Performance Evaluation of Fabric Formwork

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PERFORMANCE EVALUATION OF FABRIC FORMWORK

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ABSTRACT

Woven geotextile fabrics have excellent potential as formwork material. Because of its permeable nature, it has a property of eradicating surplus water and air-voids from the concrete while concreting. It is extremely lightweight therefore easy to handle. Due to its flexible nature, it is versatile in casting varied curved forms, which are difficult to cast using conventional formwork. This research evaluates the performance of locally available woven geotextile fabrics as formwork material. Fabrics are selected by conducting a series of tests to check their physical properties. The changes in concrete properties due to fabric formwork are investigated and documented through this research. The research resulted in encouraging results in terms of fabrics ability to increase the surface hardness of concrete and cast thin shell elements. Based upon the experiences gained from the practical experiments the paper concludes by discussing the interest and future applications for such formwork technology in the context of its compatibility with concrete.

RESUMEN

Las telas geotextiles tejidas tienen un potencial excelente como material de encofrado. Debido a su naturaleza permeable, tiene la propiedad de erradicar el exceso de agua y los vacíos de aire del concreto durante el hormigonado. Es extremadamente liviano, por lo tanto, es fácil de manejar. Debido a su naturaleza flexible, es versátil para fundir formas curvas variadas, que son difíciles de moldear utilizando encofrado convencional. Esta investigación evalúa el rendimiento de telas geotextiles tejidas localmente disponibles como material de encofrado. Las telas se seleccionan realizando una serie de pruebas para verificar sus propiedades físicas. Los cambios en las propiedades del concreto debido al encofrado de tela se investigan y documentan a través de esta investigación. La investigación dio como resultado resultados alentadores en cuanto a la capacidad de los *tejidos para aumentar la dureza de la superficie del hormigón y fundir elementos finos de la cubierta. Sobre la base de la experiencia adquirida con los experimentos prácticos, el documento concluye discutiendo el interés y las aplicaciones futuras de dicha tecnología de encofrado en el contexto de su compatibilidad con el hormigón.*

Keywords: *Geotextile-fabric, formwork, concrete, casting, permeable, density, compressive-strength, surface-strength*

1. INTRODUCTION

Size of structure, shape of structure, its location etc. leads to improvisation in formwork technology for concrete construction. Fabric formwork is a new construction technology which looks very promising due its various advantages over conventional formwork. Use of fabric as formwork material is not a new practice. Roman architect and designer Vitruvius used organic fabric made out of reed to cast curved surfaces [1]. Gustav Lilienthal during the 19^{th} century used fabric as a base to cast concrete draped upon two parallel beams [2] [3]. Similarly, James Waller an engineer from Ireland used hessian and vegetable fabric to cast concrete forms [4] [5] [6]. Waller derived and patented Ctesiphon shells, constructed with the aid of fabric formwork [7]. Fabrics up till now have been used to cast almost every building element, for example Felix Candela constructed shells with it in Mexico [8], Miguel Fisac cast beams and bricks with it [9], while Kenzo Unno [10] and Rick Fern [11] used fabrics to construct wall panels and columns respectively. These are some of the many examples of construction with fabric formwork.

Woven synthetic fabrics substantially changed the history of fabric formwork. It is observed that permeable nature of fabric, leads to higher concrete strength. A complex vacuum apparatus was prepared by Karl Biller to remove excess mix water from horizontal concrete surfaces which improved the concrete strength by lowering the water cement ratio and reducing the amount of air bubbles and blow holes [12]. Prof. Mark West at Center for Architectural and Structural Technology (C.A.S.T.) which is a facility developed for architectural exploration of fabric formwork, is responsible for the most recent innovations done in fabric formwork. They have cast highly expressive columns, optimized trusses, singly and doubly curved thin shells using spandex and geotextiles [13] [14]. Professor Joseph John Orr at Bath University made significant contribution to this field by studying effects of fabric formwork on concrete properties and design & construction of beams [15] [16] [17]. The research described in this paper checks the performance of locally available fabrics procured from Ahmedabad, India as formwork to cast concrete elements. It checks the changes in concrete properties due to fabric (woven geotextile) formwork.

