Global Scientific JOURNALS

GSJ: Volume 7, Issue 11, November 2019, Online: ISSN 2320-9186

www.globalscientificjournal.com

MECHANICAL PROPERTIES OF 3-D SPACER FABRIC REINFORCED CONCRETE CANVAS AND ITS APPLICATION AREA

By

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NOVEMBER-2019

ABSTRACT

This research was carried out to study the behavior of fabric reinforced concrete, specifically compressive and flexural strength, by incorporating recycled 3 dimensional spacer fabric as fiber reinforcement in the concrete. Another aim of the research is to determine the maximum proportion of fibers to be added in the concrete. The specimens were tested for flexural strength, tensile strength, water absorption test and fire and chemical resistivity test. Laboratory test results based on short term investigation reveals that the compressive strength and flexural strength of fabric reinforced concrete are higher than of normal ordinary Portland cement concrete. Furthermore, the environmental sustainability of FRC was evaluated in comparison to conventional RC. The purpose of this study is also to produce a comparative study of irrigation canal lining by the use of fabric reinforced concrete canvas. This study reveals lining irrigation canals using concrete impregnated fabric reduce the construction and maintenance cost. Fabric reinforced specimens with dimension of 250×250 and 150×150 were cast with PVC bottom layering having three different thicknesses 5, 8 and 13mm to measure their tensile, flexural and durability strength.

Keywords: Fabric reinforced concrete canvas (FRCC), experimental methods, durability, sustainability, RC.

1. INTRODUCTION

Concrete is the most commonly used construction material which is used in today's rapidly developing construction field. There are so many advantages and benefits carried by concrete but while discussing about flexibility property then we found many difficulties as concrete restricts its boundaries in flexibility. Concrete as construction material is recognized globally but the inquest to improve its flexibility has always attracted the attention of researchers. As there are many advantages of concrete but one thing makes it inefficient i.e., it isn't flexible when hardened. As the concrete is not flexible so it creates many difficulties in certain essential works in construction. Fabric reinforced concrete canvas is a revolutionary new construction material. The main aspect of Fabric reinforced concrete canvas is a flexible concrete sheet which is impregnated by cement and changes into hardened concrete layer after hydration and gives us a tough, strong, thin and water resistance concrete layer. Simply the FRCC is a flexible concrete in the form of cloth which can very easily be positioned. After hydration, the fabric reinforced concrete canvas turns into hard, durable concrete structure within 24 hours [4].

The increasing cost of repair work due to weathering actions, ground surface damage, and seepage in water canals always remained a concern. A new technique has developed called fabric reinforcement which makes the defects free from concrete & which is flexible and easy to use. The concept of using fabric as reinforcement is not new. In ancient times tiny fibers was used in mortar and straw in mud bricks. In 1900s asbestos fibres also were used in concrete. But asbestos was discouraged due to detection of health risk [7].

Textiles fabrics are small pieces of reinforcing material possessing certain characteristics and properties. Fibres are considered as a construction material to enhance the flexural and tensile strength and as a binder that could combine cement in bonding with fabric matrices. Cement based composite is one of the most widely used man-made composite materials in many fields, such as building, roadway, bridge , side ditches, slope stabilization and so on.

In order to solve these defects in utility of applications, various reinforcements have been added into concrete. The invention of steel reinforced concrete has improved this situation to a certain extent. However, steel is vulnerable to corrosion which will result in damage of the reinforced concrete structure. Moreover, the steel industry often consumes a lot of energy and produces large amounts of green house gases which may cause destruction of ecological environment. Therefore, in recent years, chopped synthetic fabrics, such as polyethylene, polyvinyl alcohol, polyethylene terephthalate and polypropylene have been attempted to use as reinforcement to enhance the mechanical properties of concrete. However, the disadvantages of fiber reinforced concrete are local agglomerate and partially un-oriented distribution of fibers over the total cross-section, thus reducing the concrete effectiveness. With the development of weaving technology, fiber-reinforced concrete has gradually been replaced by fabric/textile-reinforced concrete [5].

Fabric-reinforced concrete composites make up for deficiencies of steel-reinforced concrete and fiber-reinforced concrete. Fabric-reinforced concrete is corrosion resistant compared with steel-reinforced concrete, thus prolonging the service life and reducing the maintenance cost of the concrete composite. On the other hand, fabric could be placed in the position where necessary in the direction subjected to tensile or flexural forces, thus enhancing utilization efficiency of reinforcement and improving mechanical property as well as bearing capacity of the concrete composite. Therefore, fabric-reinforced concrete composites have wide application prospects in low-rise building, side ditches, irrigation canal, slope stabilization/protection, embankments and ornamental architectures and so on [4].

2. MATERIALS AND METHODS

2.1 General

The mechanical properties of material composed of Portland lime cement, sand and spacer fabric were studied. A total of $2m^2$ wide 3d spacer fabric were used for different thickness of canvas were casted, cured and tested for fresh and hard properties of concrete. The Engineering properties of the concrete like flexural, split tensile strength and water impermeability were tested. Finally the results of strength obtained by the methods of various thickness of spacer fabric in concrete were compared.

Fabric reinforced concrete canvas preparation process in comparison to conventional steel reinforced concrete was studied. Before setting of the cement powder on the surface, a flexible 3D spacer fabric impregnated with cement powder can be placed like a soft cloth. Water can be sprayed afterward on the top surface of cloth for hydration requirement. On getting hardened, a thin composite layer, that is flexible and durable, water-resistant and fire-resistant. The study was planned to prepare concrete canvas with 5mm, 8mm and 13m. The materials utilized for the test are cement (Dangote PLC), sand and water.

2.2 Materials

2.2.1 Three Dimensional Spacer Fabric

The 3D spacer fabric plays an important role in offering a space for the cement powder filling and enhances the tensile strength of the composite. Normally, the thickness of the 3D spacer fabric is about 5-13 mm. The 3D spacer fiber is a matrix of three woven fabric layers. The upper and bottom face layer are of tightly knitted fabric layers and the space between these layers is hold out by third fabric layer known as pile yarns. Pile yarns are vertical and inclined extended fiber woven from upper to bottom face layer and it essentially works as a column in between upper and bottom face layers. The space between the upper and bottom face layer is then filled with cementitious material and the addition of water makes it set and durable. There are two fundamental directions in 3D spacer fiber i.e. Warp and Weft direction. Warp is a series of threads that run from the front to the back, and “weft” is a series of threads that run in a pattern through the warp. The warp direction is also known as machine direction. In addition, there are two different types of spacer yarns are present in the fundamental mechanism of 3D spacer fabrics. Spacer yarn I and Spacer yarn II, in which spacer yarn I is of vertical nature of outer textile substrates, and another one spacer yarns II, is of inclined nature of outer textile substrates as shown in fig 3.3.

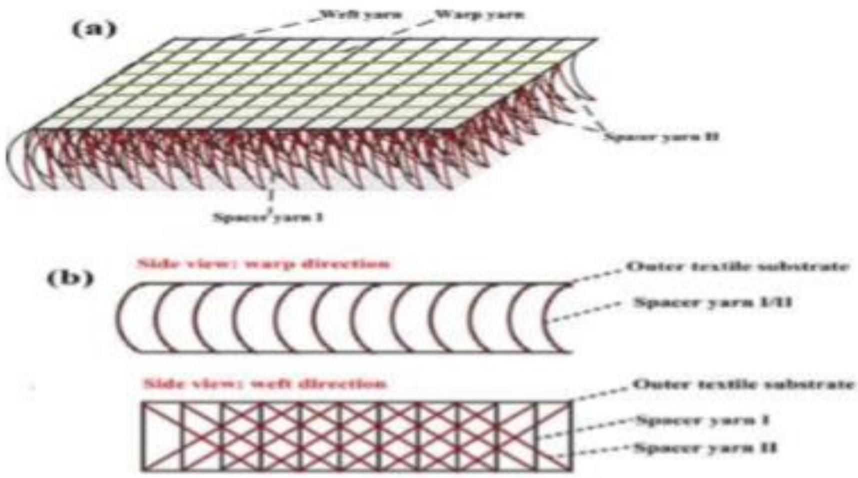


Figure 3.3. Geometrical structure of 3d spacer fabric

Table 3.2. Test performed on 3-D spacer fabric & its results

S.N	NAME OF THE TEST	RESULTS
1	Tensile Strength	
	Warp Direction	0.73 Mpa
	Weft Direction	0.68 Mpa
2	% Elongation	
	Warp Direction	64.40%
	Weft Direction	116.85%

2.2.2 Cement

Portland lime cement (PLC) is a kind of cement which has a unique identity as compared to Ordinary Portland Cement (OPC) obviously due to its chemical composition and its high-performance characteristics. The rapid hardening property of Portland lime cement is differentiating it from the other types of Portland cement. Comparatively, a very high amount of heat is exerted through the hydration of PLC within a day which is responsible for the increase in material temperature. The workability of PLC due to its rapid hardening property is a much difficult issue and it varies with the respective water/binder ratio. The temperature also has the adverse effect on working time as well as strengths of PLC. The working time will reduce in hot climates. PLC was initially developed for the application against sulfate attack and high sulfate environment. PLC is more resistance against acid attack as compared to OPC. PLC contains fewer amounts of alkalis which limits the production of calcium hydroxide as the hydration product which increases the effect of resistance against corrosion when PLC compared to OPC.

