How Can New Technology Improve Façade construction of office building, in Iran

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Title:

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Abstract:

It is evident that available technologies on office building sector in Shiraz relay on traditional construction especially on wet methods. Wet system process depends on human interpretation (The human interpretation is the basics of the systems) which cause major problems in construction quality. For this propose this dissertation focus on construction method in office building in Iran.

Compared to wet construction, dry system is new technology in the construction industry. Dry construction system is commonly used for new office buildings; it becomes a major investment in both construction and long-term success of the building.

Nowadays prefabrication, evens the simpler types, are far more sophisticate products than current counterparts. Prefabricated system technology has developed, over the years, into a proliferation (reproduction) of highly engineered design. During the investigation, various dry method prefabricated facade possibilities for office building in Shiraz were studied and analyzed.

Office building facades, apart from its appearance, functions as an external enclosure to protect the building from weather and to provide maximum comfortability for citizens. Its construction is not only an assembly of several components, but an advanced technology with involves sophisticated consideration. To achieve the aim of the thesis, facade of few buildings which were constructed in Shiraz was studied according to construction system and performance efficiency. Thereafter, best solution was developed regards to:

•Construction system
•Installation
•Performance efficiency
•Sustainability
•Aesthetic and adaptability
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Introduction:
Introduction:

Many countries have put considerable efforts into the optimization of the construction industry. These efforts range from reduction of energy consumption to the lesser use of materials and labor, all of which aim at reducing the costs as well as time of construction. The importance of construction development in improving socio-economic status has led the construction market in developing countries moving towards industrialization.

However, developing countries lack the fundamentals of industrialization, in technology and logistics alike. These deficiencies include a lack of appropriate factories for the production of prefabricated products, a low number of trained labor, lack of business and organizational structures, and the knowledge to efficiently implement industrialization. Therefore, these countries would have no other choice but to import pre-fabricated products, which in turn would impose on them great costs that are usually hard for them to afford. This dissertation considers new construction methods as sufficient and feasible options for providing the basics of industrialization for the construction market in developing countries.

Façades Background

The developments in building design in the last decades were driven by a continuously growing amount of technological requirements. Among others, these requirements find their origin in construction issues – industrialization and pre construction elements – and sustainability issues like the reduction of energy usage. Modern buildings consist of numerous complex interlinked technical solutions for the load bearing structure, technical equipment and the façade. Especially the façade itself is subject of increased complexity, while the modern building envelope plays a key role in the performance of the building when it comes down to aspects as energy saving and economics.

Under influence of these trends, façade details have developed into technological complex structures which provide thermal separation, water drainage, ventilation, sun shading, and so on. In the last years, technically advanced, but relatively small improvements are made in façade technology. This raises the question what new technological discovery is necessary for a new development to break through.

Technically seen, the current developments in façade design are driven by aspects of user comfort and interaction, sustainability (energy and materials) and construction process of facades. The trend for façades can be typified by:
Further emphasis on technical developments with improved design tools, manufacturing methods and system variants, as well as simplifying the façade by integrating components and functions into facades that might be complex to design but easy to manage.

**Objective:**

The below question leads me to investigate the facade construction quality of office buildings in Iran;

*How Can New Technology Improve Façade construction of office building, in Iran?*

**Improving:**

- Facade function and their quality
- Precise detailing and junction
- Decrease the construction time

**Hypothesis:**

Facade construction technology open a vast area of actuation that is not answerable with traditional systems.

According to nowadays construction system's problems of office building in Iran, it was tried to find appropriate answer for “if we applied the pioneer technology such as low weight prefabricated panel in big format size for office building in Iran, then, is it possible to reduce cost, time and energy usage of construction? Also, is there any possibility to reconcile facade appearance with our culture and traditional building?”

To achieve the ultimate goal of this dissertation is necessary to investigate and identify new methods of construction.
Methodology:

The dissertation was extended to three main parts. The first step in my research of facade construction was evaluated and identify (determine) problems in the construction methods of office buildings in Shiraz. Doing technical investigation on various examples help to understand what factors were affect construction of building facade in Iran. In this respect, the five office buildings which are representative of nowadays typical office buildings in Shiraz were surveyed.

- 2000- University the Medical Sciences of Shiraz
- 2003- Engineering Council of Shiraz
- 2004- Alubond Company, Office in Shiraz
- 2005- Social insurance office in Shiraz
- 2010- Headquarters and control center Shiraz Urban Railway

Qualitative data were collected from the case studies. All the information that was collected (analyzed) during this phase was intended as criteria (base information) in order to choose the best method of construction in phase two.

The second step was to familiarize with logical and modern techniques with a focus on construction issue. In the following, depending on the information given on the first step, efficient and rational systems in connection with design and fabrication of building envelope was mentioned, classified and analyzed.

Finally, considering to all above, an integrated panel toward the ultimate goal of this project was designed and demonstrated.
Case Studies:
Introduction:

Construction System:
The majority of facade construction in Iran and Shiraz are built using masonry wall. There is a deep historical and psychological attachment to masonry appearance that has contributed to its continuation as the main facade system in the Iran. A national survey found that masonry wall is the most used method for construction of office buildings in Shiraz.

As technology, manufacturing processes and construction knowledge increase so do the number of house construction methods available to house builders. Dry construction covers a number of build systems and it is classified as a modern methods of construction. It is the second most popular technique for office construction and has higher quality than masonry wall for construction in the Iran. Normally used in big cities with easy accessibility to machinery and technology.

Fig 1 - University; Medical Sciences of Shiraz. - Dry Construction - Glass curtain wall. (Type 1)

Fig 2 - Social insurance office in Shiraz. - Wet Construction - Brick wall. (Type 2)

Fig 3 - Headquarters and control center Shiraz Urban Railway. 
Dry Construction - Glass curtain wall. (Type 1&2)
In order to investigate the above mentioned systems for construction office buildings in Shiraz few cases will be presented. Five case studies are summarized in three categories: 1-Dry Construction, 2- Wet Construction, 3- The combination of Dry and Wet Construction. The case studies show how different modular and integral instructional strategies can respond to the future challenges. Advantages and disadvantages of different façade solutions, potential for innovation are investigated.

Fig. 4 - Engineering Council of Shiraz
Wet Construction- Brick wall with glass appearance. (Type 1&3)

Fig. 5 - Alubond Company, Office in Shiraz.
Wet Construction- Brick wall with aluminum cladding. (Type 3)
Type 1: Dry Construction:

Dry construction facade system is a type of construct that consists of several factory-built components or units that are assembled on-site to complete the facade without mortar or water-based cohesive. Dry construction is best known in the context of prefabrication because of factory tolerances and workmanship is of a higher quality and consistency to that achieved on site.

Prefabrication is the practice of assembling units or components of a structure in a factory or other manufacturing site, and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located.

