

**Substitute Material of Cement: Glass Fiber Reinforced**

<sup>1</sup>ABDULGADER MOHAMED AHMED BERRANI

\*<sup>1</sup> İnşaat Mühendisliği, Mühendislik Fakültesi, Kastamonu Üniversitesi, Kastamonu

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**ÖZET**

Şehirlerimizi oluşturan binaların cepheleri, binaları hava ve su gibi fiziksel etkileşimlerden korurken, aynı zamanda binaya prestij katmaktadır. Binaların iç tasarımı sadece kullanıcıları tarafından bilinmekle birlikte, cepheleri şehri kullanan herkes tarafından algılanmaktadır. Cephe tasarımları özellikle mimarlar için çok önemlidir. Mimarlar, binalarını farklı bina cephe tasarımları ile kentte farkedilebiliyor. Bu bağlamda, farklı renkler, desenler, dokular ve eğriler (tek, çift ve serbest) sağlayan cam elyaf takviyeli beton cepheler bu talepleri büyük ölçüde karşılayabilir. Birçok ünlü mimar veya tasarımcı tarafından tercih edilen paneller hizmet ömrü, darbe dayanımı, üretim kalitesi ve üretim hızı ile ön plana çıkıyor. Bu çalışmada, cam elyaf betonarme uygulama alanları, sağladığı biçimsel olasılıklar, avantajlar ve dezavantajlar incelenecektir.

**Anahtar Kelimeler:** Çimento, Yedek Malzemesi, Cam Elyaf Takviyeli

**ABSTRACT**

The facades of the buildings that make up our cities protect the buildings from physical interactions such as air and water, while at the same time they add prestige to the building. While the interior design of the buildings is known only by their users, their facades are perceived by everyone who uses the city. Facade designs are very important especially for architects. Architects aim to make their buildings noticeable in the city with their different building facade designs. In this context, glass fiber reinforced concrete facades which provide different colors, patterns, textures and curvatures (single, double and free) can meet these demands to a great extent. The panels preferred by many famous architects or designers come to the forefront with its service life, impact resistance, production quality and production speed. In this study, the application areas of glass fiber reinforced concrete, the formal possibilities, advantages and disadvantages it provides will be examined.

**Keywords:** Substitute Material, Cement, Glass Fiber Reinforced

## INTRODUCTION

Precast concrete means pre-fabricated concrete. Precast concrete is the building products obtained by pouring concrete components into the mold at the factory and assembling the produced products on the construction site [1]. Facade elements consisting of concrete or reinforced concrete layer and ready for construction area are named as concrete based precast facade panels. Insulating layer is added to these facade elements and thermally insulated facade panels are formed. These concrete panels protect the building from external influences as a shell on the outer wall of the buildings and provide both time and labor gains due to their installation after pre-production. Concrete-based precast facade panels are also called architectural precast concrete. The first use of these panels' dates back to the 1920s, and their more widespread use began in the 1950s. In recent years, product diversity has increased with the development of insulation and anchorage methods. This provides flexibility in the design of the technical staff (architect, interior designer, etc.) involved in the design process [2]. Many different designs and applications can be made with concrete based precast panels. The Heydar Aliyev Cultural Center in Baku (Figure 1), which is the design of Zaha Hadid, is one of the best examples of the original use of concrete panels.

Precast concrete panels can be used for both mass production and special production. The dimensions of the precast panels can vary from the jambs rotating around the window to the integral elements between the bearing column axles. The dimensions of the panels are limited to the existing transport and installation methods. Precast coatings are generally used as wall panels mounted on carriers [3] [4].



Figure 1 Heydar Aliyev Cultural Center, Baku

Advantages of precast facade panels [1],

- In the process of building structural elements of the building, the production of facade panels at the factory accelerates the construction. Ready-mixed concrete components can be spilled and replaced annually without being affected by weather conditions.
- They can provide different visuals with texture, color and coating properties. Concrete panels can be used to create more economical panels that are similar to granite, limestone, brick and other masonry systems.
- Thanks to their large clearance properties, they can provide design flexibility by creating free interior and exterior spaces.
- Since the surface wear rate is low over the years, the service life is considered as 50-60 years.
- Due to the presence of glass fibers, they have high resistance to impacts.
- They provide energy efficiency due to the high thermal mass of the material. In energy-insulated panels, energy efficiency can be further increased.
- Sustainable building certificates ensure that they receive points by applying the criteria of sustainable materials in their applications.
- Production at the factory is produced in high quality due to the fact that the ambient conditions can be fixed and quality control can be done in a standard way.