2. METHODOLOGY

1.1. Testing for physical properties of fabric.

Navkar Industries provided 3 different samples of geotextiles: two samples of polypropylene and one sample of polyester (Refer Fig. 1).

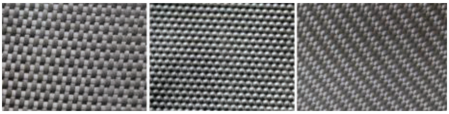

Figure 1: Selected fabrics: Polyester, polypropylene (a), polypropylene (b).

Since, the procured fabrics have never been used before as a formwork material, it is necessary to know their capability to cast various building elements out of concrete. In order to know that, mechanical tests are performed on fabrics (Refer Fig. 2)

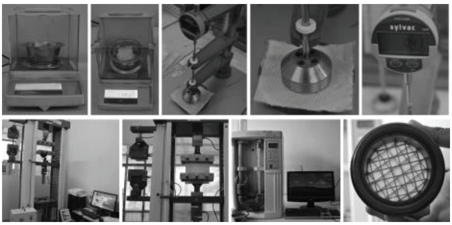

Figure 2: Mechanical Tests on Fabric

1.2. Checking fabric's compatibility with concrete.

To check fabrics compatibility with cement concrete and its appropriateness as a formwork material a list of tests are performed.

1.2.1. Percentage of water and cement passing from fabric.

Due to vibration and compaction of concrete, compression waves are generated in concrete and because of which it exerts pressure against the formwork wall. This forces the pore water pressure in concrete to push the trapped air and water outside the formwork, which is quite indifferent to the impermeable conventional formwork system [18] [19]. The assembly (Refer Fig. 3) checks the amount of cement and water bleeding out of fabric. Plywood with fabric stapled and glued to 150 mm x 100 mm slits, allows water and cement from the mortar placed on top of it to pass through the fabric. Below the fabric pieces, containers collect the water and cement that seeps out. Polypropylene (b) type of fabric percolates maximum of water (19.98 %) and minimum of cement (0.10 %) out of the three procured fabrics, which is apt for its use as formwork material

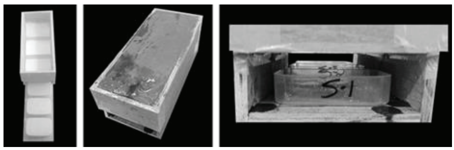

Figure 3: Test setup for measurement of percentage water and cement passing from fabric

1.2.2. Creep of fabric under sustained concrete load.

Fabric being flexible and tensile in nature is suspected to elongation. Therefore, under sustained load of concrete, fabric may tend to elongate and this phenomenon might change the dimensions of the designed building element cast in fabric. So, to avoid that, creep of fabric was measured under sustained loading. Due to unavailability of proper testing system an assembly is prepared taking ASTM D-5262 as a reference for methodology and equipment specification [20]. The assembly consist of indigenous and easily available materials; bamboo poles, clutch wires and plywood (Refer Fig. 4). Load equivalent to concrete weight of 300 mm x 200 mm x 150 mm which is 21.6 kg is applied for 36 hours and readings are taken at time interval of 1, 5, 10, 30, 45 minutes; 1, 2, 3, 4, 8 hours and; 24, 36 hours.

Figure 4: Test setup for measuring creep in fabric

It is observed that the fabrics underwent elongation for first 2 hours of loading (Refer Fig. 5, Fig. 6, Fig. 7). After which no significant elongation is observed till the end of the test. A graph paper of 0.001m accuracy is used to measure the elongation. During the entire test, no irregular deformation or stretching failure is seen in the fabric.