Reasons (advantages) such as factory made products, shorter construction time than other method; less than half of conventional cast in situ construction; and increase in the quality of construction made prefabrication the most famous method of construction.
Stick system mostly used for manufacturing dry construction facade in Iran. The sequences of implementation are as follows:

At first, fixing brackets are fastened [Fig 9], thereafter mullion and transom are attached [Fig 10]. Thirdly, opaque panels or glazed units are fixed with temporary point fixings [Fig 11], and finally, the seals, pressure plates and cover caps are applied [Fig 12].
1-Headquarters and control center Shiraz Urban Railway

**Architects:** Bayand Group Consultant  
**Client:** Shiraz Municipal  
**Floor Space:** 12000m²  
**Completion date:** 2010  
**Location:** Shiraz-Iran  
**Category:** Office

Control center Shiraz Urban Railway building is one the newest example (case study) which was built in 2010 by Shiraz municipality. Northern and southern facade of the building are made of composition of stick system and aluminum louver. Problems in relation to this project are, firstly, time-consuming assembly of prefabricated components in the project site and secondly, skilled workers are needed to run the system. Moreover, maintenance and periodic review of facade are necessary.
Legend:
1- Double layer of glass units
2- Aluminum Profile.
3- Aluminum louver.
4- Grating base.

Fig. 15 - Glass façade-Elevation

Fig 16 - Glass façade-Section

Fig 17 - Glass façade-Plan
1-Headquarters and control center Shiraz Urban Railway

Fig 18 - Glass façade with Aluminum Louver
2-University; Medical Sciences of Shiraz

Architects: Amir Payvar
Client: Shiraz University
Floor Space: 12000m²
Completion date: 2000
Location: Shiraz-Iran
Category: Office

One of the oldest building in Shiraz which used dry system in its construction is University; of Medical Science. Similar to other buildings, Stick system was utilized to manufacture the facade in this building.

Legend:
1- Double layer of glass units.
2- Aluminum profile.
3- Mullions are hung from slab using adjustable anchorbracket.
4- Column Structure.

Fig 19 - North facade; Glass Curtain wall
Fig 20 - Glass facade- Section
Fig 21 - Glass facade- Plan
2-University; Medical Sciences of Shiraz

Architects: Amir Payvar
Client: Shiraz University
Floor Space: 12000m²
Completion date: 2000
Location: Shiraz-Iran
Category: Office

Performance of the building during an earthquake and how absorb movements result from earthquake is very important. Maintained, periodic review and prevent water penetration are the major problems of this project.

Legend:
1- Double layer of glass units with translucent isolation.
2- Extruded aluminum mullions.
3- Double layer of laminated glass door.
4- Column Structure.
5- Concrete parapet wall.
6- Cement mortar.
7- Stone veneer.

Fig 22- South facade; Glass Curtain wall

Fig 23- Glass façade-Section

Fig 24- Glass façade-Plan
2-University; Medical Sciences of Shiraz

Fig 25 - South facade; Glass Curtain wall

Fig 26 - North facade; Glass Curtain wall
Type 1- 
Dry Construction Conclusions:

As it is known dry system is a construction system desired and used for office building construction which can be utilized to reduce construction time and cast in situ, promote sustainable development and quality of construction, as well as offering cost savings.

In contrast, this construction type (Stick system) there are several disadvantages which need to improve:

Stick system has been the principal method of dry construction for office buildings in Shiraz, nowadays. In stick system, most of the buildings are built by transporting prefabricated components to the building site for assembling. On site assembling leads to several disadvantages associated with these types of buildings:

- Gasket cutting and mastic/silicone sealing at mullion/transoms joints is critical to the success of the project.
- Regular maintenance is necessary for instance sealant should be replaced every 10 years.
- Slow process of assembly on site.
- Achieving to desirable quality of installation directly related to the time. But the more time, the more expensive.
- It is difficult to accommodate building movements due to sway or seismic events.
- Scaffolding and machinery are required during installation.
- Trained and skilled field operatives must be used.
Type 2:  
Wet Construction:

Brick masonry is widely used in Iran till the last decade in Iran for walls in many low rise buildings, such as offices, dwellings, schools, and alike. The design and construction of such walls is regulated by the Iranian Masonry Code in 1995. However, technical literature in masonry is still quite limited, and significant efforts are needed to teach construction practices correctly. Bad constructions practices and non-engineered construction are widely observed in Shiraz.

Fig 27–Wet construction method

Fig 28–Social insurance office in Shiraz

Fig 29–Headquarters and control center Shiraz Urban Railway
Used material, quality of mortar, method of implementation of each part by skilled worker can significantly affect durability and quality of masonry construction. A masonry wall comprises brick, cement block, light concrete block, 3D polyester sheet. The width of the wall for many years was generally 40cm, but nowadays it is more likely to be 20cm due to the replacement of old materials with new ones. The reasons for the widespread use of masonry wall are:
The materials and skills required to build are widely available across the Shiraz and is almost certainly the cheapest structural system for construction in comparison with other systems.
Common disadvantage (damage) found in the masonry wall include the following:

It is extremely material-intensive. These buildings consume a lot of bricks, and are very heavy. This means that they are not green, as all this material has to be trucked around from where it is produced to the site.

It is extremely labor-intensive, as it is built mainly of masonry, which is made by hand. Humans have still not developed a machine that produces masonry! This also makes for very slow construction speed in comparison with modern methods that are much more mechanized.

It does not perform very well in earthquakes because of being a multi-layer (facade) may cause lack of proper connectivity and integration in facade against the dynamics of earthquakes.

Fig 32–Main wall and Façade veneer in earthquake

Fig 33–Low quality of mortar and wrong junction the stone veneer to main wall.
Factor affecting the quality and construction of facade is how to connect window’s profile to main structure. (In Iran it happen (done) along with structural damage.)

As a form of ‘wet’ construction, masonry needs time to dry out. As a result, masonry is likely to be slower than prefabricated construction.

Wall leakage. The movement of rain through brick walls involves leakage at the brick-mortar interface which because of the open pore structure of bricks.

Cracking in masonry walls may be attributed to drying shrinkage of the bricks. No movement joints were provided in the brickwork of the buildings affected by cracking.

Fig 34 – Windows Installation in masonry system-
Wrong installation the window profile to the concrete column, welding the strap to the vertical reinforcement by hammered the concrete column.

Fig 35 – Main wall and Façade veneer in earthquake
3-Headquarters and control center Shiraz Urban Railway

Architects: Bayand Group Consultant
Client: Shiraz Municipal
Floor Space: 12000m2
Completion date: 2010
Location: Shiraz-Iran
Category: Office

For construction Shiraz Urban Railway both wet and dry system are used in east-west and north-south respectively. 3D polyester sheet utilized as main wall (12 cm) and non-load bearing layer of stone (3cm) used as cladding (final layer of facade).