Although concrete-based precast facade elements are classified according to many different criteria, they are classified according to their weights in this study [5].

#### CONCRETE BASED HEAVY PRECAST PANELS

Heavy precast concrete panels with concrete basis are defined as panels in which concrete mortar and steel reinforcement are combined at the factory and then moved to the construction site after taking the power. These panels, which can be multi-layer, have a weights of m2 greater than 150 kg/m2 [6].

#### CONCRETE BASED LIGHT PRECAST PANELS

Concrete-based lightweight precast facade panels are the name given to concrete reinforced with different fibers (glass fibers, carbon and polymer fibers) instead of reinforcing steel. Corrosion of different fibers from steel, lightweight, high strength and low thermal conductivity in recent years due to the materials are very interesting. The fact that steel reinforcement steel in the concrete is corroded over time, with temperature differences and especially in contact with salt water, is one of the main reasons for the development of fiber reinforced concrete. These composite materials consist of high strength fibers embedded in the concrete matrix [7].

The lightweight precast facade panels allow the carriages to have a smaller cross-section and to be built with lower costs due to less load on the building. It also allows the use of relatively small cranes in heavy panels to lift the panels in place during assembly of the panels [8].

#### GLASS FIBER REINFORCED CONCRETE (GFRC)

Glass fiber reinforced concrete, known as GFRC (Glass Fiber Reinforced Concrete) in international literature, is a special production material. GFRC production consists of fine aggregate, high cement mix, special granulometry blend of alkaline resistant glass fiber and polymer added concrete. In GFRC production, there are two basic methods of spraying with hand spray and pouring into the mold by pre-mixing [9]. In the standard production, white cement, silica sand, alkaline resistant glass fiber, water and plastic polymer are placed into the concrete, while colored pigments, marble dust, mirror secret pieces or reflective painted special aggregates can be added in different productions [10].

GFRC is a durable material for durability and strength. It is waterproof due to its high compactness and low porosity. As glass fiber is used instead of steel reinforcement, the sections are thin and the load on the building decreases considerably. The lightness of the material also brings with it the ease of installation. The weight of the GFRC panels corresponds to 1/5 of the weight of the heavy precast systems and 1/2 of the weight of the granite cladding. In addition, the panels can be applied without interruption of the thermal insulation material made from the outside of the building [10].

One of the important reasons for GFRC is the fact that the European standards are insulated with thermally insulated facade panels and equivalent panel systems (55-65 kg / m2) and less than 50% compared to the facade cladding. Stone wool, which is used in heat insulation, is suitable for A1 flammability class which is compulsory by glass wool and fire regulations. When applied according to TS 825 with aluminum foil on the applied rock wool, it prevents condensation completely. For these reasons, GFRC panels allow construction contractors to save time and cost.

GFRC panels are resistant to outdoor weather conditions. These panels can be produced with flat surface, single curvature, double curvature and free form. The fact that the form depends solely on the production of the mold allows the designers to make unique designs.

## Production Processes of GFRC Panels

Glass fiber has high tensile strength, elastic value and heat resistance. In addition to these, they have different advantages such as being transparent, chemically resistant and inert (unreacted) [11]. GFRC panels are more resistant to corrosion as they are not metal. Lighter than heavy precast systems provides advantage in building carriers and foundations.

Two types of molding system can be used in the construction of GFRC panels. They explain premix into the closed mold (previously mixing the vibrating placement) and open into the casting mold is sprayed with a hand sprayer system method. In both methods, the materials are mixed by weighing with a calibrated scale. In the first method, it is placed in the mold by means of vibrations to prevent air from lingering. In the second "direct spray" method, finely chopped glass fiber with cement mortar is sprayed into the mold simultaneously with hand spray. It must be calibrated in accordance with the standards of the International Glass Fiber Reinforced Concrete Association (GRCA). These tests should be carried out for each pump at the beginning of each shift, after any change in equipment controls and after any insufficient washing outside the test results. It is not necessary to carry out these tests if the equipment used can give continuous readings of the mixture of glass fiber and cement [12].

