An Assessment of Bending behaviour of Textile Reinforced Concrete

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Abstract- **A prefabricated concrete sandwich panel, with insulating material acting as a structural layer able to transfer the shear stresses, is discussed. The use of an in-pressure casting technique allows to avoid the use of glue and to prevent the deboning between the layers thanks to the good bond obtained during the production. Sandwich beams characterized bya thick internal expanded polystyrene foam core and by two thin external Alkali-Resistant glass Textile Reinforced Concrete layers are experimentally investigated according to four point bending scheme.**

Index Terms- **Textile Reinforced Concrete (TRC), sandwich beams, four-point bending test, façade retrofitting element**

I. INTRODUCTION

Concrete is one of our key construction materials and it has been used forover a hundred years. Concrete is a material that is very strong in compression but remains only a tenth of that strength when subjected to tensile force.During the late 1800s, the technique to reinforce concrete was developed.Steel rods are casted into the concrete to absorb the tensile forces the structure is exposed to. Basically two materials with different properties areworking together as one unit, which is called a composite material.(Engström, 2004)

In recent years, many new techniques for reinforcement of concrete structures has been developed. One of them is textile reinforcement. Textile reinforcement makes it possible to cast thin elements. In comparison with conventional steel reinforcement less concrete cover is needed since the textilereinforcement is not in need of protection against corrosion. Textile reinforced concrete is however a relatively new composite material and currently there is more to investigate in terms of material properties and applications. (Engström, 2004)Another method is fiber reinforced concrete where short fibers are mixedinto the fresh concrete and improve the tensile strength and ductility of theconcrete. Commonly used materials for fibers are steel, glass or plastic.When designing new buildings, the ability to cast thin elements increasesthe freedom in design. The low weight of a textile reinforced concrete element has many benefits, for example a lower dead load for the constructionand simplified transportation. The thin concrete slabs that constitutes the experimental work in this thesis, could be regarded as a part of a façade panelsolution.

II. RELATED WORKS

Concrete is one of our most common and most important construction material. Concrete is composed of cement, water, aggregates and additives. Theconcrete is bound together by water and cement and is called cement paste.The cement properties are mainly determined by the ratio between water andcement, the so-called water-cement ratio. The properties of concrete can bevaried by varying adding varying amounts of the components of concrete.The ingredients are mixed and then the casting begins, after a few hours thecement bond which results in that the concrete hardens. (Burström, 2006)Cement is a hydraulic binder, this means that it hardens by reaction withwater and forms a product that is resistant to water. The most commonlyused type of cement is called Portland cement. Current cement types arecommonly made of finely ground limestone that are burned in rotary furnaceat about 1450 degrees Celsius. After that the material is taken out of the ovenand cooled and formed into cement clinker. The final cement product is obtained by grinding cement clinker with gypsum (5 percent) to a powder.When combustion occurs a chemical reaction that explains the cement characteristics.Limestone ($CaCO_3$) is burned and emits carbon dioxide (CO_2)and limestone is transformed to calcium oxide (CaO). The calcium oxide ismixed with water (H_2O) and forms calcium hydroxide ($Ca(OH)_2$). After allwater is absorbed by the calcium oxide, calcium hydroxide can begin to reactwith carbon dioxide and the cement hardens and the excess water evaporates. (Burström, 2006)

Steel reinforced concrete: Concrete has high compressive strength but low tensile strength. To use concrete as a construction material it is combined with a material with high tensile strength. The oldest and most common method is to combine, or reinforce, concrete with steel. In reinforced concrete structures there is interaction between concrete and steel so that concrete can absorb compressiveforces and the steel can absorb tensile forces. Concrete usually breaksthrough brittle failure which occurs suddenly without warning. Steel has amore ductile behavior. The combination of concrete and steel creates a composite material that can undergo larger deformations before breaking.

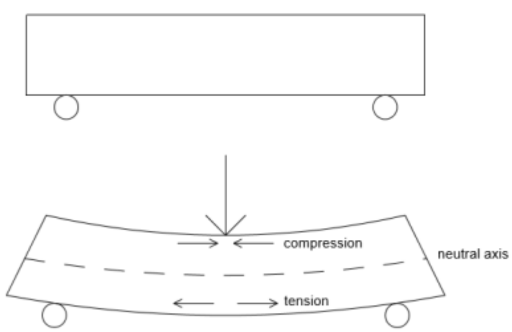

Fig.1 compression and tensile zone of a beam subject to bending

An element under bending moment will have one part subject to compression and one part subjected to tensile force see Figure 1. Since the tensilestrength of concrete is weak, an unreinforced element will break when thetensile strength of the concrete is reached. To meet the high compressionstrength in the concrete steel bars are placed in the tensile zone.To get good use out of a composite material, concrete and steel, it is requiredthat the force transfers between the materials work well. This is done bygood bond between the materials. Bond includes several mechanisms, adhesion between cement paste and steel, friction between steel bars and concreteand the bond in the interface between steel bars and the roughness of theconcrete. (Isaksson, et al., 2010)

When using steel bars to reinforce concrete it is important to have enoughconcrete cover. The thickness of the concrete cover is of great importancefor corrosion protection and fire but also cracking. It is common for a steelreinforced concrete element to have a minimum cover thickness of 30 mm.