The procedure of building facade was as follow:
after placing 3D polyester sheet, concrete with thickness of three cm was shot-Crete on both side. The concrete layer was added to increase the sheet resistance. Thereafter, stone facade (cladding) was performed by scope with mortar on the main wall.
3-Headquarters and control center Shiraz Urban Railway

Architects: Bayand Group Consultant
Client: Shiraz Municipal
Floor Space: 12000m²
Completion date: 2010
Location: Shiraz-Iran
Category: Office

Legend:
1- The Inner skin is plastered by gypsum Board.
2- 3d polystyrene wall panel (Consist of 2 layer welded wire fabric with polystyrene core)
3- Field applied "Shotcrete". (in both side of panel)
4- Stone, steel scope to stabilize veneer.
5- Cement Mortar layer.

Fig 38– Main wall- Section

Fig 39– Main wall- Plan
4-Social insurance office in Shiraz

Architects: Mr. Ghafar Pasand
Client: Social Insurance
Floor Space: 2000m2
Completion date: 2005
Location: Shiraz-Iran
Category: Office

The whole facade was made of brick. The facade consist of internal brick wall with 20 cm thickness as main wall and 6cm brick wall for the final cover of facade. Quality of materials and mortars were used determine the final quality of the building facade.
Due to the building location in heart of city (Shiraz) any type of sound insulation was not utilized which is principal problem of this edifice.

Fig 40– North and west façade- Brick wall
4-Social insurance office in Shiraz

Architects: Mr. Ghafar Pasand
Client: Social Insurance
Floor Space: 2000m2
Completion date: 2005
Location: Shiraz-Iran
Category: Office

Legend:
1- Single Layer clear float glass-8 cm thickness
2 -Galvanized Steel window profiles with PVC weatherseal
3- Anchorages required- Concrete with 8 cm thickness
4- The outer skin is the brick wall that provides the aesthetic. The two skins are connected by cement mortar.
5- Cement Mortar layer.
6- The inner skin is the main wall-Constructed using brick laid on beds of cement mortar.
7- The Inner skin is plastered by gypsum mortar

Fig 41– Main brick wall- Section

Fig 42– Main brick wall- Plan
5-Engineering Council of Shiraz

Architects: Jaffar Kashef
Client: Shiraz Municipal
Floor Space: 3000m²
Completion date: 2003
Location: Shiraz-Iran
Category: Office

Engineering Council of Shiraz was built by wet construction system. It is made entirely of masonry material which in parts of facade combined with glass frame. Mentioned glass frame just has a beautiful aspect. In this case also, two layer of brick wall with 20 and 6 cm thickness utilized for internal and external wall respectively. Connection between the wall was done by mortar. Again the same as previous examples there are not any type of sound and thermal insulation in this building.
5-Engineering Council of Shiraz

Architects: Jaffar Kashef
Client: Shiraz Municipal
Floor Space: 3000m2
Completion date: 2003
Location: Shiraz-Iran
Category: Office

Legend:

1- Single Layer clear float glass-8 cm thickness
2 -Galvanized Steel window profiles with PVC weatherseal
3- Anchorages required- Concrete with 8 cm thickness
4- The outer skin is the brick wall that provides the aesthetic. The two skins are connected by cement mortar.
5-Cement Mortar layer.
6- The inner skin is the main wall- Constructed using brick laid on beds of cement mortar.
7- The Inner skin is plastered by gypsum mortar

Fig 45– Main brick wall- Section

Fig 46– Main brick wall- Plan
Type 2-
Wet Construction Conclusions:

Masonry wall buildings are a significant portion of the existing building stock. In order to improve the quality of the interiors of office buildings in Iran it would be essential to improve method of construction.

Although masonry wall have been implemented throughout Iran with successful results, there are still major needs for continued work and consideration on this topic, including the following:

Increase speed of construction
Improving the seismic performance
Improving precision manufacturing on the site of project
Type 3:
The combination of Dry and Wet Construction:

Dry system is used to modify the appearance of building with masonry construction. Buildings appearance in this system and drying system are the same but construction process has less complexity. Combination of dry and wet system comprises the main masonry wall and cladding which is chosen by the architect to achieve the desired visual effect. Stainless steel, weathering steel, anodized aluminum, glass and terracotta are all materials which can be used. The rails are supported by brackets from a masonry wall.

Interfaces between masonry wall and cladding systems may take various forms as it can be seen in case studies:
Brickwork support systems by stainless steel angles and brackets.
Attachment to masonry wall for both vertical and lateral support by the structure or the edge of the floor slab.
Projections for louvers or canopies.

Fig 47 – Combination of wet construction with different appearance

Fig 48 - Alubond Company, Office in Shiraz
Fig 49 - Engineering Council of Shiraz
6-Engineering Council of Shiraz

Architects: Jaffar Kashef
Client: Shiraz Municipal
Floor Space: 3000m²
Completion date: 2003
Location: Shiraz-Iran
Category: Office

Facade in this example is consist of two layer of brick wall with thickness of 20 and 6 cm as internal and external respectively. In southern facade and entrance just to change the appearance of the building glass panel is used on the main facade. The glass panel is used as a shading (sun protection) on the southern facade. Connection between panel and main structure are made by steel profiles. The main problem in this facade is the lack of coordination between glass panel and main wall which leads to thermal cracking.
6-Engineering Council of Shiraz

Architects: Jaffar Kashef
Client: Shiraz Municipal
Floor Space: 3000m²
Completion date: 2003
Location: Shiraz-Iran
Category: Office

Legend:

1- Single Layer clear float glass-8 cm thickness
2- Galvanized Steel window profiles with PVC weatherseal
3- Anchorages required- Concrete with 8 cm thickness
4- The outer skin is the brick wall that provides the aesthetic. The two skins are connected by cement mortar.
5- Cement Mortar layer.
6- The inner skin is the main wall- Constructed using brick laid on beds of cement mortar.
7- The Inner skin is plastered by gypsum mortar
8- Galvanized Steel profiles for glass units.
9- Single layer blind glass units.
10- Welded Catwalk assembly anchored to structural stay for horizontal load resistance.
11- Intermediate channel slip connection on angle with slotted attachment to catwalk assembly.

Fig 51 – Main brick wall with Glass appearance - Section

Fig 52 – Main brick wall with Glass appearance - Plan
6-Engineering Council of Shiraz

Fig 53–Glass entrance facade

Fig 54–Glass Entrance Facade

Fig 55–Catwalk assembly anchored to structural
7-Alubond Company, Office in Shiraz

Architects: Mr. Abbaspour
Client: Shiraz Municipal
Floor Space: 2000m2
Completion date: 2004
Location: Shiraz-Iran
Category: Office

In the process of facade analysis another office building in Shiraz was chosen which are surrounded by street in east and north. In order to create different appearance for facade, after making the main wall with masonry component, cladding was (final cover of facade) constructed with dry system.