Table 3.3.Cement property

S.no	Physical properties of PLC cement	Result
1	Specific Gravity	3.15

2	Standard Consistency (%)	30%
3	Initial SettingTime	45min
4	Final Setting Time	530min
5	Fineness	7%
6	Soundness	4mm

2.2.3 PVC Membrane Backing

An Impermeable PVC Membrane on one side making the concrete canvas water proof against any attack by moisture or water from the surrounding. A hydrophilic fiber (polyethylene and polypropylene yarns) membrane is attached to the opposite surface to the PVC membrane which helps in hydration process and is used for drawing water into the aggregate. PVC (poly vinyl chloride) is a water resistant material which is widely used all over the world. It is an excellent chemical resistant has electrical insulating properties.

2.2.4 Hydrophilic Sheet

It is economical & can be used in the construction. The advantage of using (Nylon) is that it can be remolded in any shape because it is thermoplastic in nature. Hydrophilic sheet affords greater design flexibility & can be permanently set into the fabric.

2.2.5 Adhesive

Adhesive is used for getting good bond strength & it dries in a hard-flexible film resistance to water and corrosion also. Simple way to protect its strength & durability is applying to the walls by brush or roller as the paint is applied.

2.2.6 Water

It is a very important in any construction works carried out through its whole process because it defines it's all strength characteristics. If more amount of water used in the construction it may cause bleeding of the materials and segregation of the materials takes place. Generally, 3/10 of weight of water is added to the concrete for complete hydration of the materials and it achieves good strength. W/c ratio =0.3 is used for the conventional concrete. If fabrics are introduced in the construction, the excess water present in the concrete absorbs the water by the fabrics and makes it's free from segregation & bleeding & water should be added within its permissible limits & less water is used.

2.3 Methods

By controlling the following variables in manufacturing, it is possible to produce a filled fabric where the void ratio and swelling is controlled so as to limit the space available to be occupied by the liquid component.

- The arrangement, shape and physical properties of the linking fabrics, the selection of the filler materials with suitable physical characteristics including density and Grain size analysis,
- Careful control of manufacturing process especially loading the fill to the correct bulk density within the material and Control of the ratio of reagents and fillers within the dry fill.

MV – OV = X * LV ………………………… (Eq.1) [27]

Where:

MV= the maximum volume of the space within the cloth (per unit area of the cloth); thus MV includes both the volume of empty space in the cloth before addition of the powder material, and an additional volume resulting from any expansion of the space due to the pressure exerted by the swelling of the powder material during the addition of the liquid or during the setting of material.

- **OV=** the volume of the space within the cloth that is occupied by the particles of the powder material, which volume does not include the volume occupied by voids within the powder material (per unit area of the cloth);
- **LV=** the volume of liquid (per unit area of the cloth) that results in the maximum long term (28 day) compressive strength, of the fill blend when set; this can be derived empirically or from the reagent manufacturer/blenders recommended liquid to reagent/blend ratio; and
- **X** = a factor between 0.65 and 1. For example using a particular OPC based Cement formulation, where the liquid is water, the value of X used is 0.75.

The methodology devised to conduct the study was planned and performed by conducting laboratory test for the concrete and concrete making materials referring different standards. Intensive desk study has been conducted regarding properties of fresh and hardened concrete.

STANDARD	TITLE
EBCS	ETHIOPIAN BUILDING CODE STANDARDS
ASTM-D6768 2006	STANDARD TEST METHOD FOR TENSILE STRENGTH
BS-EN 12467 2012	STANDARD TEST METHOD FOR BENDING STRENGTH
BS-EN 12467 2012	STANDARD TEST METHOD FOR WATER IMPERMEABILITY

2.3.1 Mix Design

In Ethiopia, while casting concrete blocks to tests its mettle we just follow some guidelines shown through below. These show a path to precede the work as a reference / practical work. But, these were written in accordance with rigid nature of concrete. As we know that many of the conclusions were made based on a popularly used technique i.e., Trial and Error Method. Assumption is the first word that defines this method. As we were unaware of the Code books related to fabric reinforced concrete, So that the only way to gain the best proportion is through Multiple Proportioning. It is a complicated one, to make it simple assuming a component of proportion as constant and varying the thickness of the 3D spacer fabric. As we are using finer elements, mainly cement and fine aggregate.Considering X: Y i.e,X = cement as one part, Y = fine aggregate as other part.Assuming Cement as unity, following are the Proportions that were kept for testing and are listed below.

Table 3.1: Mix proportions of Cement: Sand mixture

S.NO	Cement :Sand(Ratio)	Wt. of Cement in gm	Wt. of F.A(Sand) in gm	Wt. of Concrete Canvas in gm
1	1:03	200	600	1225

2.3.2. Work procedure and Sample Preparation

The following are the steps that are involved in laying fabric reinforced Concrete Canvas,

1. Before the start of the experiment, it is important to know how could be the surface that is used for laying fabric spacer
2. The surface that is recommended is to be flat so that no undulations can be seen beneath and proper alignment of the layers is done without any error.
3. At first, Place a PVC sheet of required size (1m*1m) for testing on the flat surface and place the 3D spacer fabric on the PVC sheet of same size using the strong Adhesive with high Pressure. Meanwhile take a plastic / steel pan for making design mix, follow the above mix proportion and take weights using weigh balance.
4. Mix the cement and the sand thoroughly to get a uniform mixture.
5. Now pour the dry cement filler into the spaces of the Air mesh and compact the material using vibrating machines.
6. After then, the top face is covered with a hydrophilic layer which is attached by using an adhesive in a pattern manner. So that no fall out of material takes place. The importance of this layer is to prevent the dry mix to coming out and at the time of curing it acts as a media to distribute and drain out the water uniformly throughout the cloth.
7. Finally, the cloth is ready to use at site. It is flexible and rolled in bulks.

8. Coming to Curing, The volume of water that is required to cure the laid sample of fabric reinforced concrete canvas given by the formula. X = (Normal consistency of cement sample / Optimum water-cement ratio)
9. Gently sprinkle the water over the top layer with hand or with the help of spraying equipment. (Don't disturb the Concrete Canvas until it sets.)
10. Test the 3D spacer fabric reinforced concrete canvas laid for 1, 3, 7 and for 28 days.
11. Go through the tests that are explained in chapter 5
12. Record the results obtained and tabulate the observations.

A total of having an area 2 m^2 three dimensional spacer fabric is used. Preparation of the sample is executed at room temperature around 28^{o}C. First, the spacer fabric is glued with PVC membrane by fevicol. Left that sample to dry for 10 up to 15 minutes. Once the layers get bound together and can't separate by acting manual force then start to fill the dry concrete mix gradually into the specimen holding spacer fabric until the 3D spacer fabric is completely impregnated with the cementitious material. When the cementitious powder and sand is filled uniformly overall the thickness by vibration and compaction then patch the upper hydrophilic layer with another face of spacer fabric layer for the perseverance of the specimen. Left that specimen for several hours, the purpose is to dry the bond between hydrophilic layer and 3D spacer fabric. Now the specimen is ready for hydration. The weight of cementitious material should be noted in order to calculate the water/cement ratio. ASTM-D6768 2006, BS-EN 12467 2012 and BS-EN 12467 2012 standard was adopted and modified to prepare and taste 3d spacer fabric reinforced concrete canvas.

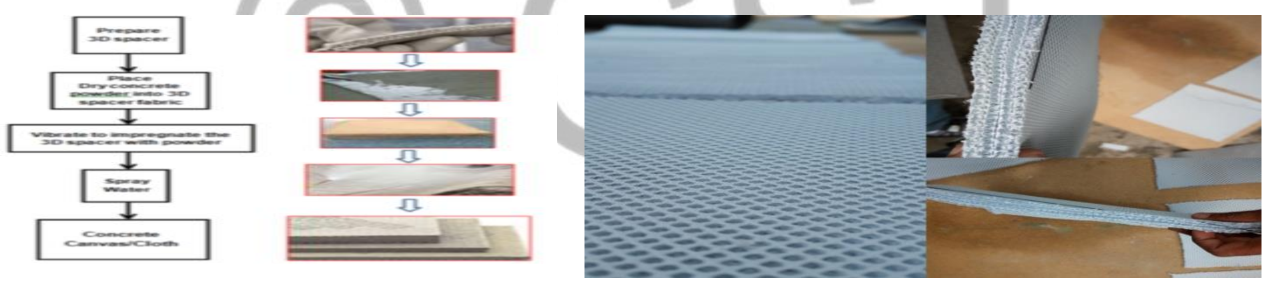


Figure 3.1 typical 3D spacer fabric and compositions of concrete canvas and Preparation flow chart of Concrete Canvas/ Cloth

Finally, tap water is spread over the hydrophilic surface for the hydration of FRCC panels. Once fabric reinforced canvas panel gets hydrated it is only workable for 2 and half hours. Spraying of water will immediately stop once the water penetrates alongside the bottommost layer of the Concrete canvas sample. An excess in water/cement ratio always recommended. Use the spray nozzles for the best results do not use high-pressure jet directly on specimen as gets disturb the unset concrete canvas panels. Once fabric reinforced concrete canvas gets hydrated by water it becomes solid and to form a thin, strong and waterproof concrete layer.

