A Review on Textile Products for Reinforcing Concrete Sandwich Panels

Manar Yahia Ismail Abd-El-Aziz
Clothing and Knitting Industrial Research Department, Textile Research and Technology Institute, National Research Centre, 33-El-Behouth St., Dokki, Giza, P.O.12622, Manar.Yahia@hotmail.com

Abstract:
Concrete sandwich panels have gained considerable popularity in the construction industry. Based on their structural and thermal performance, sandwich panels have been employed in industrial, residential, and commercial structures. Two concrete outer layers are connected by connections that run through the interior insulating material, which is isolated from the exterior layers by an insulating stiff foam core to increase thermal effectiveness. There are numerous issues with the steel used for reinforcement including corrosion, high cost, heavy weight, increased thickness, and thermal bridges. Textile reinforcing concrete (TRC) is a solution for these issues, for that; researchers have attempted to replace steel with various textile goods to improve the quality of sandwich panels. Many researchers used textile' grides for enhancing sandwich panels' thermal isolation and reinforcing properties as nets or as a connector. This article reviews and observes methods of reinforcing concrete sandwich panels with TRC with different materials, constructions, behavior and application of textiles for investigating sandwich panels' performance as well as textile reinforcing of concrete and discussing differences between these applications. It was found that TRC can be used for reinforcing concrete sandwich panels as core, as grid or as a connector, All these shapes of TRC effect on the performance of concrete sandwich panels positively.

Keywords:
Sandwich panel, Technical Textile, TRC, Thermal bridges, Textile Reinforced Concrete, Wythe

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1. Introduction:

Concrete reinforcing first appeared in structural buildings in the middle of the 19th century, and its uses are continuously evolving today. It is necessary to integrate steel bars with plain concrete for reinforcing and boosting its tensile strength because plain concrete alone has strong compressive strength but a very low tensile strength. Additionally, corrosion attack issues in steel-reinforced concrete structures have been found to cause structural integrity to be lost after weakening the concrete's protective layer [1,2]. Textile reinforced concrete is a brand-new, high-tech composite material that can be made from carbon fibers or fiber glass fabrics that have been reinforced with cementitious matrix or another alkali-resistant matrix, for example. And it has several advantages over steel, including light weight, slender, modular, and freeform constructions that lower or completely eliminate the risk of corrosion [3].

2. Sandwich panels:

A sandwich panel is any building with a low-density core and two thin skin layers attached to either side. Sandwich panels contain two thin, rigid face sheets at the top and bottom and a lightweight, fairly thick core in the middle. Sandwich panels are created with a lightweight core connecting the solid face-sheets in order to provide good bending stiffness and buckling resistance. It also has outstanding energy absorption and shear stiffness properties. Although a number of materials can be used to create the core, cellular materials like foams or periodic lattices are most frequently used. In a sandwich panel, the face sheets support bending and in-plane stress while the cellular core supports transverse shear stresses [4]. Sandwich panels are composite because they have a thick inner structure, lightweight and two thin laminate outer layers. Due to the core structure, such composites are distinguished by their rigidity. Despite the thickness of the core, sandwich composites are lightweight and offer large flexural strength. The spatial organization of these composites affects how effective they are as thermal insulators. Sandwich panels are used in civil engineering, ships, transportation by land, and aeronautics. The sandwich component specifications and production process have a direct impact on the mechanical characteristics of those same composites [5].

3. Concrete Sandwich Panels:

Two concrete exterior layers are sandwiched between an insulating rigid foam core to provide improved thermal performance. Two steel grids are added for reinforcement, and the two layers are joined by connectors that pass through the inner insulating core as shown in Fig.1 [6].

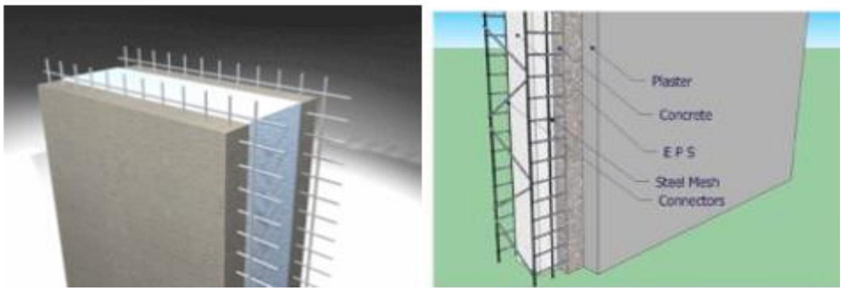

Fig. 1 Reinforced concrete sandwiched panel [7].