At first, main wall are made with brick and mortar (20 cm). Then, mullions and runners of Alubond facade are connected to the main wall. Finally, the alubond panels are bolted to the runners.

Although the building is located beside the street, there are not any type of sound and thermal insulation in this building.
7-Alubond Company, Office in Shiraz

Architects: Mr. Abbaspour  
Client: Shiraz Municipal  
Floor Space: 2000m²  
Completion date: 2004  
Location: Shiraz-Iran  
Category: Office

Legend:

1- Single Layer clear float glass-8 cm thickness  
2- Galvanized Steel window profiles with PVC weatherseal  
3- Anchorages required- Concrete with 8 cm thickness  
4- The Inner skin is plastered by gypsum mortar  
5- The inner skin is the main wall-Constructed using brick laid on beds of cement mortar.  
6- Cement Mortar layer.  
7- Steel bracket.  
8- Extruded aluminum mullion.  
9- Aluminum composite panel.

Fig 57 – Main brick wall with Aluminum appearance -Section

Fig 58– Main brick wall with Aluminum appearance-Plan
Type 3:  
The combination of Dry & Wet Construction; Conclusion:

This formalize type of office buildings are constructed with masonry structure but the appearance is similar to dry wall.

Defects found in this method are very similar to the problems of masonry wall. Most failures occur at the junction between the main and embedded structure (use for cladding) particularly in waterproofing junctions.

Due to use of different materials with different heat capacities cracks appear on the surface of the material.

Concomitant use of iron and brick lead to telltale staining in the brick and corrosion in the iron.

Final conclusion case study:

An investigation about facade construction for office buildings was presented. Respect to construction systems, case studies were analyzed and typified. Also problems were identified and reviewed.

It has been concluded that all methods of construction have major defects such as:

• On-site construction and assembly.
• Inappropriate wet construction.
• Imprecise construction.
• Additional costs and time during the construction process.
• Lack of attention to climatic conditions.

Consequently, to achieve the ultimate goal of this dissertation is necessary to investigate and identify new methods of construction which can eliminate all above problems.
Analyses, Wall construction systems:
Introduction:

An analysis on facade construction system for office buildings was presented in previous chapter. By considering disadvantages were mentioned in conclusion, a particular type of facade will be designed according to nowadays demands and trends for office building.

Few office buildings are constructed by modern techniques. However, critical construction problems exist in new method of modern facade construction because of difficulty and affordability to perform quality control on parts are assembled at site.

In addition, It was shown in the first chapter that significant percentage of office building was built by wet system, that are not previously design or following any reference, so in wet system we need more advanced technology for improve their problems according to their deficiency.

Therefore, in this chapter , with retrospect to problems, will presented how it would be better to choose a construction systems technology which is prefabricated and have more security in details and also confirmed by a reference. Then it is necessary to know which materials and systems can have a similar appearance to Iranian traditional materials such as stone, ceramics and so on. Finally, for designing junction and selecting multi layer system the climate of Iran should be considered.
1. Design Considerations:

Generally, for choosing and analyzing the construction systems, a series of issue from the overall objectives of the project was considering, like, modifying construction system, improving the thermal performance and indoor condition, reducing energy usage.

1.1- Structural Efficiency (weight)
Lightweight facade construction system is one of the main items that it should be considering here. The heavier material costs more for transport and storage, also in process of installation need's more attention.

1.2-Installation
Installation is a critical aspect to the successful implementation of a façade construction. Installation issues vary between the systems and relevant considerations must be attend as important goal. If not, much expensive field labor time can be wasted adjusting the system to accommodate in project.

1.3- Materials and Processes.
While supply and process of each material according to character and project's demands will be selected.
For this criterion, a brief description of the most common materials and processes used, and the identification of any relevant issues with respect to them, will be provided.

1.4- Sustainability
A technology incorporating high performance materials and processes may not be sustainable on a widespread basis, but may be quite sustainable on office and public buildings as a feature element. Certainly façade construction technology is sustainable in some appropriate context, like supply material, structural efficiency, transportation, storages, even in thermal performance.

1.5- Aesthetics & Adaptability
Each of the different construction types, while sharing many common attributes, possesses a unique general aesthetic. Here the aesthetic attributes, traditional appearance according to socio-cultural and ability of produce by new technology that characterize systems, are identified.
1.6- Spanning capacity
Structural façades are long-spanning systems intended for spans of approximately 4 m height and up. Also, it should have ability to fixed from slab to another slab for covering all the surface. The longer the span, the more important the efficiency of the spanning system.

1.7- Durability and Maintenance
The materials that comprise façade construction technology are all prime materials with long life expectancy in normal applications. Differences do exist however, between the systems. Lifecycle and lifecycle maintenance considerations will be taken into heed.

1.8-Building Movements
The structural systems used in facades should be flexible with respect to movement under load, seismic, wind and change in temperature and moisture content. The facades systems are designed to accommodate this movement.

1.9- Design issues
This criterion identifies design considerations particular to each of the various project.
These include considerations of structure, anchorage, cladding, and layer add-on.

Considerations Summary:

There are wide areas of overlap in applying these criteria to the construction types, resulting from the many interacting variables present in any specific application of a system. While prefabricated façade type may be generally the most expensive of the façade types and simple masonry systems the least, it is entirely possible to have a simple and efficient application of a prefabricated façade that is little or no more expensive that a masonry system in the same application in Iran, depending on the variables. Nonetheless, there are some important differences between the systems with respect to the criteria presented here, knowledge of which should prove useful to the designer in selecting a construction system for a façade build.
2. Design Process:

2.1-Dry Construction
Regards to the cases studied in the previous section, generally building construction systems in Iran are divided in two form of Dry and Wet. Despite the wet manufacturing systems having many problems such as inadequate details' design for each project individually this leads to lack of precise details during construction, Furthermore, Lack of good mortar quality, low speed performance, sidelong costs during construction, inconsistency in different layer are major disadvantages of wet construction system. Interestingly, more than 80% of the current Iranian construction is done by wet method. Considering the disadvantages mentioned above, this dissertation attempts to offer a suitable alternative to wet methods which can partly solve the construction problems of nowadays of Iran. The most efficient method respect to speed, quality and freedom of performance (due to climate), accurate detail and coordinated with the modern technology is Dry construction method.

2.2-Prefabrication
In rare cases, as was seen in the first chapter, drying system is used but due to non-conformance with the requirements and precision technology of construction has many disadvantages. The dry system in Iran in the absence of advanced pre-built systems is made in site. The method of making a dry system in site provide wide range of problems such as Increase in cost, time of construction, lack of detail, the need for ongoing maintenance, the need to install scaffolding, wasting a lot of materials and requires a large space for storing materials. For this purpose, prefabrication can be the perfect solution to overcome the above problems.