For the construction with flexible concrete fabric sheet or even before its use it is very essential to make a comparative study of flexible concrete sheet with the conventional plain cement concrete and also with reinforced cement concrete. Cost comparison and methodology of lining FRCC were studied.

2.3.3 Comparison of Construction Costs for Different Concrete Lining

In this study concrete lining and tile lining are commonly used and discussed fairly and a compression with respect to economically and durability. Concrete Canal linings are expensive. In usual terrain a lined canal may cost twice as much as an equivalent unlined earth canal; however, in rough terrain a lined canal may be less expensive in first cost than an unlined canal because of savings in excavation and structures in the smaller sections of a lined canal. In view of the probable increased first cost, a decision to use lining needs justification. It may be based on intangible benefits, long-range tangible benefits, or a combination of tangible and intangible benefits.

For the construction with flexible concrete sheet or even before its use it is very essential to make a comparative study of flexible concrete sheet with the conventional plain cement concrete and also with reinforced cement concrete. In view of this, the cost comparison of flexible concrete sheet has done as follows:

To prepare a comparison of costs for lining an open rectangular ditch 1m x 1m, 1m in length.

The comparison for construction costs prepared, were:-

• In Situ concrete lining, average thickness 150mm.

• Precast Concrete Paving Slabs, laid on sand / cement screed.

• Sprayed Concrete (Gunite) average thickness 100mm with mesh.

• Concrete Canvas FRCC-8mm.

As per the Current Schedule rates of Addis Ababa city government finance and economy development bureau year 2011 first quarter market price the following data the cost of the following construction material and labor is found in the following way: -

TABLE.4.3.in Situ Concrete Lining

	Rate	Qty	BIRR/hr	
A. GANG RATE				
Labor Ganger	18.75 birr/hr	1	18.75	
Gen Ops	16.25 birr/hr	3	48.75	
Total/hr			67.5	
Total Labor/day		8		**540 birr /day**
Plant 6 ton Dumper	1500 /day			1500 /day
Single tool comp plus poker	200 /day			200 /day
Small tool etc- allow	50 /day			50 /day
2.5ton Excavator	2000 /day			2000 /day
Total Labor and Plant				**4290 /day**
B. MATERIAL SUPPLY COST				
C-25 Concrete (150mm thick) mechanical mix 1:2:3	1372birr /m^3	0.15		165birr /m^2

Wastage (10%)	10%			16.5birr /m^2
Total Material /m^3				**181.5 birr /m^2**
C. OUTPUT RATE CALCULATION				
Ditch lining volume (3x0.9x0.15)	**0.405 m^3/lm**			
Average rate	**6.0 m^3/day**			40.0 m^2/day
A. Labor and Plant	**4290 birr /day**			107 BIRR /m^2
B. Materials	**181.5 birr /m^2**			**181.5 birr /m^2**
Total Per SQM Cost				**288.5 birr /m^2**
supervision/transport/welfare	**10%**			**317.35 birr /m^2**
Total Per SQM Cost	12.5%			**357.01 birr /m^2**

TABLE.4.4. Sprayed Concrete (Gunite)

	Rate	Qty	BIRR/hr	
A. GANG RATE Labor Ganger Gen Ops Total/hr Total Labour/day Plant Mobilization	18.75 birr/hr 16.25 birr/hr 1,500.00	1 3 8	18.75 48.75 67.5	540 birr /day 166 birr /day
Total Labor and Plant				**706 birr /day**
B. MATERIAL SUPPLY COST Spray concrete (includes equipment costs) Steel mesh Wastage (5%)	980 /m^2 250 /m^2 5%			980 /m^2 250 /m^2 5%
Total Material /m^2				**1291 birr /m^2**
C. OUTPUT RATE CALCULATION Average rate A. Labor and Plant B. Materials	130 m^2/day 706 birr /day 1291 birr /m^2			130.0 m^2/day 5.5 birr /m^2 1291 birr /m^2
Total Per SQM Cost				1296 birr /m^2
supervision/transport/welfare	10.0%			1425 birr /m^2
Total Per SQM Cost	12.5%			**1425 birr /m^2**

Table.4.5. Precast Concrete Paving Slabs

	Rate	Qty	BIRR/hr	
A. GANG RATE Labor Ganger Gen Ops Total/hr Total Labor/day Plant 6tn Dumper Small tool etc- allow	18.75 birr/hr 16.25 birr/hr 1500 birr /day 100birr /day	1 3 8	18.75 birr/hr 48.75 birr/hr 67.5 birr/hr	540 birr/day 1500 birr /day 100birr /day
Total Labor and Plant				2140 birr/day
B. MATERIAL SUPPLY COST 900x600x50 slabs Wastage (0%) Sand /cement screed (3:1) (60mm thick) Wastage (10%)	210 birr each 0% 750birr /m^3 10%			420 birr /m^2 0.00 60 birr /m^2 528 birr /m^2
Total Material /m^2				528 birr /m^2
C. OUTPUT RATE CALCULATION Average rate A. Labor and Plant B. Materials	6.0 m^3/day 2140 birr/day 528 birr /m^2			40.0 m^2/day 53.5 birr /m^2 528 birr /m^2
Total Per SQM Cost				581.5 birr/ m^2
supervision/transport/welfare	10.0%			639 birr/ m^2
Add overheads and profit	**12.5%**			719 birr/ m^2

Table.4.6.Fabric Reinforced Concrete Canvas – Type Frcc-8mm

	Rate	Qty	BIRR/hr	
A. GANG RATE Labor Ganger Gen Ops Total/hr Total Labor/day Plant 6tn Dumper Water Bowser plus hoses Small tool etc- allow	 18.75 birr/hr 16.25 birr/hr 1500 birr /day 100birr /day 100birr /day	 1 2 8	 18.75 32.5 51.25	 410 birr /day 1500 birr /day 100 birr /day 100 birr /day
Total Labor and Plant				**2110 birr /day**
B. MATERIAL SUPPLY COST fabric reinforced Concrete canvas type CC8 (including 1:3 cement to sand ratio and PVC backing) Wastage (5%)	 150 birr /m^2 5%			 150 birr /m^2 157.5 birr /m^2
Total Material /m^2				**157.5 birr /m^2**
C. OUTPUT RATE CALCULATION Average rate A. Labor and Plant B. Materials	 412 m^2/day 2110 birr /day 157.5 birr /m^2			 412.0 m^2/day 5 birr /m^2 157.5 birr /m^2
Total Per SQM Cost				162.5 birr /m^2
supervision/transport/welfare	10.0%			178.75 birr /m^2
Add overheads and profit	**12.5%**			**200.5 birr /m^2**

Table.4.7.Cost Comparison for Ditch Lining

Lining Materials	**Materials** BIRR/sq.m	**Labor and Plant** BIRR/sq.m	**Total** BIRR/sq.m	**Installation time** Sq.m/day
1. Insitu concrete	**181.5**	107	357.01	40
2. Precast concrete paving slabs	**528**	53.5	719	40
3.Spayed concrete (Gunite)	**1291**	5.5	1425	130
4. Fabric reinforced Concrete canvas FRCC8	**157.5**	5	200.5	400

2.4. Applications of 3D spacer fabric reinforced concrete canvas

Concrete canvas is typically used to replace conventional concrete (in-situ, precast or sprayed) for erosion control, remediation and construction applications. Some typical examples are given below.