Concrete sandwich precast panels have gained a lot of traction in the construction industry owing to their outstanding thermal and structural performance. Since the 1960s, North American industrial, commercial and residential structures used sandwich panels. As the awareness of global warming and the necessity to minimise power usage has developed, it has been used to provide thermal insulation to buildings in order to save heating and cooling energy inside building spaces [8].

3.1 Concrete layer (wythe):

The load-bearing and facade layer is made of concrete. Structural and architectural factors dictate its thicknesses especially the inner layers (load bearing). The non-composite panel's wythes are commonly thicker than a composite panel's at the same stress. At its thinnest point, the load-bearing wall has to be minimum 75 mm thick. The connectors and anchors of the element should be adequately covered by this thickness to act as protection. The needed fire resistance for each construction determines the thickness of the concrete layers as well. The bottom border of load-bearing wythes is often reinforced by longitudinal ties. [9].

3.2 Wythe anchors and connectors

To improve construction efficiency, concrete sandwich panels can really be connected using a number of methods (Figure 18). The most popular shear transferring has been steel, carbon-fiber-reinforced polymer (CFRP) or fibre reinforced polymer (FRP). Steel connectors have restraining ties that can withstand vertical loads brought on by wind load, temperature changes, or weight changes in the facade material. According to Swedish requirements, steel connectors must be supported with anchors in order to withstand torsion, vertical loads, and horizontal forces from the wind and lifting operations. FRP connectors outperformed steel connectors in terms of thermal and structural performance, But the study of fibre connectors is ongoing [9].

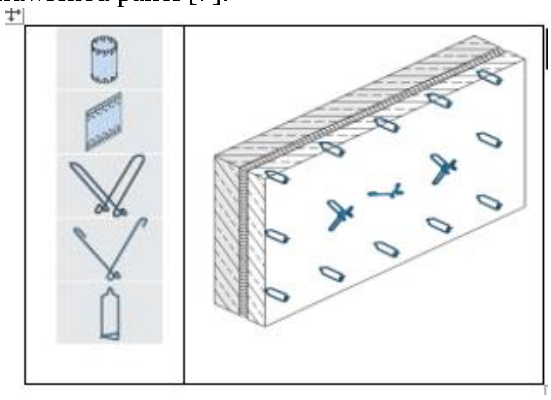

Fig. 2 Concrete sandwich wall element Steel connectors and anchors

In their 2016 study, Natalie et al. modified the GFRP connector Fig.3., which is a flat stainless-steel connector made of two reinforced bars incorporated inside sandwich panels as well as continuing to support anchors for holding eccentric loads as well as vertical loads caused by dead loads and horizontal loads caused by warping and wind [10].

Fig. 3 Illustration of the GFRP flat connector

4. Composite behavior of concrete sandwich panels

Concrete sandwich panels can be made as complete composite, partial composite, or non-composite panels. In fully composite panels, the two concrete wythes function as a single integrated system with a linear strain profile from the exterior to the internal wythe. This necessitates complete lateral shear transmission between the both wythes, which the shear bar ought to offer [11]. A totally composite item has light and thin wall sections, which leads to poor thermal performance relative to its lateral or gravity load resistance. Additionally, shear stresses caused by bending between the exterior and internal concrete wythes can be transferred through the connectors in a fully composite part [9]. Without shearing transfer, load is still distributed across the two wythes in the non-composite condition. Depending on the system's thickness and load-transfer insulation, each turbine works independently with its own load [11,12].

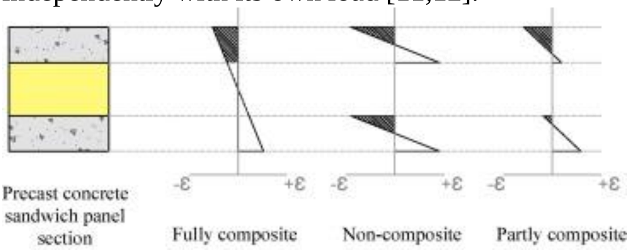

Fig. 4 Approximate strain profiles for different flexural behaviors [11,12].