Fiber reinforced concrete: Fiber reinforced concrete consists of concrete or mortar mixed with randomly distributed short fibers. Combining short fibers with textile reinforced concrete generates an increased strength and a better crack pattern,with several small cracks instead of one or two larger cracks. The fiberscan be made of many different materials for example steel or glass. Thistype of reinforced concrete is more of a homogenous material than for example steel reinforced concrete, although it still consists of two differentmaterial with different properties, because of that fiber reinforced concretecan be called a homogenous composite material. (Xu & Li, 2007)

The fibers can be of varying length, short fibers help bridging the smallestcracks and longer fibers help bridging larger cracks, see Figure 2.

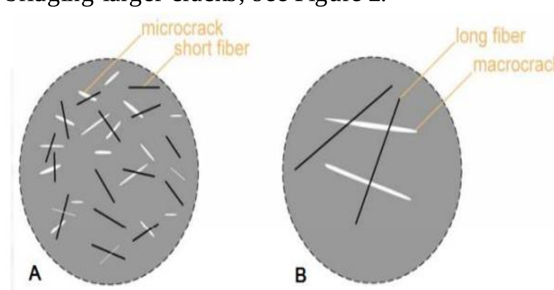

Fig.2 Fibers bridging cracks (Mehta &Monteiro, u.d.)

Textile reinforced concrete:A relatively new method of concrete reinforcement is the use of textile reinforcement. Fine-grained concrete joined with an open mesh structure of textile. This means that it is possible to cast very thin structural elements astextile reinforcement does not impose any requirements on the concretecover since there is no risk for corrosion. The mesh may consist of different materials such as carbon and glass fiber.Textile reinforced concrete (TRC) can be seen as a combination of steel reinforced concrete and fiber reinforced concrete thus it also combines thepositive characteristics of the aforementioned reinforcing methods as shownin Figure 3. (Hegger, et al., 2006)

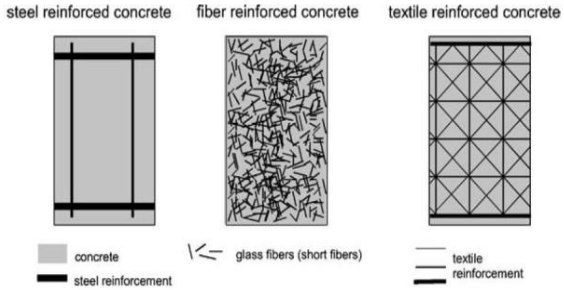

Fig.3 Different methods for reinforcing concrete (Hegger, et al., 2006)

Textile reinforcement consists of fibers however, for this concept the fiberscan be placed where they are most useful and in the direction of the forceas short fibers in fiber reinforced concrete are randomly distributed in thefresh concrete. Figure 5 schematically shows an example of how textile reinforced concrete combines conventional reinforced concrete and concretereinforced with short fibers. Textile reinforcement have the many of thebenefits gained by fiber reinforced concrete plus the fact that it can beplaced in the tensile zone in the direction of the tensile force.

III. THE SUGGESTED APPROACH

The investigational campaign - whose results are presented in this paper - concerns the investigation on sandwich beamstested according to a four point bending scheme.

The sandwich beams investigated are characterized by two external layers 10 mm thick made of Textile ReinforcedConcrete (TRC) connected by an insulation layer of expanded polystyrene foam (EPS) 100 mm thick. The expanded polystyrene foam used is commercially known as EPS250 and is characterized by a compressive strength85 of 0.25 MPa at a strain equal to 10% and by a low thermal conductivity (0.034 W/mK according to EN 13163 [20]). The

86 elastic modulus is equal to 13.7MPa: it was measured performing compressive tests on three 100x100x150mm^3 nominally identical specimens (Figure 4). According to uniaxial tensile tests performed on a similar EPS [16], the tensilebehaviour is expected to be elastic-brittle, with an higher strength in tension rather than in compression. The shearmodulus can vary between 4.14 and 4.41 MPa for this class of expanded polystyrene foam according to ASTM C 578-92.