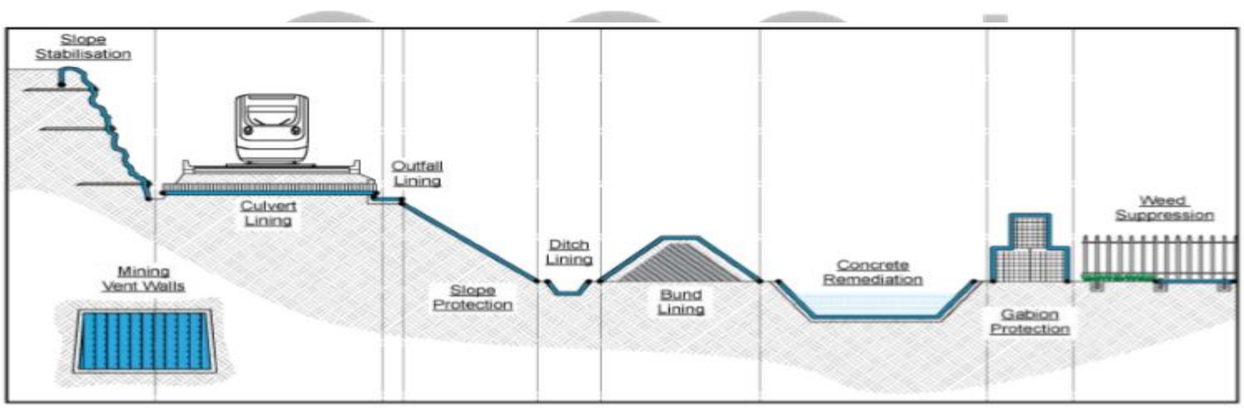


Figure 4.4. Fabric reinforced concrete canvas applications

Fabric reinforced Concrete canvas can be used to provide a hard wearing erosion control surface for lining ditches for drainage and irrigation. FRCC is typically used as an alternative to conventional concrete drainage and where vegetated or earth lined ditches are unsuitable due to high flow rates, containment requirements or the need to reduce maintenance.

FRCC can also be used to provide a hard wearing erosion control surface to protect slopes from environmental degradation. It is typically used to replace shotcrete and where vegetated slopes are unsuitable due to ground water, arid climate or poor soil conditions. Slope Protection is suitable for applications where the body of the slope is inherently stable but the surface of the slope is prone to erosion from weathering and surface slip. Slope Stabilization is suitable for applications where the body of the slope is unstable and is at risk of suffering from deep slip (where a large mass of the slope collapses). This may be caused by ground-water lubricating the soil or from other factors such as ground vibration. Conventional solutions include shotcrete, steel mesh and soil nails which are used to stabilize the slope by providing structural reinforcement. FRCC can substitute for the shotcrete component of this type of design for many projects.

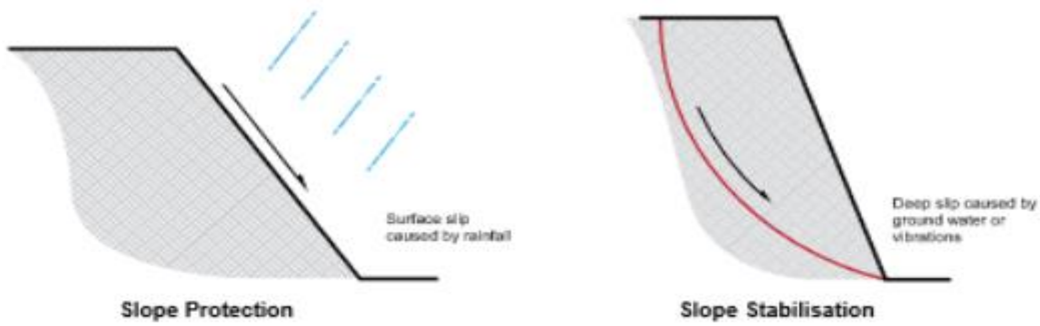


Figure 4.5. Slope protection and stabilization

FRCC can be used to provide hard amour capping of secondary containment bunds around petrochemical tank farms, munitions depots and flood defenses. FRCC is typically used to protect the bund from environmental degradation, animal damage, improve impermeability and prevent weed growth. FRCC is used to extend the life of existing infrastructure, reduce leakage and improve flow characteristics. FRCC can be used as an alternative to rebuilding or where lining with a flexible membrane is unsuitable due to the flow conditions or durability concerns. FRCC can be used to reline steel and concrete culverts which have degraded due to scour and corrosion. It is used to extend the life of culverts and provide a hard wearing erosion control layer with improved impermeability and flow characteristics. It can also be used as an alternative to relining with bitumen, GRP, polyurethane or sprayed concrete.

It can be used to provide long-term weed growth prevention in areas where maintenance is difficult such as around sensitive infrastructure or in remote locations. FRCC is typically used as a replacement for precast concrete slabs and where conventional geo textiles do not provide sufficient durability. Fabric reinforced Concrete canvas can be used to cover steel basket and geo textile gabions to prevent damage from corrosion, UV damage and vandalism. Concrete canvas significantly extends the life of gabions providing a hard wearing surface that will last for decades. FRCC can also be used to cap earth filled gabions to prevent foreign object damage in military applications and prevent water ingress which can lead to slump. Concrete canvas can be used to construct walls in underground mines to create ventilation stoppages and blast walls. It typically replaces walls constructed using brattice cloth, breezeblocks or plaster board where it provides a long-term solution that is fast to erect with a small logistical footprint.

2.5 Fabric Reinforced Concrete Layup Techniques

Fabric reinforced Concrete canvas can be laid along the length of the ditch (longitudinal) or across the width (transverse). 5mm is supplied in roll widths of 1.0m, 8mm and 13mm in roll widths of 1.1m. Consideration should be given to the channel profile design in order to minimize wastage. Some example profiles are given below based on a standard overlap of 100mm between adjacent layers. Care should be taken to position the overlap in the direction of water flow (like shingled roof tiles).

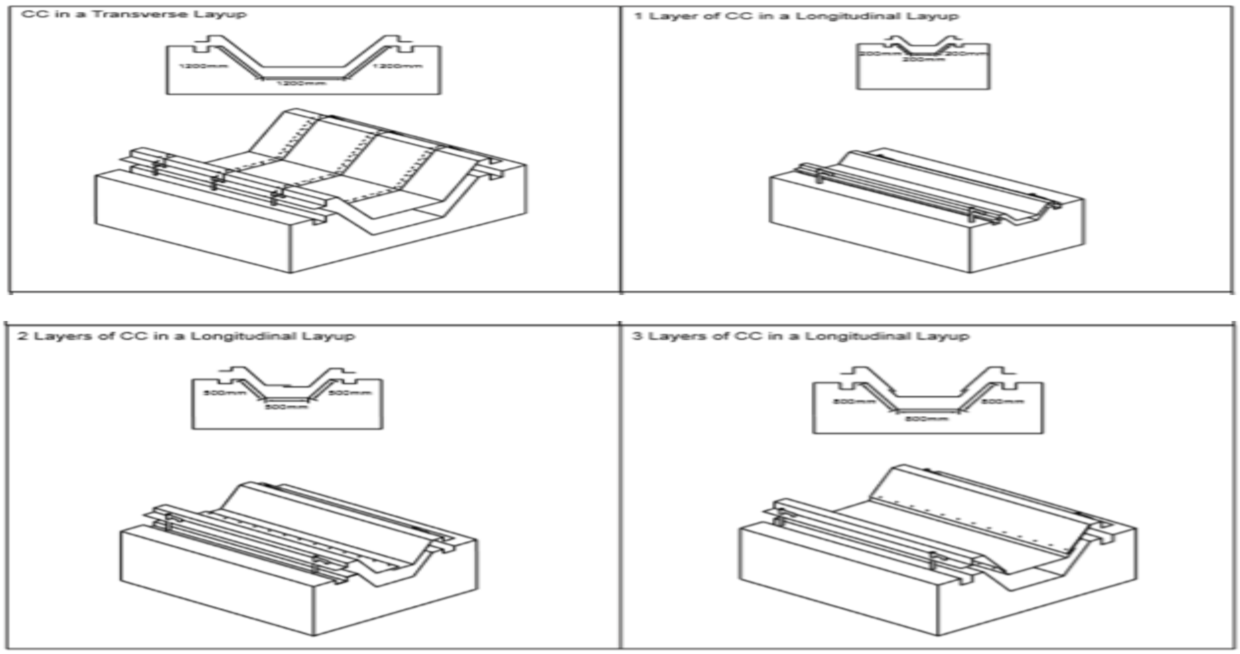


Figure 4.6. Fabric Reinforced Concrete Layup Techniques

Lying longitudinally is typically faster than lying transversely. However a transverse layup may be preferable if:

- The channel side slope is greater than 0.8m as this makes securing the Concrete Canvas difficult when using a longitudinal layup.