5. Thermal bridges:

As a result of international measures to increase building energy efficiency, the use of stiff thermal insulation materials in precast concrete sandwich panels is growing more and more common. Compared to mineral wool, which was historically the dominant insulating material, these materials have less heat conductivity. In regions that could be considered thermally functional when mineral wool insulation is employed, the installation of rigid insulation creates new issues. The connection between the layers of concrete, where stainless steel diagonal tie connectors are frequently utilised in Estonia, is one particular problem. As depicted in Fig.5, these are normally positioned vertically at a 0,6 m distance between insulating boards. Rigid insulation, as opposed to soft mineral wool, cannot be wrapped snugly around the diagonal ties, creating a cavity that extends the entire height and depth of the insulation layer. Technical instructions from producers of diagonal ties and insulation advise adding further thermal insulation to this cavity. This would prevent cavity natural convection, which might greatly raise the average thermal transmittance (U-value) of the building envelope. However, there is proof that Estonian PCSP manufacturers are not adequately following these regulations [13].

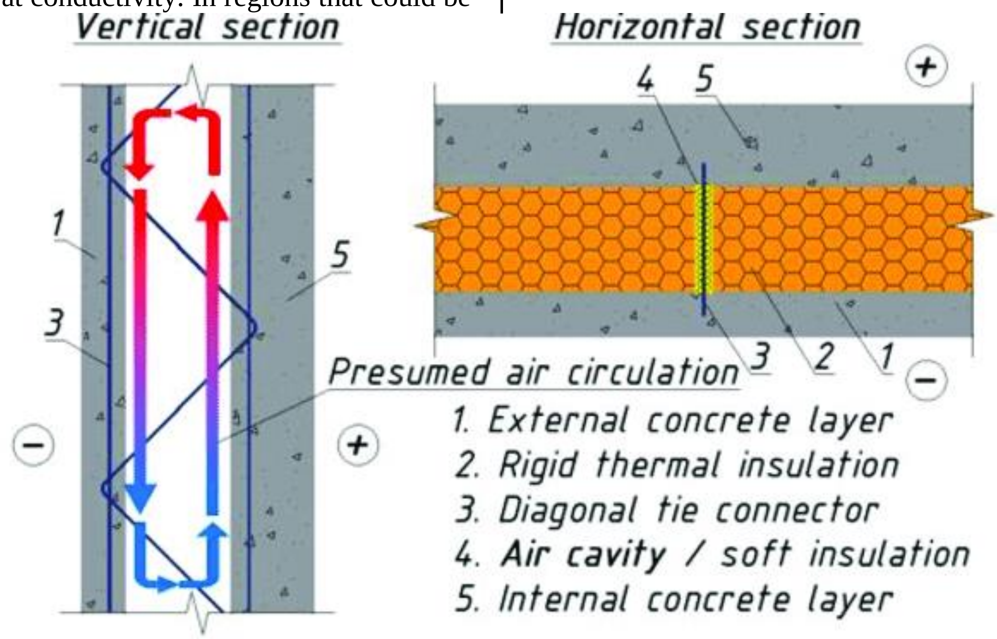

Fig. 5 Stainless steel diagonal tie connector and presumed natural convection between insulation boards (left), additional soft thermal insulation around diagonal tie (right) [13].

6. Panel's applications:

It can be used in various applications including Floor Slabs [14], Roof, and Interior & Exterior Wall [15]. at schools, office buildings, roof and Buildings of one floor.

Fig. 6 Panels' applications.

7. Properties needed in Sandwich panels:

According to the use of the sandwich panel, its properties be different such as:

7.1 Thermal resistant

The core, the material utilized, and the panel thickness all affect how thermally resistant a panel is. Additionally, the thermal isolation is impacted by how the panel is installed.1.2 m length were built for this purpose; the design was essentially identical to the bigger panels. The thermal test was prepared utilizing concrete thermal characteristics measurement. Additional thermal testing was conducted on the empty insulation panels alone in order to verify the manufacturer's claims regarding their thermal resistance and to assess how well they held up under stress. Fig. 7. displaying the hot box's measurement. The central blue area represents the vacuum insulation, whereas the surrounding green area represents the polymer foam insulation [16].