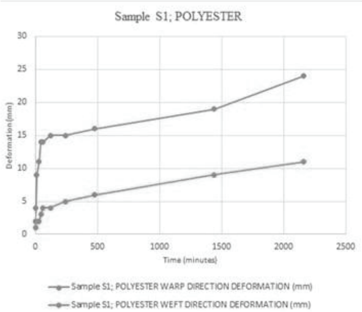

Figure 5: Deformation of Polyester under creep load

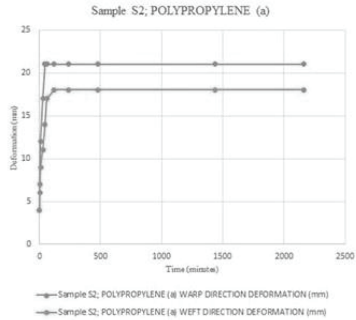

Figure 6: Deformation of Polypropylene (a) under creep load

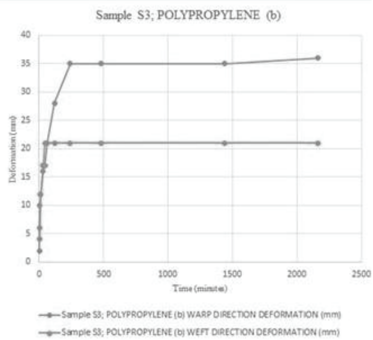

Figure 7: Deformation of Polypropylene (b) under creep load

1.2.3. Casting of concrete cylinders.

It is essential to evaluate the strength and surface parameters of the fabric cast concrete as compared to concrete cast using metallic molds (Refer Fig. 8, Fig. 9). After 24 hours the cylinders are demolded. Fabric being synthetic in nature peels off easily without the need to apply any demolding agent. Fabric gives a nice textured finish which is preferable for exposed concrete structures.

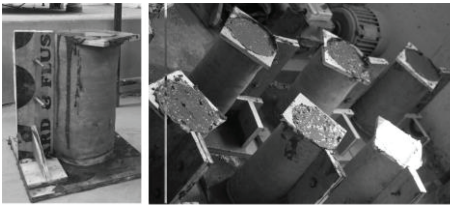

Figure 8: Fabric Cylindrical Mold Assembly

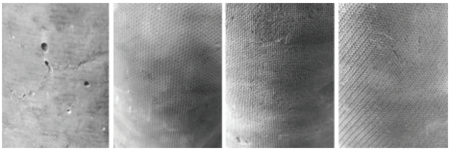

Figure 9 : Concrete surface texture: a) metal mold b) polyester mold, c) polypropylene (a) mold, d) polypropylene (b) mold.

1.2.4. Measuring density of concrete.

The permeable nature of fabric might affect density of concrete. To give it a check the density of concrete cylinders is calculated (Refer Fig. 10).

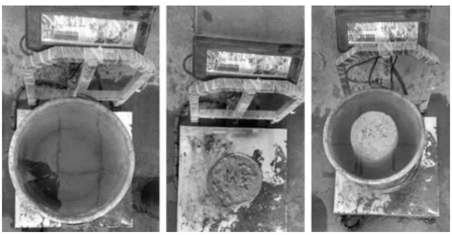

Figure 10: Setup to measure density of concrete

A slight increase in density of fabric cast cylinders ranging from 1% to 5% as compared to metallic molds was observed. Fabrics having maximum permeability, minimum pore size, maximum water seepage, minimum seepage of cement resulted in highest density (Refer Fig. 11).

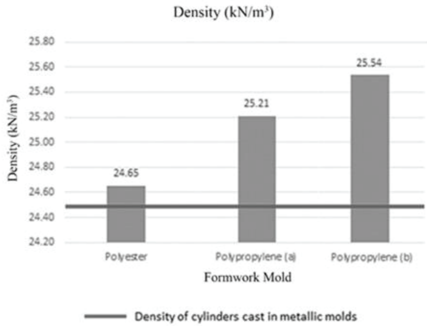

Figure 11: Density (28 Day) Comparison Chart of Concrete Cylinders

1.2.5 Rebound hammer test on cylinder.

Cured and dried cylinders clamped with aid of compression testing machine were tested under rebound hammer test, with readings taken at an interval of at least 25mm (Refer Fig. 12).