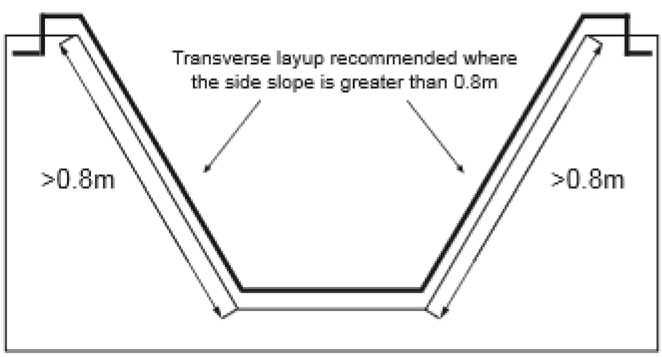


Figure 4.7. Fabric Reinforced Concrete longitudinal Layup Techniques

2.6 Fabric Reinforced Concrete Canvas Ground Fixing Method

FRCC can be fixed down along the shoulder of the ditch using pegs, an anchor trench, or preferably both. Peg spacing will differ depending on loading and flow conditions. However, for a longitudinal layup pegs are typically spaced every 2m in the anchor trench, whilst for a transverse layup pegs are normally applied at every joint (1m spacing).In addition to pegging the edge of FRCC we recommend burying the material along the shoulder using an anchor trench to prevent undermining from surface water; this is particularly important for interceptor drains that collect water runoff along their edge. Burying CC also provides a neat aesthetic transition to the

GSJ: Volume 7, Issue 11, November 2019
ISSN 2320-9186

surrounding landscape. A typical anchor trench used to prevent undermining can be between 150-300mm deep depending on the ground conditions.

A properly designed anchor trench can be used as a substitute to pegging but would normally only be used on low flow-rate applications or where pegs are unsuitable due to the location of sensitive underground infrastructure such as power cables. A ‘snap off’ type disposable blade can be used for cutting FRCC before it is hydrated or set. When cutting unset FRCC a 15-20mm allowance should be left from the cut edge due to potential loss of fill. FRCC can also be cut using a powered disc-cutter, a self sharpening fabric cutter or hand saw. Set FRCC can be cut using the same tools used for cutting conventional concrete, such as disc cutters, angle grinders or good quality tile cutters. FRCC sheets can also be water-cut for applications where a high resolution is required such as for signage or sculptural works.

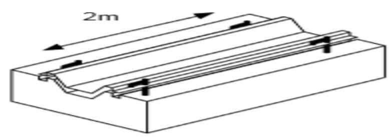


Figure 4.8. Pegging for a longitudinal layup

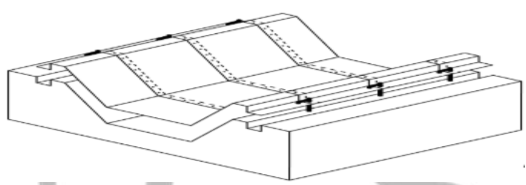


Figure 4.9. Pegging for a Transverse layup

Pegs may be sourced from alternate suppliers but must have a sufficiently sharp point to penetrate the FRCC and a head design that will capture the surface of the canvas. Peg length and spacing should be selected based on soil conditions and application. Pegs should be applied at joints where possible to secure adjacent layers together. Burying is an effective means of securing the edge of the material when used in surfacing applications such as along the shoulder of a ditch or crest of a slope. An anchor trench may be used in addition to, or instead of, pegging, and will also help to prevent undermining from surface water and provide a neat aesthetic transition to the surrounding landscape. For high load applications or where ground conditions are poor, such as slope protection, slope stabilization or for high flow applications. The anchor plate design should be circular where possible or have corners to avoid stress concentrations. To use on hard or rocky substrates, the number and type of rock bolt should be selected based on the pull-out force requirement. A suitable head design should be selected to prevent stress concentrations. A minimum head diameter of 15mm is normally recommended and plates up to 150mm have been used. Ideal for fixing Canvas to wire mesh, gabion baskets or fencing, hog-rings are available in a range of sizes and can be applied with a manual or powered hog-ringer. The hog rings should be applied to FRCC prior to hydration. Self-drilling screws such as tech-screws are suitable for fixing the Canvas to sheet steel. A washer may be required to prevent pull-through. A range of conventional fixings can be used to fix FRCC to substrates such as wood. In its pre-hydrated form canvas behaves like a thick geo textile and can be fastened with suitable screws, staples, nails or adhesives. A suitable mortar can be used to join and seal canvas to existing concrete infrastructure such as head walls and slabs. Most off theshelf mortars will bond well to the fibrous surface of Canvas. Applying the mortar to the Canvas immediately after hydration or wetting the FRCC surface is recommended. A range of conventional masonry fixings, such as self tapping masonry bolts, wedge anchors and “Hilti” type nails, can be used to fix Canvas to other concrete surfaces. We recommend a minimum washer/head diameter of 15mm for most fixings of this type to prevent pull-through is recommended.

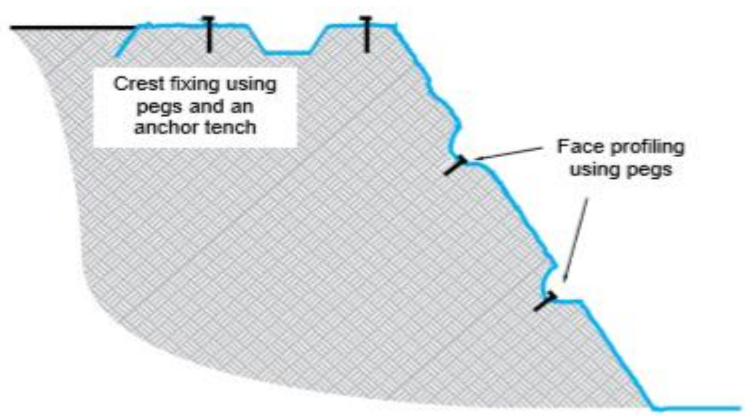


Figure 4.10. Slop stabilization fixing techniques

2.6 Fabric Reinforced Concrete Canvas Jointing Method

FRCC can be jointed along the overlap by screws, sealants, grout or thermal welding. Effective jointing method for ditches uses a screwed joint which provides a good mechanical bond and sufficient impermeability for most drainage applications. We recommend using stainless steel screws inserted at 200mm intervals along the overlap. The screws should be positioned between 30-50mm from the edge of the joint and applied prior to hydration or directly afterward. The concrete within FRCC will then set around the thread of the screws.

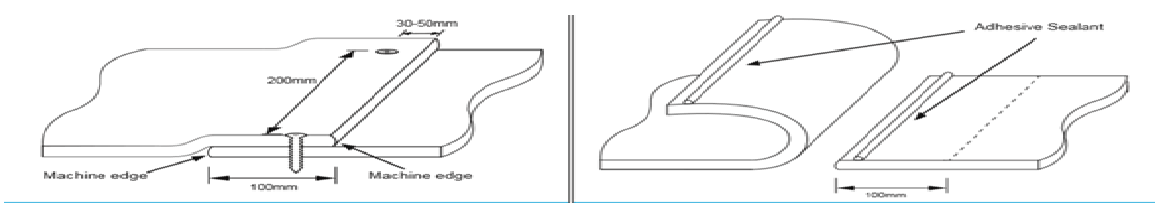


Figure 4.11.Overlapping techniques

Overlapped Joint is suitable for the majority of FRCC applications and involves overlapping adjacent sheets of FRCC by a minimum of 10cm, For erosion control applications, care should be taken to position the overlap in the direction of water flow (like shingled roof tiles). Jointing cut edges of FRCC the material can be folded back on itself to form a knuckle joint. Which covers the cut edge and improves the seal between layers? We would recommend fixing the overlap with one of the following methods

2.7 Installation Steps of Fabric Reinforced Concrete Canvas

1. Ground Preparation

FRCC will conform closely to the underlying surface contours of a ditch profile, therefore any vegetation and sharp or protruding rocks should be removed. The ditch should have a uniform profile for ease of future maintenance and where possible a shallow anchor trench should be cut into the shoulders of the ditch.

2. Laying FRCC

The FRCC into the ditch profile ensuring the fibrous top surface faces upwards, with the PVC membrane in contact with the ground. For a transverse layup, tuck the leading edge of the FRCC into the anchor trench before cutting to length.

3. Positioning and Fixing FRCC

When positioning subsequent layers ensure there is at least a 100mm overlap between layers in the direction of water flow. Peg the FRCC in the anchor trench of the ditch, at each overlap joint for transverse layups, or at 2m intervals for longitudinal layups.

4. Hydrating Overlaps

Hydrate the material under the overlapped sections of the canvas. Once hydrated, the material remains workable for 1 to 2 hours. Once positioned, FRCC should be hydrated by spraying with. Spray the fabric surface with water until it feels wet to touch for several minutes after spraying.

Figure 4.12.FRCC hydration

An excess of water should be used as fabric cannot be over hydrated (minimum ratio of water:FRCC is 1:2 by weight). It is important to ensure that overlapped and anchor trenched sections are hydrated.

5. Jointing FRCC

The fastest and easiest method of jointing is using stainless steel screws at 20cm spacing as described above. Insert stainless screws at 200mm centers, 30 – 50mm from the edge of the joint. These can be applied using an auto-fed collated screw driver. The impermeability of the joint can be improved by applying an adhesive sealant between the layers, prior to screwing.