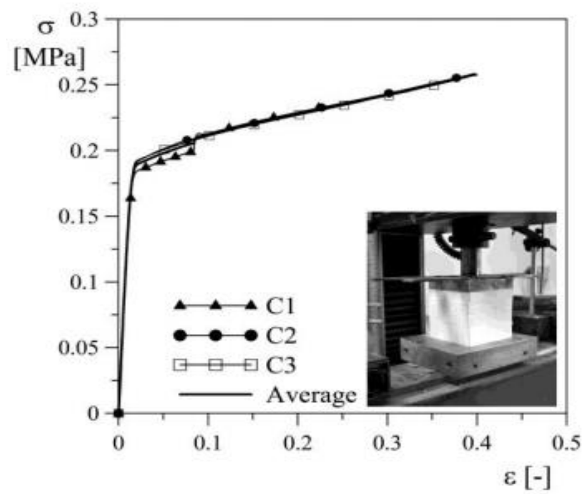

Fig. 4 EPS behaviour in compression

TRC is obtained reinforcing a high strength fine grain mortar with an Alkali-Resistant glass fabric, manufactured by means of a leno-weave technique and covered with an epoxy coating.The fabric used as reinforcement, whose geometrical and mechanical characteristics are collected in Table 1, was selected after performing several investigations aimed at optimizing the performance in terms of TRC strength and ductility, the bond between matrix and fabric, and the internal filament slip. The variables considered in the preliminary study werefabric geometry (warp and weft spacing and their cross-section), fabric weaving and fabric coating. The nominal strengthof the selected fabric obtained in the warp direction is equal to 820MPa. Further information on the testing procedure101 and some considerations on the results can be found in Colombo et al. [22].

The cementitious matrix used is characterized by a water to binder ratio equal to 0.225 and by a superplasticizer to cement108 ratio equal to 9.3%. The maximum aggregate size selected is equal to 1 mm. These properties guarantee a high flow109 capability and, hence, a good bond between matrix and fabric and the possibility to cast the mortar in pressure.The in pressure casting technique (Figure 5) is adopted in order to minimize the voids (defects) in the mortar and to enhance the bond between TRC layers and EPS, also because just the insulating material is used to transfer the shear between the external TRC layers. A proper formwork characterized by transparent walls was built in order to check by visual inspection the injection of the mortar (Figure 5a). An EPS layer with an AR-glass fabric fixed on each side is first placed into the formwork. This EPS prism was simply cut from a larger block and no particular surface treatment was performed. After mixing, the fresh mortar is allowed to flow into a tank (Figure 5b), that, once filled, is closed (Figure5c) and then pressurized. In this way the mortar can be injected in the formwork from the bottom through a sphericalvalve (Figure 5d). 48 hours after casting, specimens are demoulded and then cured in air at least for 28 days before testing.

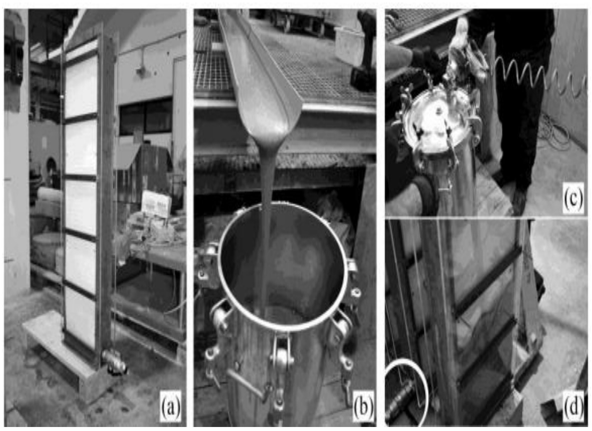

Fig. 5Casting of the sandwich beams: formwork with the EPS panel and the fabrics placed inside (a), tank filling (b),tank closure (c) and in-pressure injection of the mortar inside the framework (d).

IV. CONCLUSION

The experimental campaign provided in this paper allows us to attract a few conclusions on the conduct of the multilayered sandwich answer followed whilst a 4-point bending scheme is taken into consideration. First of all, considering both the geometries investigated, a large ductility is experienced in each the cases this ductility is completed via both big compressive plastic pressure within the EPS important center and the multi-cracking pattern in the TRC layers. The multi-cracking pattern appears to be affected, specifically in the small geometry, by way of the fabric position inside the TRC layer thickness; however, the special crack pattern does now not affect the global reaction of the specimen. This consideration may additionally lead to conclude that material position is extra important at Serviceability Limit State (SLS) when crack beginning displacements are regarded, rather than at the Ultimate Limit State (ULS), when the most bearing capability is taken into consideration.

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