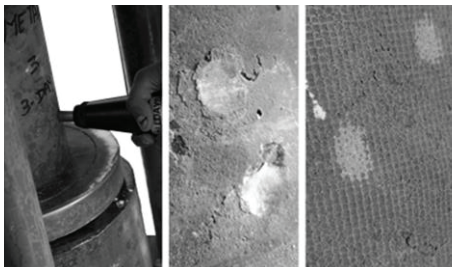

Figure 12: a) Rebound hammer test setup b) effect of rebound hammer impact on concrete surface c) metal cast cylinder, fabric cast cylinder.

The results show significant increase ranging from 32% to 40% in the surface hardness of fabric cast cylinders as compared metallic mold cylinders (Refer Fig. 13). Permeable nature of fabric can be major reason for such drastic increase in the surface strength of concrete, because it forces the air voids and excess water adjacent to the surface to percolate out.

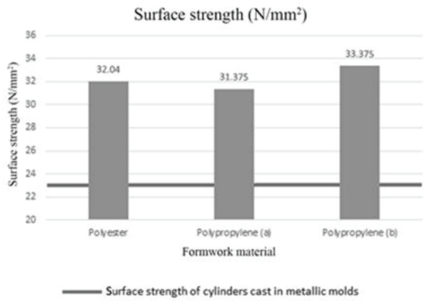

Figure 13: Surface strength (28 day) comparison chart of concrete cylinders

1.2.6. Compression strength test on cylinders.

Performance of uniaxial compression test (using is 516 clause no. 5.5. as reference) [21] on both cylinder types gives an idea of overall compressive strength (Refer Fig. 14).

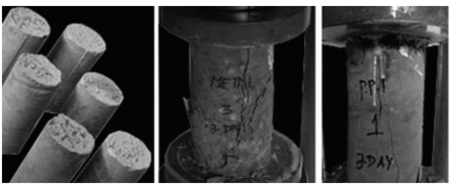

Figure 14: a) Demolded cylinders (left: fabric cast, right: metal cast) b) metal cast cylinder under compression c) fabric cast cylinder under compression.

There is no significant change (2% to 10% increase) in the overall compressive strength of cylinders cast using fabric molds (Refer Fig. 15)

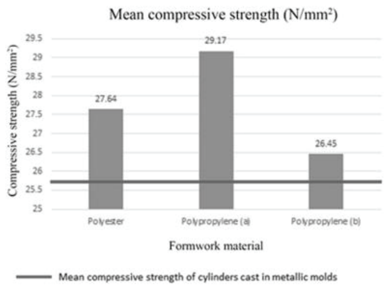

Figure 15: Compression strength (28 day) comparison chart of concrete cylinders

3. CONCLUSION

The research done concludes the following points

1. The polypropylene (b) type of fabric procured from Navkar industries, Ahmedabad is the most suitable woven geotextile fabric available in vicinity of Ahmedabad region, to be used as fabric formwork. Its mechanical properties (water permeability and maximum pore size), compatibility with concrete (surface strength and density) where most suitable amongst the 3 procured fabrics.
2. The rebound hammer test done on the concrete cylinder of M-25 grade showed that the surface strength of fabric mold cylinders increased by 32% to 40% with respect to metal mold cylinders. Fabric formwork

would increase the surface hardness of the concrete and thus would result into more durable concrete by reducing carbonation and chloride ingress penetration depth.

3. A slight increase in density (2% to 5%) and compressive strength (2% to 13%) of fabric mold cylinders was observed. The surface strength did increase significantly but the overall density and strength did not have a major impact on concrete.
4. The fabric cast cylinders had a nice surface texture without bug holes, honey combing, color variations. The surface finish is appropriate for exposed concrete surface.

5. FUTURE SCOPE

The following is the future scope of research for evaluating performance of fabric as formwork material.

1. Fabric formwork is an evolving construction technology. Despite of its several advantages, the usage of fabric formwork is scarce, which is mainly due to the need for proper construction methods and systems. A much-felt need is seen in producing and evolving proper construction methods for casting concrete elements using fabric formwork. If the time consumption and required skill level of labor could be reduced, by generating thumb rule construction methods as it is in case of prismatic formwork technique then the usage of fabric formwork on commercial level could increase.
2. The ability of fabric formwork to cast curved shapes should be checked by casting more varied and complex curved surfaces.

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