GRC products in China. It has a standard width of

600mm. The length ranges from 2500mm to 3000mm at a thickness of 90mm. At a thickness of 120mm, the length can be increased up to 3500mm. This product is guided by national standard GB/T 19631 - Glassfibre reinforced cement lightweight hollow panel for partition, which was upgraded from building materials standard JC/T 666 - Glassfibre reinforced cement lightweight hollow panel for partition, established in 1999 and revised in 2005. GRC partition wall panel was developed following the government's Wall Reform policy, which was targeting lighter weight and better insulation wall materials. This product is normally made by either group-shutter cast process or spray process. Figure 17 is a picture of a hollow wall type GRC partition wall panel.



Figure 17 GRC hollow wall panel for partition wall

GRC exhaust ports are widely used in kitchens and toilets in high-rising residential buildings. This product is normally bespoke. As a general rule, the height of the port is the story height subtracting 100mm, sectional size is proportional to building height. Port number is based on the practical requirement. The GRC industry standard JC854 - Glassfibre reinforced cement duct for ventilation has been established in 1999 and revised in 2008. Figure 18 shows a typical product.

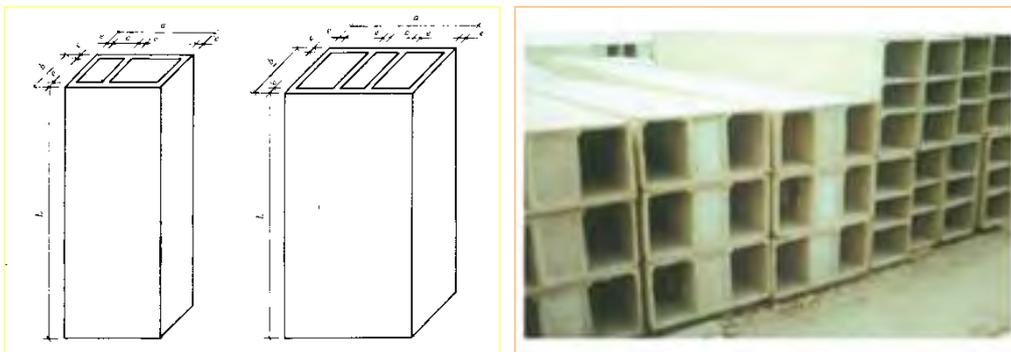


Figure 18 GRC exhaust port

3 Concluding remark

Figure 19 shows two pavilions made of GRC in 1984, after 27 years, They still stand soundly around the hurst in the compound of China Building Materials Academy.



Figure 19 Pavilion made of GRC in 1984

It has been 30-odd years since the China GRC industry emerged. Development and application of new products has never stopped. After years of concerted efforts and promotion, GRC products have been accepted by many architects and designers and have gradually developed into one of the main building components. This component well fit into building environment. Main GRC products dominating the market in different decade were, sandwich wall panel, landscaping ornament, sewage tank, solar cooker, bath tub, granary, corrugated sheet in 1980's, lightweight hollow panel for partition wall, integrated insulation panel used as exterior wall, exhaust port, architectural moulding and landscaping ornament in 1990's, decorative panel for exterior wall and ceiling used in prestigious buildings, GRC hollow core formwork used in large area roof or floor, GRC box-room used in electrical and telecom engineering, GRC wall panel for partition and GRC exhaust port used in residential buildings in the new millennium. The GRC market grows more than 50% each year in the last 5 years and it is confident to believe that GRC will become an even more attractive building material in the near future.