2.3- Panel
Prefabricated system is adaptable to any project and contains details that are specific to it. One of the factors affecting prefabricated systems is transportation between the factories to the project site and its associated costs. Therefore, the use of components with large dimension in form of panel can be an appropriate response in order to reduce the cost and ease of transport. Use large pieces require less space for storage and are much easier to install it. These complete pre-built panels are transmitted to the site which improves the ultimate quality of the construction.
2.4- Panel Type
Panels used in office buildings should be able to cover the full span of the floor to ceiling with only 2 connections at the top and bottom of panels in each floor. Unitized panel is an excellent option due to the above description, also has capability to produce and assemble in factory. It just needs to transfer from manufactory to site of project.

2.5-Main Structure
The load-bearing part of panel is required a material that can be compatible with a large dimension of panel. For this purpose, concrete, GRC, wood, steel, aluminum or combinational material can be used.

Aluminum is denied, because this material resources is low in Iran, as well centralize far distance from the shiraz ,it can't be sustainable to finding suppliers and subcontractors to facilitate the construction phase of the project.
Alike as wood, all the forest located in north of Iran, and it’s not is not economical to import from the other part.
As it not possible the material with more than 100 kg/m2, for more efficient transport and storage, concrete was rejected.
Finally, GRC ,as most lightweight and sustainable material to make a panel, was chosen.

2.6-GRC
The most obvious advantage of GRC which leads to the selection of this material is its low weight with 60-80 kg/m2. Moreover, high formability and no need for long term formatting are others benefits of this material. With the addition of a layer of expanded polystyrene between two layers of GRC panel insulation against heat and sound are significantly increased.
Another advantage can be taken of its higher strength than the concrete, fire-resistant, waterproofing and has a much lower environmental impact.
2.7-Cladding
The panel final covering is the most important factor in aesthetic appearance of the building facade and harmony with the culture and traditions of the society. In retrospect, we simply find brick is the most common materials used in traditional facades of buildings in Shiraz. For this reason, to create more harmony between tradition and modernity it would be better to use panels with small brick parts that be produced as prefabricated. Hence, the new generation system of prefabricated huge brick panels that can be used in this study are as follows:

2.7.1-Brick in steel sheet format:
This format was denied because it must be bolted to the load bearing part, so it would be difficult to make ventilated facade with a air barrier layer. Also, are limited for various panel size.

2.7.2-Brick by hanging from stud:
In one hand, Harder transporting, handling and storage of large units by special arrangements and transportation, in other hand, provided other subsequent works on-site by this system, were considering to rejecting this system.

2.7.3-Brick and wet mortar:
wet construction, and limitation in various size of panel, causes difficulty to make ventilation and different type of facade.

2.7.4-Brick in mesh format:
Due to the great variety in size, this system has capability to use in various situations.
Integrated system with a punctual fixing to the load bearing panel gives the ability to run ventilated facade. Furthermore, this especial type of integration brick, firstly has Similar appearance of traditional buildings in Iran, secondly is a kind of dry construction and eventually has easy portability.

*Flexbrick* system, selected as cladding that has all considering features.
This hanging facades saving material costs and installation times by plumb vertically under its own weight.
Also, ease of maintenance treatment, flexibility in shape and design, easy to transport, sustainability, and previously designed, are other features.
2.8-Double Layer
Regards to climate of Shiraz which has extremely hot summers and sunlight exposure; there is an urgent need for thermal insulation. Utilization of double layers facade with approximate distance of 10cm in order to ventilation can significantly prevent the transfer of heating from outer layer to inner space. Usage of grid brick system for cladding also provides additional ventilation in facade. Also, to prevent the transmission of heating in cold and warm seasons into the buildings a 2.5 cm layer of thermal insulation is used on panel of GRC.
Proposal:
Introduction:

Evaluation of various building systems in the previous section leads to:
• Choosing big format Panel from curtain wall facade system because high quality of panels, increasing construction time, precise detailing, prefabrication big size panel and minimal On-Site process.

• Due to the climate of Shiraz and long-term exposure to the sun through the day, Ventilated facade was chosen because of, ventilation, Solar protection, acoustic isolation and Water protection.

• GRC panel is proposed in order to use as a principle structure which have integrated the thermal and acoustic isolation, sustainability, recyclability, and light weight for handling.

• Finally, Flexbrick system, due to the great variety in size and shape has capability to use in various situations. this Integrated system gives the ability to have ventilated facade with dry construction and ease to transportation.

• Respect to climate and environmental conditions this chapter is going to focus on retrofitting methods for GRC Panel, design various layer of Panel, vertical and horizontal junctions by considering sealing between the components.
1. The proposed GRC Panel:

1.1- GRC sandwich panel:

The sandwich panel is composed of two sheets of GRC 1 cm thick and a core of expanded polystyrene from 6 to 10 cm, which gives the panel mechanical stiffness and a high degree of thermal insulation. In this case, I was chosen a sandwich panel with 10 cm polystyrene foam for better resistance in thermal and sound isolation, also for more rigidity suggest outer ribs every 1 m with 20 cm thickness. The resulting thick are 12 cm in panel and 20 cm in outer ribs.

1.2- Typical Panel Dimension:

![Diagram of Panel Dimensions](image1)

- Min, Mullion width: 200 mm
- Max, Height of panel: 6 m
- Max, Width of panel: 2 m

GRC thickness minimum 6mm maximum 18 mm. This is 12 cm in panel and 20 cm in ribs.

![Diagram of Panel Plan](image2)

Fig 59 – Panel Dimension

Fig 60 – Panel Dimension – Plan
Fig 61 – Panel Dimension - Sec
1.3- **Horizontal and Vertical Junction:**

Construction joints in façades are subject to great stresses. Heat, cold, rain, sun, wind and movement of building components are factors which need to be taken seriously and which require the use of special jointing materials. Panel, closed joints are sealed by polysulphide sealant sheet in horizontal and EPDM rubber strip in the vertical joint is lapped over the face of horizontal joints.

Fig 63 – Horizontal and Vertical Junction-Sec-Plan
1.4-process of Completion panel:

- The sandwich panel is composed of 12 cm thickness was proceed with local fixing set in inside.

- An insulating layer is used as needed, depending on the location.

- The thermal insulation is screwed to ribs of GRC panel by clamps.

- Then, ceramic sheets were hanged from panel clamps‘ and anchored to the panel as to make a strong ceramic cladding.