Premix method and hand spray method compared in terms of sustainability: Hand spray method requires lower water / cement ratio. It produces less waste as the required amount is sprayed on the material. It also reduces water consumption, as it is easier to clean the mold. Apart from these, hand spray is more advantageous in terms of strength, cost and surface texture diversity [13]. But also in terms of tensile and torsional strength of 18 MPa pressure resists the premix method, hand spray can withstand up to 10 MPa. [13].

This method allows the removal of forms with dimensions of size, texture, color and multiple curvature. Also, the same mold can be used many times depending on the capacity of the mold material. This provides advantages in terms of mold cost, production speed and consumption of raw material resources [9].

The biggest advantage of GFRC panels is the variety of forms. Panels can be made corner turn and can be made both corner turn and surface flush. This formal diversity makes it possible to create a delicate, clean combination of details to be created on the facade [14]. These formal finishes are shown in Figures 2a and b.

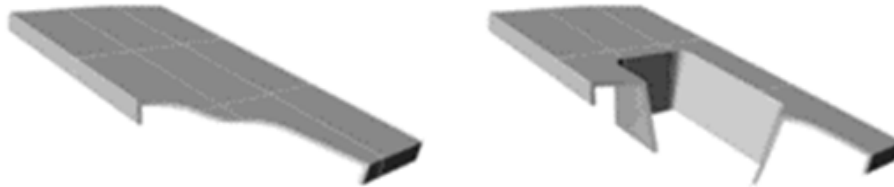


Figure 2 a) Corner turn flat panel, b) Flat panel with corner turn and surface flip.

Especially with the development of computer technologies in the late 1970s and 1980s, the forms of GFRC panels will be able to be designed in more complex forms. GFRC panels can be used in complex geometries [14]:

1. Positive and negative curvatures can be produced on the same panel.
2. The panel may have corner rotation.
3. Providing the same surface quality on both panel surface and corner turns.
4. There are fewer gaps, air bubbles and blemishes than the cast-iron panels.

The technical specifications of the GFRC panels vary according to the ratio of the mixes [4].

Depending on the number of repeats of the product to be produced, the mold material is determined. Molds can be steel, wood, polyfoam and polyester. Styrofoam-based molds for molds to be used one-time, steel molds for molds to be used in close to 100 are preferred. Accordingly, the molds are designed and manufactured. The proportions of the concrete mixture are determined according to the geography and climate data to be used and the desired appearance of the material. The prepared concrete mortar and glass fibers are sprayed on the mold by hand spray. Immediately afterwards, the layers of material are compressed by means of rolls. At this time the thickness of the product is controlled from different locations. After the product is cured inside the mold, the steel carcass is placed inside. The material is mounted to the building using this carcass system. In the case of expansion and contraction, which may occur during the life of the building due to being a composite material, the concrete part and the steel part can be moved separately. Flexible hooks are placed at the joints of the carcass and the material to compensate for the different tensions that may occur in the facade material [9].

The joint gaps between the applied facade systems are filled with polyurethane roving, polyurethane sealant or swelling band applications. In this way, air-water flow is prevented as well as facade elements provide flexibility in movement. Steel anchors suitable for the system are mounted to the building with bolts. This system ensures that the displacement ratio of the loads that may occur during a possible earthquake is tolerated.

The molds are prepared according to the project plans and details. The system is connected to the GFRC with the source of the flex anchoring elements by selecting the appropriate sections according to the dimensions of the carrier carcass and the dimensions of the GFRC elements. Completed production, maintenance and control elements are shipped to the construction site by appropriate stacking technique. The facade panels are anchored to the building by a specialized installation team and a crane selected according to the size of the building.

Panels can be produced in white color and can be produced in almost any color or texture with colorant additives. GFRC panels as shown in Figure 3, concrete, limestone; plain and curved concrete surfaces, wood, brick, stone and marble can be produced in different textures and colors.