7.2 Sound reduction:

Sound reduction index (SRI), commonly referred to as sound transmission loss, is a measurement of how well building components like walls, floors, and doors block the passage of sound [17].

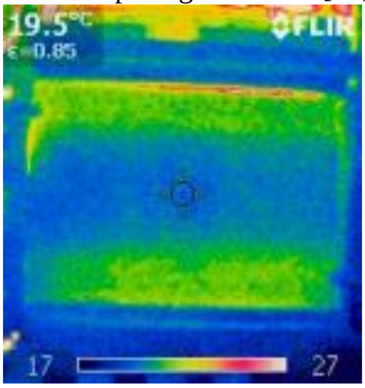

Fig. 7 Hot box test of a panel.

7.3 Mechanical properties:

It is necessary to evaluate the panel's density, bending, and flexure. The panels were placed through structural testing to determine their strength and ability to function as intended. The moment capacity of the panels was evaluated using a three-point bending test, as shown in Fig. 8 [16].

Fig. 8 Instrumented panel in place for structural testing [16]

7.4 Fire behavior:

Sandwich panels' fire reactions, resistance, or behaviors vary depending on factors like metal thickness, foam, coating, etc. Depending on their needs, the buyer will have to choose amongst various sandwich panel kinds. [18].

8. Construction of textile reinforcing concrete sandwich panels:

Fibers, yarns and textiles' nets as woven, warp or weft knitted fabrics were used for reinforcing concrete in researches for reinforcing concrete with different materials [1].

9. Materials used as TRC:

Different types of fibers can be used to improve properties of concrete; the main types are steel, glass and polypropylene fibers [19].

9.1 Polypropylene:

The use of polypropylene fibres in concrete increases the concrete's tension and compressive strength [19,20]. Hydrophobic fibres, such as polypropylene, do not absorb water [21]. Polypropylene fibres melt at around 160 degrees Celsius, creating pathways in the concrete for moisture to evaporate. (PP) fibres have been used in concrete to prevent shrinkage cracking and (to a lesser extent) to increase toughness and impact resistance, therefore improving the energy absorption capacity of the concrete [22,23,24]. Many recent studies have shown that adding a small amount of Polypropylene fibers to fresh concrete can significantly reduce plastic shrinkage cracking in the early stages, and that these fibres can also significantly restrain surface bleeding and aggregate settlement in fresh concrete, reducing the possibility of setting cracks [22,25].

9.2 Poly-Amide:

To previous research, polyamide (PA) fibres are used as an effective support in cement paste [26, 27,28]. It should be emphasized, however, that the presence of aggregates in the cementitious matrix is likely to affect the composite's behaviour [26]. researchers demonstrated that (PA) fibres edges are holding together at post-cracking [22, 29,30]. Evenly distributed fibres in new concrete assist to avoid the creation of plastic shrinkage fractures, while they also help to inhibit the emergence of micro-cracks in hardened concrete [22, 31, 32]. Other researchers discovered that adding fibres affected the workability of fresh concrete [22,33,34], particularly when using synthetic fibres with a high characteristic ratio (length/diameter) [22,34].

9.3 Glass Fiber:

Fiberglass is a material made up of very thin glass fibres. Many polymer products employ it as a reinforcing ingredient; the resulting composite material, officially designated as fiber-reinforced polymer (FRP) or glass-reinforced polymer (GRP), is commonly referred to as "fiberglass" in use and applications [35]. Because of their high tensile strength of 1.700 - 3.700 N/mm2 and excellent connection with the cement matrix, glass fibres can increase flexural strength. However, this impact is only seen at extremely high fibre concentrations of 3 to 5% of volume of concrete [36,37].

9.4 Poly-Ethylene:

PE fibres were used to compare the average flexural and impact strengths of concrete with those of PP fiber-reinforced concrete. It was found that adding 0.1 percent by volume of PE fibres enhanced the average flexural and impact strengths of the concrete 5.8 times by 21%, significantly [38].

10. Textile application for investigating concrete Sandwich panel:

Composite textiles were used in researches to investigate concrete sandwich panels' performance. While Textile composites are defined as having a textile fibre, yarn, or fabric system inside a resin system [39,40].