Fig 64–Local fixing, screwed to the ribs for hanging cladding sheet

Fig 65–The process of Completion panel
This ventilated facades consist of a wall construction, with GRC sandwich panel, with an internal insulating layer (and external depend on location) and brick envelope. The air gap between the insulating and cladding surfaces is used for the ventilation of the facade.
1.5- Panel Character:

• Increasing construction time by big format panel.
• Finished interior and exterior panels layer
• The same looking as our traditional facade.
• Insulated panel.
• Ventilated panel,
• Portable panel by hanged brickwork.
• Cladding part can made by variety material, such as composite material, ceramic, stone veneer.
• Minimal work on-site labor

Fig 68– Final Panel appearance
1.6- Panel connections:

Fig 69–Panel Connection to structure by fixed anchors
1.6.1- Anchors:

Curtain wall anchors connect the wall to the building and can be broadly acted as both gravity and lateral load anchors (fixed) or as just lateral load anchors (slotted). Aside from their primary load-carrying function, anchors must be designed to allow for adjustment to site condition.

Mounting lug assembly to keep panels at intermediate floor level together was chosen to provide ease applying horizontal junction sealant.

Fig 70–Panel, Bottom Connection to structure
Fig 71–Panel, Top Connection to structure
Fig 72–Panel Connection to structure
1.7- **FlexBrick System:**

Flexible brick has patented and developed different patterns of tissue configurations that can be customized. The cladding panels can be made of a variety of material such as metal, composite materials, ceramics, timber etc. and offer the significant freedom of design with respect to project and climate.

Fig 73– Stone Patterns: Stone veneer or stone panel with minimum 6 cm width

Fig 74– Ceramic panel Patterns: Different type and size would apply in this system

Fig 75– Brick Patterns: Different model of brick depend on our desires.
Conclusion:
Conclusion:

This study has identified the following construction features for the context of Office building in Shiraz:

- Increasing construction time by big format panel.
- The same looking as our traditional facade.
- Minimal work on-site labor.
- High Performance efficiency was applied depend on project and Sustainability.

All the features that were analyzed in this study for adoption in the case study building to decrease the construction problems. The study shows that it is possible to reduce the construction time by use the new technology and hence increase the facade and interior construction quality. It should also be stressed that the theoretical framework has outlined many other options that reduce the time and also work on-site. However, only those features were selected that can be improving the construction technology and can be adopted in the context of.

Once the construction problems are identified and normal construction in Iran are demonstrated, the next emerging questions are: How is going to bring a change in the construction practice? As evident from the section on ‘Analyses, Wall construction systems’ in office buildings, the process of designing efficient facade is not a ‘one-items show’. Installation, aesthetics, adaptability and sustainability are the consideration that can bring a change in the design process. All the items are closely intertwined.

Once influenced by the sustainability, the new materials should further motivate with high performance in construction.

Finally, it depends on the technology and process of creating. If the technology and manufacturing process can compromise with the existing systems and appearance, it would be possible to built appropriate office buildings in Shiraz.

Considering the significant amount of time and energy used by on-site construction in general and the prevailing energy crisis in Iran, it is important to overcome the problems and adopt the reasonably simple efficient technology that proposed in this study that reduce the total construction time of the building and also provide comfortable inner condition to the residents. In addition to the benefits of time and energy savings from the use of this design, improving the installation quality and durability of the buildings in Shiraz can also result in reduced energy costs to users in long time residency.
Appendix:
Appendix A:

Shiraz General Information

Shiraz is the fifth most populous city of Iran and the capital of Fars Province. Its area is about 250 km². Shiraz is located in the southwest of Iran in 29°37′N 52°32′E and its height is 1540 meters from the sea level. In 2009 the population of the city was 1,455,073.
Shiraz’s Geographical

The plain located inside of Zagros Mountains and its direction is the same as mountain from western north to eastern south and generally it has a steeped form that surrounded by to high chain of mountain from north and south. The slope of this plain is from western north to eastern south and the Maharlu lake is located at the end of this direction.

Some rivers run from the mountain and irrigate plain, the most important rivers are: Roodkhane koshk (Dry River) that passes inside city, this is a seasonal river and sometimes overflows in winter or first of spring and at the end, falls in to Maharlu Lake. The other river of Shiraz plain is Sultan Abad that passes from south of city.

Climate:

Shiraz’s climate has distinct seasons, and is overall classed as a hot semi-arid climate, though it is only a little short of a hot-summer Mediterranean climate. Summers are hot, with a July average high of 37.8 °C (100.0 °F). Winters are cool, with average low temperatures below freezing in December and January.

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record high °C (°F)</td>
<td>22 (72)</td>
<td>26 (79)</td>
<td>32 (89)</td>
<td>34 (93)</td>
<td>39 (102)</td>
<td>42 (108)</td>
<td>43.3 (110)</td>
<td>42 (108)</td>
<td>39 (102)</td>
<td>34 (93)</td>
<td>31 (88)</td>
<td>26 (79)</td>
<td>43.3 (110)</td>
</tr>
<tr>
<td>Average high °C (°F)</td>
<td>12.1 (54.8)</td>
<td>14.7 (58.5)</td>
<td>10.9 (51.6)</td>
<td>7.8 (45.6)</td>
<td>7.5 (45.3)</td>
<td>7.5 (45.3)</td>
<td>7.8 (45.6)</td>
<td>7.8 (45.6)</td>
<td>10.0 (50.0)</td>
<td>12.1 (54.8)</td>
<td>14.7 (58.5)</td>
<td>12.1 (54.8)</td>
<td>14.7 (58.5)</td>
</tr>
<tr>
<td>Daily mean °C (°F)</td>
<td>5.3 (41.6)</td>
<td>7.7 (45.9)</td>
<td>11.0 (51.8)</td>
<td>16.2 (61.2)</td>
<td>23.5 (74.3)</td>
<td>27.1 (80.8)</td>
<td>27.1 (80.8)</td>
<td>23.5 (74.3)</td>
<td>16.2 (61.2)</td>
<td>11.0 (51.8)</td>
<td>7.7 (45.9)</td>
<td>5.3 (41.6)</td>
<td>5.3 (41.6)</td>
</tr>
<tr>
<td>Average low °C (°F)</td>
<td>-6.4 (20.5)</td>
<td>-1.6 (30.9)</td>
<td>2.4 (37.4)</td>
<td>7.3 (45.1)</td>
<td>13.2 (55.8)</td>
<td>17.1 (62.8)</td>
<td>19.1 (66.4)</td>
<td>18.0 (64.4)</td>
<td>14.1 (57.4)</td>
<td>8.6 (47.6)</td>
<td>5.0 (41.0)</td>
<td>1.1 (35.8)</td>
<td>9.5 (49.2)</td>
</tr>
<tr>
<td>Record low °C (°F)</td>
<td>-16 (-8.9)</td>
<td>-10 (-12.0)</td>
<td>4 (-15.0)</td>
<td>32 (89.6)</td>
<td>6 (43)</td>
<td>14 (57)</td>
<td>0 (32)</td>
<td>7 (45)</td>
<td>30 (86)</td>
<td>16 (60.8)</td>
<td>6 (43)</td>
<td>14 (57)</td>
<td>-15 (-9.4)</td>
</tr>
<tr>
<td>Precipitation mm (inches)</td>
<td>79.8 (3.12)</td>
<td>49.8 (1.96)</td>
<td>45.6 (1.8)</td>
<td>33.5 (1.3)</td>
<td>6.5 (0.26)</td>
<td>0.2 (0.00)</td>
<td>0.1 (0.00)</td>
<td>0.0 (0.00)</td>
<td>0.0 (0.00)</td>
<td>0.0 (0.00)</td>
<td>0.0 (0.00)</td>
<td>0.0 (0.00)</td>
<td>0.0 (0.00)</td>
</tr>
<tr>
<td>Avg. rainy days</td>
<td>0.7</td>
<td>1.7</td>
<td>2.9</td>
<td>8.4</td>
<td>2.1</td>
<td>0.2</td>
<td>0.6</td>
<td>0.0</td>
<td>0.0</td>
<td>1.2</td>
<td>3.7</td>
<td>7.2</td>
<td>46.1</td>
</tr>
<tr>
<td>Avg. sunny days</td>
<td>1.5</td>
<td>6.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2.7</td>
</tr>
<tr>
<td>% humidity</td>
<td>85</td>
<td>81</td>
<td>91</td>
<td>48</td>
<td>52</td>
<td>22</td>
<td>24</td>
<td>24</td>
<td>26</td>
<td>34</td>
<td>46</td>
<td>91</td>
<td>46.9</td>
</tr>
<tr>
<td>Mean monthly sunshine hours</td>
<td>217.6</td>
<td>218.5</td>
<td>236.2</td>
<td>247.7</td>
<td>234.1</td>
<td>197.5</td>
<td>244.0</td>
<td>255.7</td>
<td>218.5</td>
<td>217.6</td>
<td>236.2</td>
<td>247.7</td>
<td>234.1</td>
</tr>
</tbody>
</table>