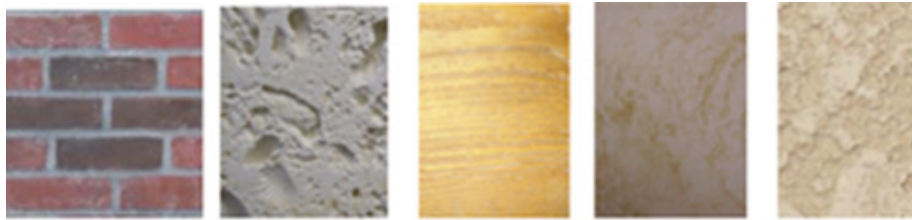


Figure 3 Surface colors and textures of GFRC panels

With the developing technology, it is now possible to produce GFRC panels with reflective painted special aggregates that shine in the dark, which are self-cleaning or light-emitting Nano-technological. In addition, panels produced in white color can be painted to the desired color, like other facades.

Although the materials used in the GFRC panels are similar, the most widely used panels are steel frame and thermally insulated panels, with different materials being used together with different materials. In the steel carcass panels, the thermal insulation layer is not inside the panel and is mounted on the wall front. In the GFRC panel with heat insulation, after the sprayed GFRC concrete mixture is taken out, the steel reinforcement is placed according to the depth and the project formed in the panel and the foam concrete is mixed, poured into and corrected. Since the panels formed in this way are in the heat insulation layer, no further insulation is done. Figure 4 shows the GFRC panel photos with steel frame.

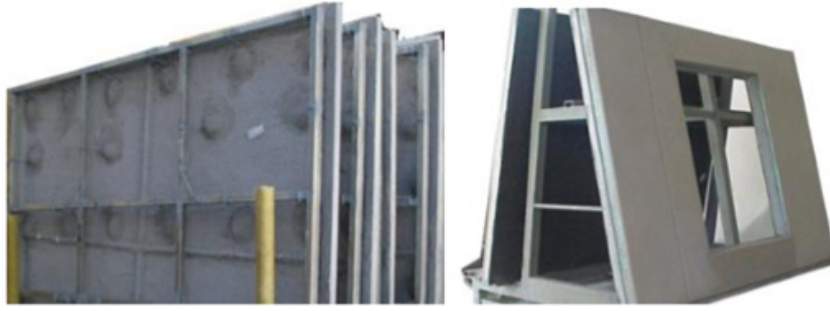


Figure 4 a) Steel frame GFRC panel, b) Heat insulated GFRC panel. [15]

GFRC panels can be as plain as seen above, as can be made with different single, double and free curves, as well as different embellishments and reliefs. Some architectural elements can be produced in the restoration of historical buildings, reconstruction of damaged areas or a different architectural movement. Depending on the formwork, it is possible to create spaces and to use these panels as a sunshade. Examples of these panels are given in Figure 5.



Figure 5 Examples of GFRC panels with different shape, form, decoration and space

The details of panel layouts, required sections, panel dimensions, panel shape joints should be well defined in the drawings of architectural and static project. If more than one type of GFRC panel is used together, the scope and location of each type should be specified in the drawings. If the structural precast facade and the GFRC facade panel are used together, care must be taken in the detail and thickness of the joint. Technical specifications and installation drawings must be compatible with each other [16].

## CONCLUSION

Glass fiber reinforced concrete panels add aesthetics to the buildings that concrete cannot give. In order to achieve this aesthetic appearance, architects should be familiar with the material they will use and be aware of the boundaries and capacity of the material. Developing technology should be used to produce panels in different geometries. The panels seen in many examples are designed in computer environment and not in classical ways. This method called parametric design has been the production of panels. Considering that the GFRC panels have a life span of 60 years, it will contribute to the use of sustainable materials in buildings. It is a material which is more resistant to corrosion than most building materials due to the absence of metal in the concrete shell of the panels. Architects generally want to do what is different and that is not around. GFRC panels which give the designer great freedom in terms of form, color and texture to design symbolic buildings suitable for this desire should be evaluated especially on exterior walls.

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