6. Hydrating FRCC

After fixing and jointing, spray the FRCC with water to hydrate. A minimum volume of water equal to 50% of the material weight is required. For example, for 8mm FRCC 6 liters of water per square meter IS required. It is not possible to over hydrate FRCC. To check proper hydration, the CC should feel wet to the touch several minutes after hydration. You should not rely on rainfall to hydrate the material.

7. Junctions, Baffles and Terminals

FRCC is easy to shape before setting and can be manipulated to form ditch junctions and terminals. Baffles can be formed by laying over fabricated structures such as sandbags. FRCC can be joined to existing concrete infrastructure using concrete anchor bolts or poured concrete.

8. Setting

FRCC hardens to 80% strength in 24 hours and is ready for use.

9. Maintenance

RFCC lined ditches require minimal maintenance, provide long term scour protection, reduce silt generation and provide effective weed suppression. In the right conditions FRCC will naturally 'green' over time with moss and blend in with the environment. However fabric will prevent root growing vegetation and weed growth, reducing the maintenance costs associated with unlined ditches.

3. RESULTS AND DISCUSSIONS

3.1 General

In these chapter FRCC compositions and its properties such as tensile strength, bending strength, water impermeability, chemical resistivity, and fire resistivity characters are studied.

3.2 Water Absorption Test

Spray the fabric surface with water until it feels wet to touch for several minutes after spraying. Spaying water on the woven geo-textile surface for several minutes is recommended. A ratio of water per FRCC and a setting time are two important factors that affect the physical properties of the FRCC during installation. The ratio of water per FRCC (w/W_{FRCC}) is defined by the weight of water per the total dry weight of the FRCC. To simulate the installation condition, the water absorption test is firstly carried out to define the w/W_{FRCC} at the saturated condition. The water is sprayed on the FRCC at 0.25, 0.50, 0.75 and 1, respectively. To determine the water per cement ratio (w_a/c) the dried FRCC specimens of 250mm*250mm are firstly prepared and weighted. Then, the water is sprayed on the FRCC and wait for a 5 up to 15 minutes to ensure that all the water is absorbed. It should be noted that since the standard for determining water absorption of FRCC is not available, duration of 5 min chosen also aims to perform this test as fast as possibly to limit the hydration of cement within FRCC. The soaked FRCC are weighted. The cement paste and wet fabrics are weighted. Some cement paste may still remain within the fabrics. After that, all components are oven-dried at 110 ^{0}C for 24 hours and weighted. After oven drying, the cement paste remaining within the fabrics are simply removed.

The ratio of w_a/c is defined by:

$$W_{a/}c = \frac{\text{weight of water absorption by cement}}{\text{Weight cement powder}}$$

Where:

- The weight of water absorption by cement = the weight of soaked FRCC– the weight of wet fabrics – the weight of cement powder
- The weight of cement powder = the weight of dried FRCC – the weight of oven-dried fabrics.

The results from the water absorption test can construct a plot between w_a/c and w/W_{FRCC} as presented in the next Figure. The result shows that when spraying the water more than w/W_{FRCC}= 0.5 the left over will flow out of the specimen. This can be concluded that the saturated water is w/W_{FRCC} = 0.5 which associated with w_a/c = 0.3 Therefore, the testing specimens are prepared according to the saturated condition of water.

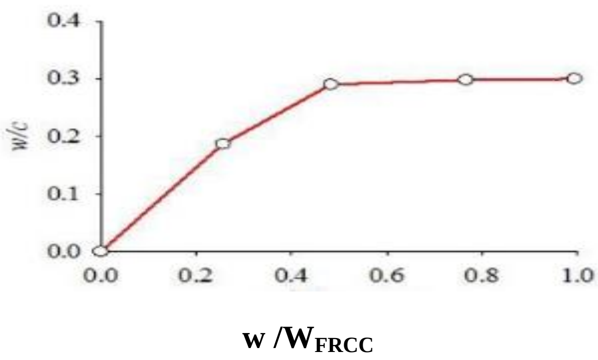


Fig 4.1. Relationship between the water per cement ratio (w_a/c) and the ratio of water per FRCC (w/FRCC) from the water absorption tests

3.3 Physical Properties

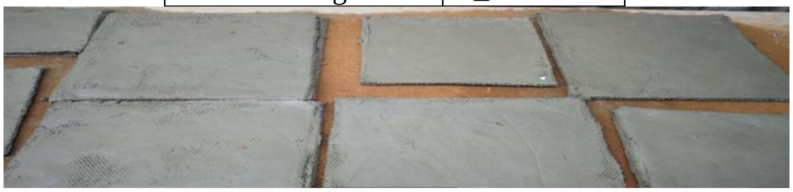
Table.4.1. Frcc thickness

FRCC type	Thickness (mm)	Width (mm)
FRCC5mm	5	1000
FRCC8mm	8	1100
FRCC13mm	13	1100

Fabric reinforced concrete canvas can acquire 70 to 80% of its strength in 24 hours of hydration.

Table.5.2. Setting Time f FRCC

Initial setting time	≥ 120 min
Final setting time	≥ 240 min



3.4 Sand

The sand specimen that is used in the physical test is fine sand taken from a river bank around 20 km north of Addis Ababa, Ethiopia. The particles that are smaller than 0.15 mm are removed. According to the Unified Soil Classification System, the sand is classified as poorly graded sand. The bulk specific gravity is 2.67 and the loose unit weight and compacted unit weight in the tests are 1368 kg/m^3 and 1526 kg/m^3, respectively. The sand is cohesion less and the internal friction angle based on a direct shear test.

3.5 Flexural strength test

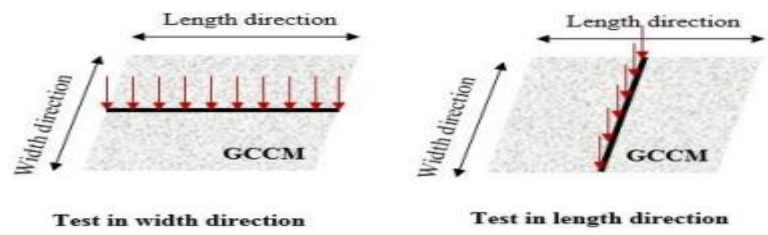
It is the highest stress developed in a material before reaching its yield strength (Moment of yield) of the material in Flexure strength. It is also known as Modulus of Rupture & some also called as Bend Strength or Transverse Rupture Strength. 3-Point method is used to test flexural strength of a specimen. Because the FRCC is expected to resist the bearing load coming from hollow parts on slope surface, drainage flow, vehicles or water flow load during the slope protection and lining of canals which may cause the bending stress. Specimens' size of 250 × 250 mm is tested under three-point bending as shown in. Displacement transducer is used for measuring mid-span deflection. Load with the loading rate of 10 mm/min is applied until the mid-span deflection reached 40 mm. Similar to the tensile strength test, four different curing ages (1, 3, 7, and 28 days) of specimens are prepared for the bending test. Results of bending test are presented in Fig. 5.5 Bending load-deflection curves Fig 5.4 (a) consist of two stages. The first stage presents a composite behavior between fabrics and cement paste. The curves exhibit the linear relationship until the first peak. At the end of the stage, cement paste is cracked resulting in sudden reduction of load. In the second stage, the fabric governs the behavior. Bending load is recovered and tends to increase with the increase in deflection. The bending strength can be calculated by:

$$\sigma_b = \frac{3PL}{2bd^2}$$

Where P is the maximum load, L is the span of the simple support, b is the width of the specimen and d is the thickness of the specimen. It should be noted that the change of specimen's cross-sectional area is assumed to be not significant during the test.

In general, FRCC shows ductile behavior under bending test. The standard errors are in the range of 0.03 – 0.43 MPa. Similar to tensile strength, the bending strength increases with curing time. As shown in Fig 5.3 the warp and weft directions in fabrics are associated with the length and width directions of the 3D spacer fabric, respectively. The bending test results also exhibit significant differences between the length and width directions. In general, the bending strengths along the width direction are 1.5 – 2 times higher than the bending strengths along the length direction.