Table 1 - Climate data for Shiraz

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Daylight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>Feb</td>
</tr>
</tbody>
</table>

Table 2 - Daylight hours, for Shiraz
Climate:

Temperature and Humidity

Long-term thermal regime of Shiraz

Evaporation and sunshine hours of Shiraz

Sunlight and Evaporation
Appendix B:

GRC characteristics.

The material and its advantages

Glass-fiber-reinforced cement is a composite material consisting of ordinary Portland cement, silica sand and water, mixed with alkali-resistant glass fibers. It has been described by Young (1980) as an ‘ideal marriage between brittle materials, cement, sand and glass, to produce a tough composite’. At that time, the most common percentage constitution of the material by weight was as follows:

- Portland cement 40%
- Water 20%
- Sand 40%
- Glass fiber 5% (for spray techniques)
- 3–4% (for premix)
- Later formulations included 0–5 % acrylic polymer.

The ultimate strength of glass-fiber-reinforced cement (GRC) is essentially determined by the presence of the fibers, and is therefore dependent upon the glass content, the orientation of the fibers, the degree of cure, and the bonding of the fibers to the cement/sand matrix.

The glass fiber is introduced into the cement mix to carry the tensile forces, thus overcoming the main disadvantage of cement, which is unreliable and has a relatively low tensile strength. The glass content controls the maximum loading that the material can withstand, the impact performance and the durability of the composite. The incorporation of sand into the GRC mix helps to reduce shrinkage during drying out and reduces in-service moisture movement.

Insulated panels

The inclusion of insulation between two skins of GRC is carried out in two main ways, as follows.

- Panels of polystyrene may be placed in position and then covered with a slurry, or preformed webs of GRC used between the sheets of insulation to stiffen the panel.

- Suitable foam may be injected between the two preformed skins of GRC. Foams include polyisocyanurate, polyurethane and phenolic. In the last case internal webs of GRC are also used, because the shear performance of the foam is inadequate.
Performance characteristics

Wind loading
Simplified tables are now available for determining the spanning characteristics of varying thicknesses of GRC in relation to wind loading. For example, 10–12 mm flat sheets will span 1.0 m under a wind pressure of 1.0 N/m², but sheet of the same thickness can be profiled or ribbed to span up to 4.0 m under the same wind pressure. For greater spans or wind pressure, it may be necessary to design using sandwich construction, ribs or, more commonly today, a stud frame construction.

Thermal characteristics
A 20 mm single-skin GRC construction of approximate density 1800–2100 kg/m³ gives a negligible insulation value, in the region of 5.0 W/m² °C. For improved thermal insulation (up to a U value of 0.7 W/m² °C), it is necessary to incorporate an insulation core into the construction or to incorporate some form of insulation behind a single-skin facade, a method that is finding increasing use in continental Europe. shows the thermal performance of varying thicknesses of GRC sandwich panels.

Fire performance
In terms of fire performance, GRC is non-combustible when tested to BS 476. Even with an organic paint finish, GRC performs to Class 0 standard when tested in accordance with Part 6. This is generally comparable to metal and precast performance. However, it is important to check the use of polymer additives, because they affect the fire performance of the panel. In terms of fire rating, 1.5 hours fire resistance is claimed by some sandwich panel manufacturers, such as Veldhoen.

Acoustic performance
A 10 mm single skin of GRC at 20 kg/m² density gives sound reduction indices from 22 dB at 350 Hz to 39 dB at 4000 Hz, or an average of 30 dB over the normal range of frequencies. Even if the single skin is increased to 20 mm, which is beyond the thickness normally recommended, the average reduction indices will increase to only 35 dB. For greater acoustic performance it is possible to specify sandwich construction; however, if it is necessary to connect the outer and inner skins for structural reasons, this will reduce the sound insulation for the whole panel.

Density
A piece of flat GRC 10 mm thick weighs approximately 20 kg/m².
Shrinkage and moisture movement

Like other cement-based materials, GRC exhibits nonreversible shrinkage during the curing process, and long-term moisture movement caused by changes in humidity. The incorporation of 40% silica sand into the matrix reduces both types of shrinkage but, even so, actual movements in use could in theory be 1.5 mm/m. In practice, movement of 1.0 mm/m may be experienced, which is approximately double that of ordinary reinforced concrete. Care has to be taken in the design of fixings to allow for this movement.

Impact loading

GRC is also good at withstanding impact loading. CemFil International quote an impact strength of 10–25 kJ/m2 for hand or machine spray products and 10–15 kJ/m2 for vibrated cast products.