10.1 Investigation in core; Reducing the amount of used concrete in TRC facade panels by rigid foam prisms core:

Chira et al 2015.'s research Three 30*70cm facade panels that were reinforced with two 2D alkali-resistant fiber glass nets and 30*30*10 polystyrene foam prisms in the middle were tested. Three other blank facade panels with comparable geometry and stronger nets were also put to the test. Six stages were taken to make these panels. For facade panels, a standard formwork is intended to secure the two reinforcement nets at 6 mm cover concrete, however for panels with polystyrene prisms, two steps were required for the concrete pour. Prior to placing at least 2 mm of concrete above the first strengthen net level, the first strengthen net was fixed with no foam. The other net was connected to after the polystyrene prisms were set up inside the formwork and after further concrete had been poured. The formwork is then sealed and turned upside-down to prevent the floating effects. The greatest amount of time that could pass between these two processes of pouring concrete is two minutes in order to prevent concrete from hardening, as shown in Fig.10. This study discovered that the amount of concrete used was reduced by roughly 20% when compared to conventional façade. Although the elasticity limit of polystyrene (XPS) panels increased by around 49 percent in comparison to conventional facade panels, the failure load increased by about 16 percent. The panels made of polystyrene can be used in place of regular ones because they have more benefits and are more thermally efficient according to the wind zone [41].

Name	Roving titer 0°/90° (tex)	Binding type	Grid spacing 0°/90° (mm)	Area 0°/90° (mm²)	Young's modulus (MPa)	Tensi stren (MPa
2D AR-Glass	2400/2400	Chain	10/25	3.80	33,250	475

Fig. 9 Textile reinforcement grid for concrete.

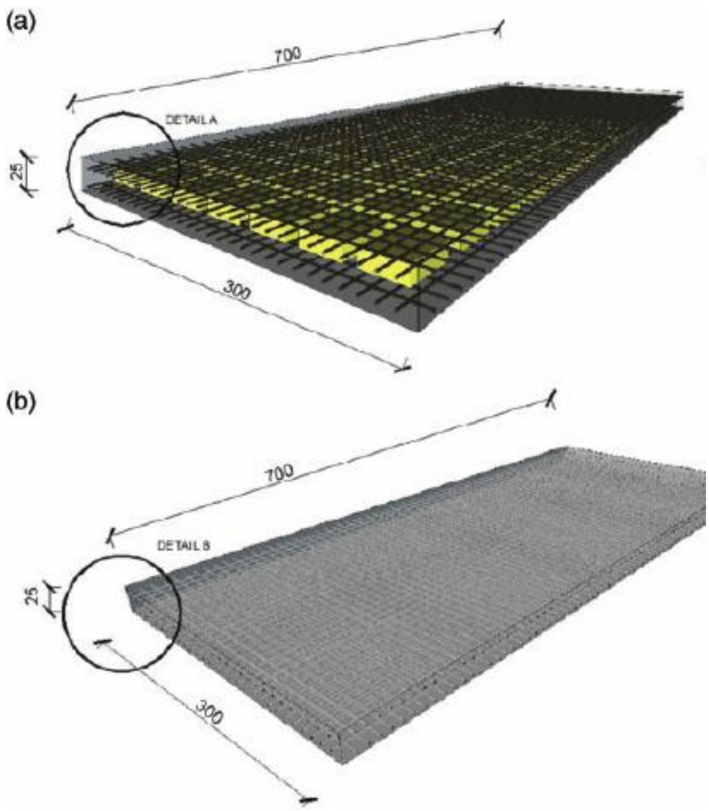

Fig. 10 The XPS panels(a) and the ordinary panel (b) [41].

10.2 Investigation in gride; Reinforcing façade by TRC to resist corrosion and minimize concrete thickness:

The properties of a new TRC composite material are investigated at Aachen University by the Collaborative Research Centre (DFG). Based on these results some of TRC first applications developed. The project used an external cladding panel from TRC for the additional room for the laboratory hall in the Structural Concrete Institute at Aachen University. Those manufactured facades from TRC gave many advantages, such as corrosion-resistant and small thickness and less concrete so it allows thin-walled elements to constructed with it [42].

Fig. 11 Curtain wall construction [42].