(a) Test setup



(b) Schematic of bending test in width and length direction

Fig.5.3. Flexural strength test

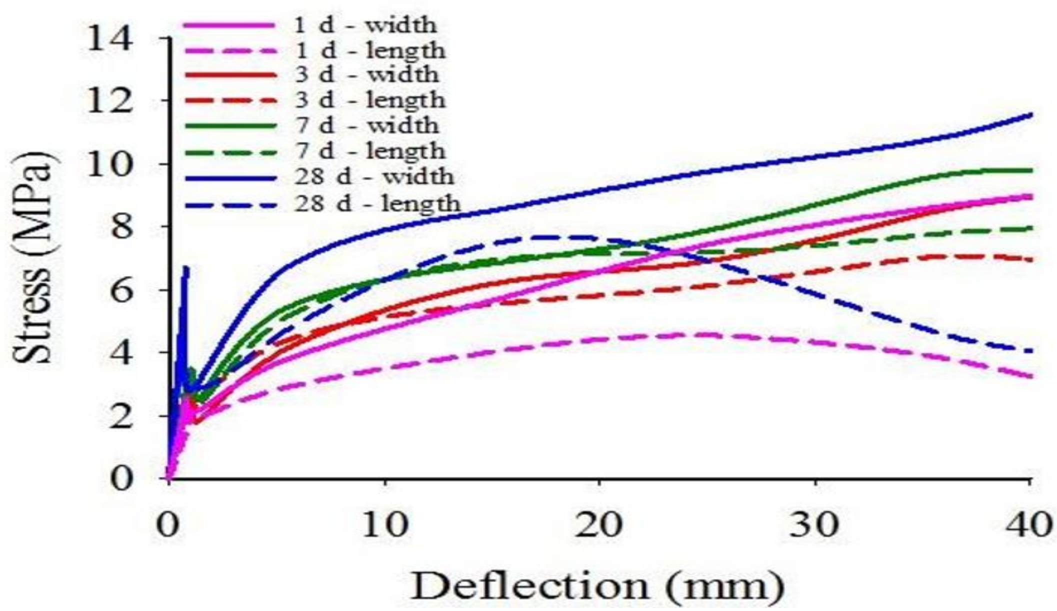


Fig 4.4.Flexural strength test

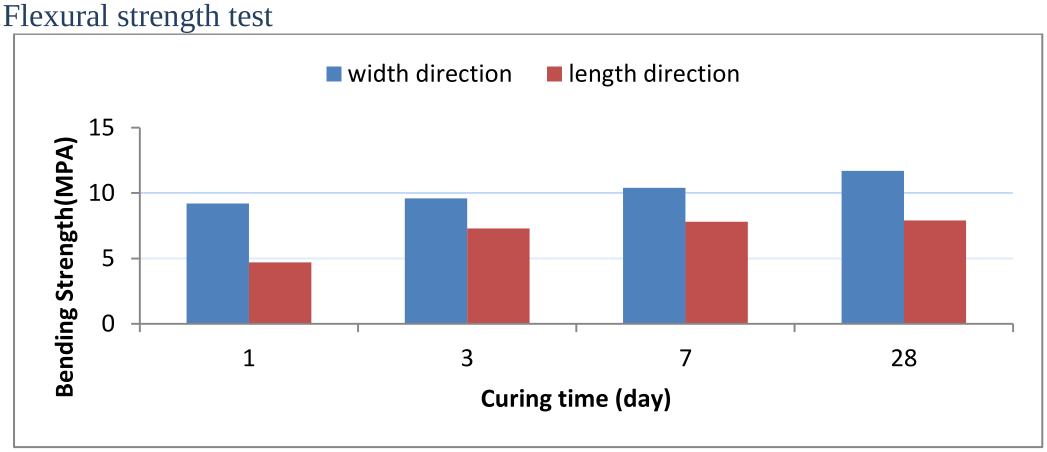


Fig 4.6.(b). Change of bending strength by curing time

3.6 Permeability test

Water Permeability test determines the resistance of specimen or a material against flow of water under hydrostatic pressure. It is a prominent one to evaluate the water passage through material when it is subjected to hydrostatic pressure. In this section the Permeability test is done on the PVC backing layer to know whether the FRCC specimen is impervious to water or not. We haven't used any equipment to measure the property of the fabric reinforced concrete canvas against water movement. The test is conducted by simple observation by pouring a liter of water into the previously mould PVC layer with a measuring jar underneath the mould for about an hour. It is observed that no leakage of water takes place through the PVC backing layer. So by this it could be used as a water resisting sheet where losses are less.Fabric reinforced concrete canvas has excellent waterproof properties and offers a level of impermeability similar to clay. The result exhibits that the FRCC is almost impermeable.

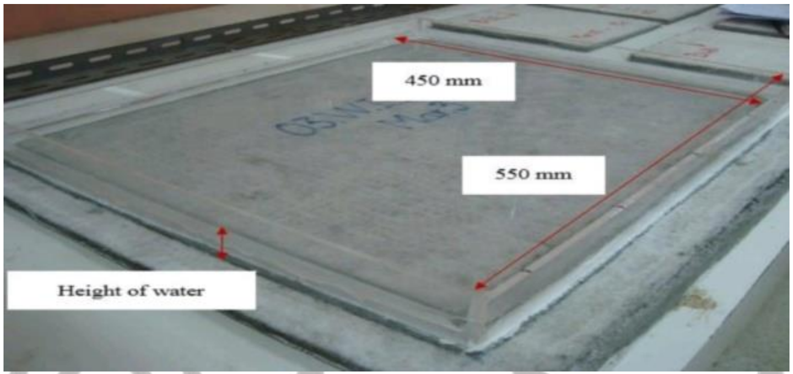


Fig 4.7. Permeability test

3.7 Fire Resisting Test

A fire-resistance rating typically means the duration for which a passive fire protection system or a material can withstand a standard fire resistance test. It is a simple test, to show how much time does a substance or a material or any specimen can withstand fire i.e., basically melting point of the material due to the transfer of heat produced by the burn out of external activity. The test is conducted on both the sides of the FRCC. On top side, it is noticed that the hydrophilic layer is resisting the fire which is applied externally, shows no tear or burn out of layer takes place and distribution of heat is limited to less area. The test conducted for about an hour. On bottom side, It is observed that the PVC backing failed by melting off. The air mesh is used as a core element in FRCC but when tested separately catches fire as they are made of polymers i.e., plastics. But when fabric reinforced concrete is tested the flame does not have impact on the 3D spacer fabric.

Fig 4.9. Fire resistivity test

3.8 Chemical resistivity

FRCC has excellent resistance to chemical attack and is generally much more resistant to aggressive compounds than conventional OPC based concretes. FRCC has been successfully tested by 30 day immersion in acid down to pH 4.0 and alkaline up to 12.5 with no loss of strength. FRCC also has excellent resistance to sulphated water, ground and salted water, and has good resistance to many compounds that attack OPC including; sewage water, chlorides, tanning oils, vegetable oils and most mineral salts. Resistance to sulphate attack is evaluated by the loss of strength. During sulfate attack testing, flexural and tensile strengths of specimens were measured after different dry-wet cycles. After 25 dry-wet cycles were performed FRCC shows that almost no strength loss and the same physical properties.

Fig4.10.FRCC Chemical Soaking

3.9 Tensile strength

The sewing process during manufacturing 3D spacer fabric might lead to a difference of tensile strength of FRCC along weft (width) direction and wrap (length) direction, so the direct tensile tests are performed for both length and width directions. Specimens are subjected to uniaxial tensile load with the loading rate of 10 mm/min. Four different curing ages (1, 3, 7 and 28 days) of specimens are prepared for the test. Stress-strain curves of specimens with different curing ages are plotted in. The curves exhibit linear relationship at the beginning and then the curves lightly become non-linear before reaching the first peak stress. After this stage, the load drops because the matrix cracked. Beyond this point, spacer fabrics take an important role to resist the load until the second peak which is the highest tensile stress. The results show that the differences of stress-strain characteristic between length and width directions are observed. In

GSJ: Volume 7, Issue 11, November 2019
ISSN 2320-9186

length direction, the fabrics slips from cement paste after the peak load. This made the reduction of stress in the stress-strain curve after the peak. On the other hand, the peak occurs at higher strain for width direction.

Fig 4.11. Tensile strength test

Tensile strength and Young's modulus averaged from five replicates for each curing age are presented in Figure below respectively. Tensile strength is calculated from the highest tensile load divided by the cross-sectional area of FRCC while Young's modulus is computed from the initial slope of stress-strain curves where the linear behavior is observed. The results show that tensile strength and Young's modulus increase with the increase in curing time. This is because the strength of cement paste developed with time. In addition, the FRCC in width direction provides approximately 48% higher tensile strength and 65% higher modulus than length direction. Since the mechanical properties of woven 3D spacer fabrics are not much different between the weft and warp directions, tensile strengths are 0.73MPa and 0.68MPa in the weft and warp directions, the difference in tensile strength of FRCC might be from the effect of the sewing process. After 7 days of curing, the tensile strengths of FRCC are 2.70 MPa and 2.02 MPa for the width and length directions, respectively. Young's modulus of width direction at 7 days is 352.4 MPa while the modulus of length direction is 240.8 MPa.