Panel dimensions and tolerances

Although in theory there is no real restriction on the length of panel, in practice this is normally limited to 4–6 m because of problems of lifting, handling and fixing of units. Maximum widths of panels depend upon the method of production. For manual spraying this is normally limited to 2 m. Where windows are incorporated within a panel, a minimum mullion width of 200 mm is recommended. Glass-fiber-reinforced cement single-skin thickness is minimum 6 mm and maximum 18 mm for sprayed material. For premix material the minimum thickness is normally 10 mm, with no upper limit within reason. Tolerances in panels are similar to those used for precast concrete, but should not exceed ±3 mm for small panels.

Recyclability

The main ingredients of GRC are based on the plentiful and naturally occurring minerals used in the manufacture of cement, aggregates and glass fibers. These natural materials are not normally regarded as pollutants. Hence GRC can be regarded as a stable mineral based material and can be simply crushed and land filled. It uses less energy and takes less time to crush GRC than reinforced concrete since the former has no coarse aggregate and the time to recycle steel rebars is saved. To take one step further, it has even been reported that ground GRC can be used as filler or fine aggregate to make new GRC (Takeuchi et al. 1998).
<table>
<thead>
<tr>
<th>Wall construction</th>
<th>Maximum recommended span (1.0 kN/m² wind pressure)</th>
<th>Fire resistance BS 476 Part 8</th>
<th>Weight (approximate)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single skin</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat GRC 8 mm thick</td>
<td>0.8</td>
<td>None claimed</td>
<td>16</td>
</tr>
<tr>
<td>Flat GRC 12 mm thick</td>
<td>1.1</td>
<td>None claimed</td>
<td>24</td>
</tr>
<tr>
<td>Profiled or ribbed GRC + 50 mm glass-fibre insulation + plasterboard</td>
<td>Up to 4</td>
<td>0.5</td>
<td>40</td>
</tr>
<tr>
<td>Profiled or ribbed GRC + 50 mm glass-fibre insulation + 100 mm concrete block</td>
<td>Up to 4</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>Increased depth of profile and stiffening ribs increases the spanning capability of the panel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sandwich construction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 mm GRC</td>
<td>50 mm polystyrene</td>
<td>10 mm GRC</td>
<td>3.0</td>
</tr>
<tr>
<td>Overall panel thickness 70 mm</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>10 mm GRC</td>
<td>60 mm polystyrene</td>
<td>10 mm GRC</td>
<td>3.0</td>
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<td>Overall panel thickness 70 mm</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>10 mm GRC</td>
<td>50 mm PBAC</td>
<td>30 mm polystyrene</td>
<td>50 mm PBAC</td>
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<tr>
<td>Overall panel thickness 150 mm</td>
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</tr>
</tbody>
</table>

Table 3 - Relationship between wall construction and GRC performance requirements
Handling of units on site and storage

Because of the ease with which GRC can be formed in a variety of shapes, it is not uncommon to avoid the potentially troublesome eaves detail by cranking or curving the panels at their junction with the roof. Special equipment may be necessary for handling such units on site, and care must also be taken in designing the fixing devices for lifting to ensure that these do not show on the outside face. Highly profiled panels are also difficult to store and transport, and cranked panels will twist and distort if stacked unsupported on edge.

Also, large up stands and long unsupported ends tend to settle when in their ‘green’ state, and care must be taken during manufacture and storage to avoid sagging of unsupported ends. If this is not done, problems can occur in controlling the size of joints between panels because of difficulties in ensuring alignment of panels during erection.

Fig. 79 - Cranked panels need supporting to avoid distortion during curing.
Appendix C:

Components Description:

Flexible Brick is an industrialized system of flexible ceramic sheets used to construct cladding facades and laminar structures panels. These flexible sheets are created using an innovative system of woven steel with fired clay pieces that offers a range of design options and construction applications with excellent results.

**FlexBrick:**

An industrial system for constructing flexible sheets of ceramic coatings and laminate structures. The revolution is its large format small parts that usually are placed one by one. A flexible steel mesh in which ceramic pieces are inserted in grid-board or breaks. The parts are safely enclosed because they have slots or holes on both end sides which serve to accommodate the wires of a steel mesh that holds the whole.

**Flexbrick** same identical aesthetic finish can be used on walls, concrete panels, structures, etc. The Flexbrick can be customized according to the needs of each project, allowing each case to choose the density of the pieces, geometric patterns tissue, work piece materials, formats and finishes.

![Image of FlexBrick units]

Fig 80 - FlexBrick, Handling of units on site and storage.
Components Description:

- **Design, adaptability and cost optimization**
  Hanging facades saving material costs and installation times because they require would outline and plumbed vertically under its own weight.

  specifications:

  - The ceramic fabric for ventilated facades is made entirely of stainless steel mesh to optimize durability and system security.
  - Clamping components are located on the fronts of the enclosures enabling manufacture are lightweight.
  - You can freely choose the thickness of the inner tube.
  - The system allows the designer of the project play a multitude of possible combinations from the full and empty concepts (continuous or lattice) and the color ranges of the tiles used.

**Transport pallets.**
The Flexbrick are flexible and delivered folded on pallets, facilitating logistics.

**Multiple building anchors.**
The steel mesh allows multiple anchors can easily be fixed by screws, depending on the aesthetic and technical requirements of each project.

**Exploded.**
The fewer cuts of Flexbrick part of a surface, fewer placement operations, crane time and supporting components shall be counted; thereby reducing the cost per square meter of the installed system.

![Fig 81 - FlexBrick Perform](image1)

![Fig. 82 - FlexBrick pattern Design](image2)
Fig 83 - FlexBrick Design
-Characteristics Flexbrick system:

-Dimensions
can design and build large formats up to 20 meters, which also reverses significant savings in labor and time. Performance with two workers and a crane can reach 250 m²/day.

Versatility with numerous applications
the ceramic fabric can run on different applications, whether walls or roofs, modified with a lower 10% of its components.

Design
Allows multiple configurations tissue (romp junta in grid, draft, etc..) and color ranges. Possible, for example, project any constant curvature and obtain alignments of its parts. Likewise, the tissue can be composed to create prints combining their multiple configurations and color ranges.

Extensive use of traditional ceramic products

Accuracy
With the use of a metal mesh, the boards are kept perfectly aligned for any length. Industrialization reverses in increased accuracy and quality of execution.

Durability
The production of only two unalterable Flexbrick materials like ceramic and stainless steel are used.

Save logistical
Flexbrick also provides storage and transportation savings as it is transported folded or rolled in coils pallets, less space and facilitating their mobility.

Sustainability
The Ceramic Flexbrick tissues is cooked with biogas. It is also easy to recycle its simple separation of elements, which are attached dry.

Flexibility
The Flexbrick sheets can be stored and transported on pallets folded or rolled into coils.

Ease of maintenance treatment,
Repair and recycling. Being a dry roller system allows "collect" the Flexbrick to facilitate any repair work on your backfill or to allow replacement or recycling.
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Table 3 - Relationship between wall construction and GRC performance requirements

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