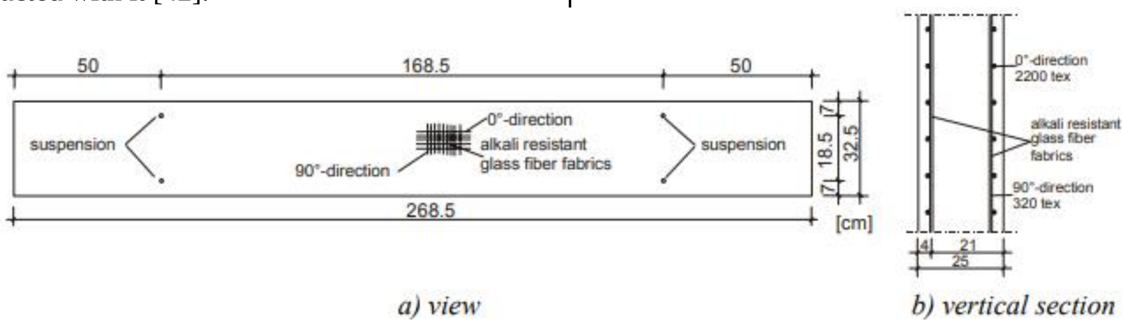

Fig. 12 sandwich panels' view and vertical section [42].

10.3 Investigation in connectors; glass-fiber-reinforced polymer (GFRP) shear grids connectors:

By shearing GFRP grid connectors, JunHee Kim and Young-Chan created a new insulated concrete system. An extensive experimental program was conducted in order to evaluate the structural performance of the insulated concrete SWPs. Additionally, the analytical forecast was contrasted with the experimental results. Due to the high degree of composite action, they produce, SWPs reinforced with GFRP grids as shear connectors often have a greater flexural capacity [43].

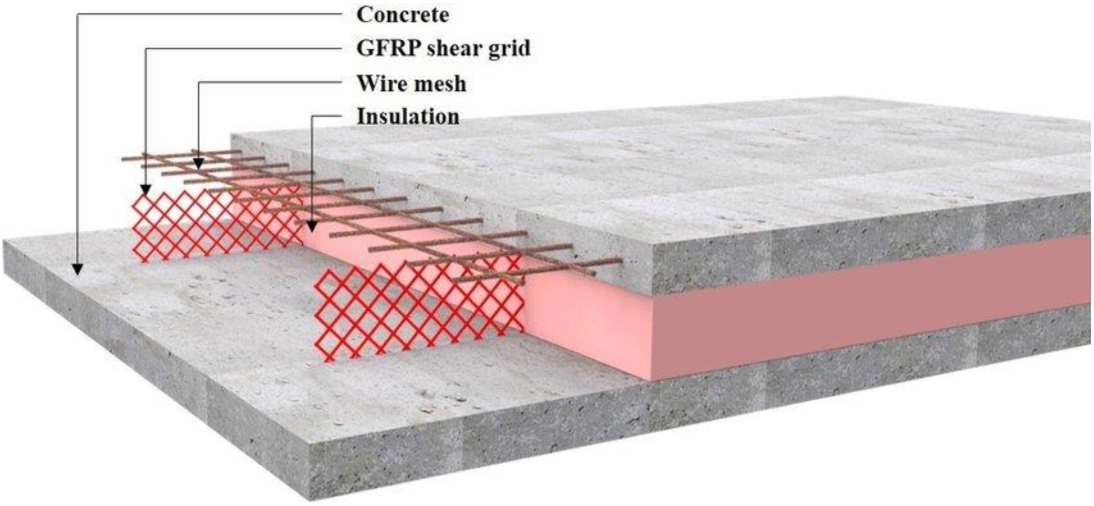

Fig. 13. Insulated concrete sandwich wall panel reinforced with glass-fiber-reinforced polymer (GFRP) shear grids. [43]

11. Conclusion:

Concrete sandwich panels have good thermal properties but need reinforcing due to the concrete known issues. Steel was used to reinforce it due to its high tensile performance although it has some problems such as corrosion, Thickness, high weight thermal bridges. Many researchers studied replacing stel by textile (TRC) which gave better performance, different materials used in researches such as fiber glass, poly amide, poly propylene and poly ethylene, Also carbon fibers and basalt fibers were used but with higher cost. TRC were investigated concrete sandwich panels as core, as grid or as a connector. Fire, thermal, sound isolation behaviors of concrete sandwich panel may be tested according to use and also structural behavior must be tested to ensure its performance. Finally, Textile reinforcing concrete need to be study more by different material and constructions with concrete sandwich panels.

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