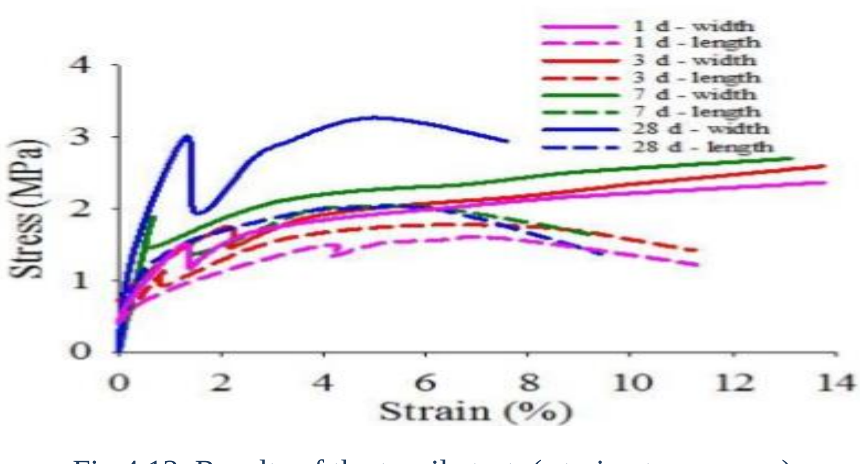
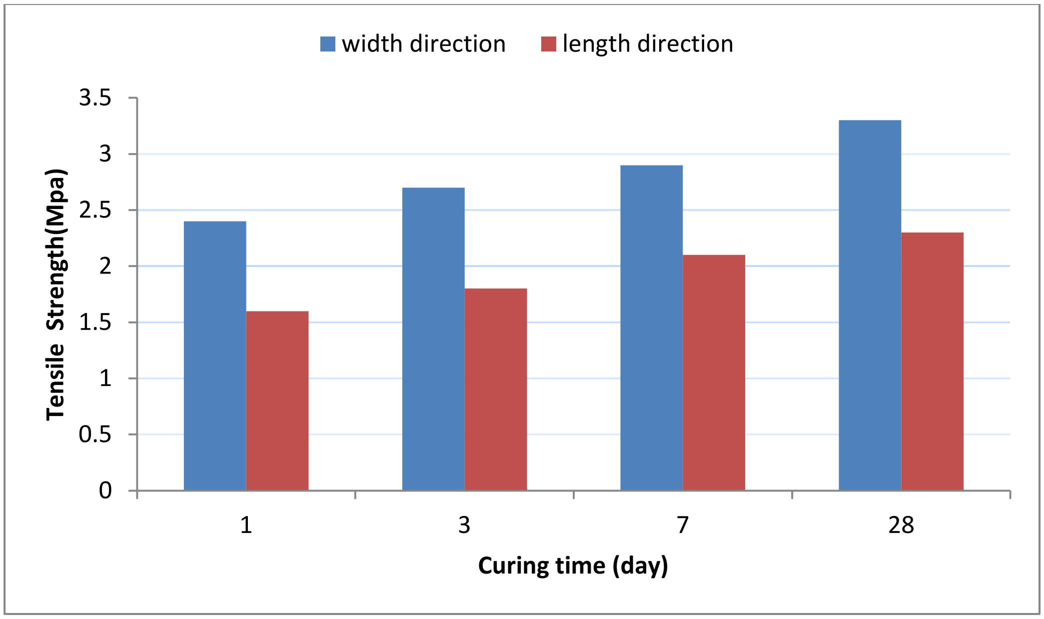
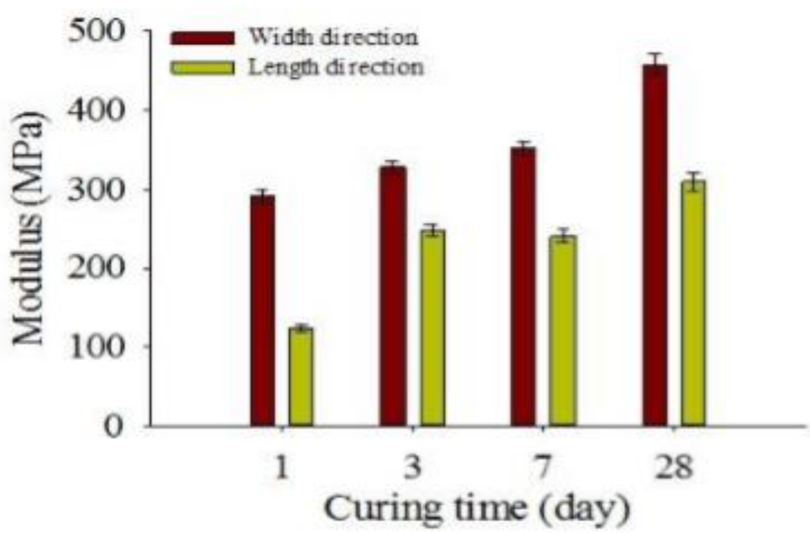


Fig 4.12. Results of the tensile test (strain-stress curve)



(b).Tensile strength



(c). Change of modulus by curing ages

3.10 Discussion

The flexural strength of fabric reinforced concrete canvas increased due to its increase with curing time. There is a suitable strong bond between the filler materials and the fabrics.

The maximum flexural strength of fabric reinforced concrete canvas is obtained from the (cement and sand) mix is about 11.85 N/mm^2 which has a greatest tensile load carrying capacity of about 143 N.

The minimum flexural strength of fabric reinforced concrete canvas is obtained from the (cement and sand) mix of about 9.84 N/mm^2 which has a least tensile load carrying capacity of about 104 N. The hydrophilic layer that is attached on the top acts a fire resistant. So that it helps the fabric reinforced concrete canvas internal arrangement is disturbed but there is a uniform distribution and transfer of heat through the cross section is greatly achieved.

A fabric reinforced composite material of concrete is flexible before adding water and rigid after adding water.

The results obtained from the numerical simulation confirm that the stiffness of FRCC and the interface friction play an important role in reinforcing the slope and good passage for irrigation and drainage water in channels.

After 28 days of curing, the tensile strengths of FRCC are 3.4MPa and 2.3MPa for the width and length directions, respectively. Young’s modulus of width direction at 28 days is 460MPa while the modulus of length direction is 320.8 MPa.

4. CONCLUSIONS AND RECOMMENDATIONS

The general objective of this study is the mechanical properties of 3D spacer fabric reinforced concrete canvas and its application area. The results of the replacement fabrics were compared with the conventional reinforcement method and the following conclusions are drawn and recommendations are forwarded.

- ✓ Experiment has done on the flexural and tensile strength of fabric reinforced Concrete Canvas. The results indicate that 3D spacer fabric sheet reinforced Concrete Canvas panel shows the substantial enhancement in respect of mechanical performance. The flexural strength of Concrete Canvas panels combined with 3D spacer fabric is 11.85Mpa which is about 5 times greater than that of pre cast Concrete considered alone (2.4 MPa).
- ✓ The study shows that FRCC is a good material for use at temporary as well as permanent purposes Specially in canal Lining, slope protection and slope stabilization, Water proofing, emergency shelters, and Construction of water reservoirs, and from cost effective point of view fabric reinforced Concrete Canvas is a competitive alternate product. Initially, Concrete Canvas is a modern construction material and has tremendous advantages and usages in concrete construction. Fabric reinforced Concrete Canvas is a revolutionary material in the field of concrete which modifies the approach towards the construction, construction materials and methods of construction. Manpower, the requirement of skills and mechanical tools during the installation and application of FRCC are significantly less.
- ✓ After automobile and Coal using power plants, Concrete is third most largest contributor for the Carbon dioxide emission. the possible reduction of concrete cover thickness and replacement of steel, fabric reinforcement proved to bring benefits whereby the cumulative energy demand and environmental impact could be reduced
- ✓ In order to reduce the seepage and leakage of irrigation water lining the canals with FRCC material is helpful. Lining the canals with the fabric minimize water loss due to silt accumulation and vegetation through the canal. FRCC can be rapidly unrolled to form a ditch or channel lining. It is significantly quicker, easier and less expensive to install than conventional concrete ditch lining and requires no specialist plant or equipment. FRCC can be laid at a rate of 200sqm/hr by a 3 man team.
- ✓ From the study, it was observed that fabric reinforced concrete canvas material performs satisfactorily role in reducing the usage of cement in the construction of canal lining which means also environmentally sound by minimizing the energy needed to manufacture the cement.

Recommendations are summarized as follows:

- Road contractors, real-estate developers, concrete pipe and precast tile manufacturer are recommended to use FRCC for the construction of water drainage works and earth retaining structures.
- The flexible fabric reinforced concrete canvas material is found to be economical, a few manpower and short installation time required for irrigation canals constructions.
- It is recommended that using a 3-D fabric reinforced concrete canvas material performs satisfactorily role in reducing the usage of cement and steel reinforcement.
- Government has to focus on such material that has a greater reduction role in installation cost and time and having a greater applicability for Addis Ababa river rehabilitation project.

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