IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 94-102

Application of Concrete Canvas In Civil Engineering- A Review

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Abstract – *Construction of any structure, concrete plays a vital role, so concrete as a construction material is being identified universally but to improve its flexibility has always attracted the attention of researchers. This paper focus on the uses of concrete canvas or concrete cloth in the construction sector. It is well known as ceramic material, and it has lots of uses in water proofing material and fire resistance, slope protection construction, mining,*

Keywords- *Concrete canvas, Concrete cloth, Flexibility, Fire resistance, structure*

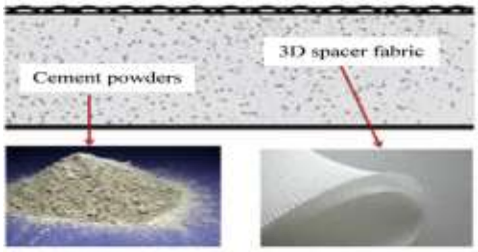
I. Introduction

Fabric Reinforced Concrete (FRC) has numerous benefits such as high tensile strength, excellent ductility, light-weight, thinner thickness and resistance to corrosion. Consequently, 3D spacer fabric has extensive application in Civil Engineering. Concrete Canvas (invented by Brewin and Crawford in 2005 in UK) is one of the most promising products [1]. Concrete Canvas (CC) is a unique registered material because of which its fire and water proof. CC is a flexible cement impregnated fabric that hardens on hydration to form a thin, durable Water proof and fire proof concrete layer. CC has a number of applications in the civil and construction sectors. Other applications for CC include Roofing, Asbestos Containment, Water Tanks, Flood Defenses, Shot Crete Replacement, Tunnel Lining, Retaining Walls, culvert, weed inhabiting, basement lining, Erosion Control, Building Cladding, and Etcetera [2].

Cracking in cementitious composites considerably influences service life of CC. In addition to the action of external load, the main reason for initial crack formation in the cementitious composites structures is partially attributed to its drying shrinkage [3, 4]. It is also known that fibers in cementitious composites provide significant restraint on their drying shrinkage, which has been widely studied by various researchers [5-7]. In fact, the restraint provided by fibers is mainly realized by bonding strength through the contact interface between fibers and matrix [8,9]. Once cement matrix undergoes shrinkage, fibers are subjected to compressive stress whereas cement matrix is subjected to tensile stress due to the shear stress produced on their contact interface. In the case of CC, both spacer yarns and outer textile substrates of the 3D spacer fabric can provide restraint on its drying shrinkage, and the influence of 3D spacer fabric should be investigated.

This papers aims to provide a review about the study done by researchers all around the globe on the behaviour of fabric with cement including its effects on abrasion-resistance, tensile strength, anisotropy of mechanical performances and drying shrinkage.

(a) 3D spacer fabric product



(b) internal structure

(c) final product

Fig. 1. A typical 3D spacer fabric and compositions of concrete canvas [1]

II. A brief history of Concrete Canvas

The story behind its initiation is somewhat unusual. Few years ago, we entered a competition run by the British Cement Association. At the time, we had no idea that our entry for a rapidly deployable emergency shelter would result in the launch of our own technology development company. Our research has now included trips to disaster zones around the world, including Uganda and New Orleans.

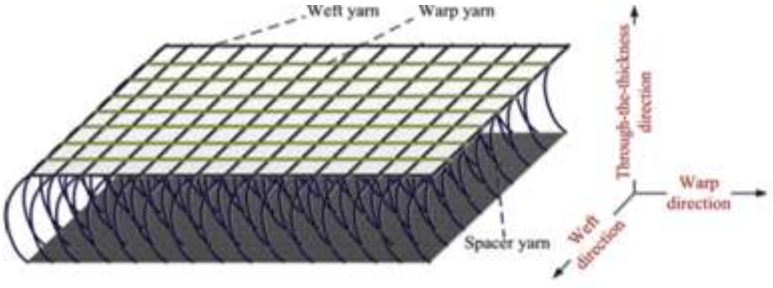
Some years later, the concept has matured into a technology that has applications far beyond emergency shelter. Following development funded through a combination of private equity investment and grants, the company relocated to a dedicated production site in South Wales, UK, where we have begun volume production of Concrete Cloth and Concrete Canvas Shelters. The British Army quickly saw potential uses for this new material and started trials using Concrete Cloth as a method of reinforcing sandbag defenses. This solution, shown in Fig 1, reduces degradation of sandbag walls in harsh environments such as Afghanistan, where the combination of wind, sand, and extreme temperatures mean frequent repairs to frontline defenses. In addition, damage is caused by incoming fire and outgoing muzzle flash. Concrete Cloth is completely fireproof and has performed very well during range trials where it was tested with small-and transported medium-caliber weapons. The material comes in 10 m (33 ft) rolls to eliminate the need for heavy lifting equipment and plant machinery. This is a big advantage when operating in remote areas where most supplies have to be by helicopter. The material is then simply unrolled over the sandbag wall, secured using battens, and sprayed with water. A durable and hard wearing surface is produced within 24 hours. Key to the success of the material is the fibers that form a reinforcing matrix within the Concrete Cloth. These provide a stable failure mode, absorb energy, and help maintain the structural integrity of the concrete when impacted. A ballistic projectile will pass through the cloth, but crack propagation is limited. The sand in the sandbag is therefore retained within the concrete shell. In contrast, standard sandbag cloth will typically tear, and the fill is lost very quickly [2].

Fig. 2. CC used to sandbag protection in defenses [2]

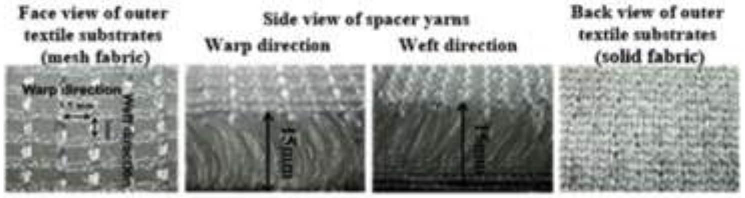
III. Raw materials

A. 3D spacer fabric

The 3D spacer fabric plays an main role of offering a space for the cement powder filling and enhances the tensile strength of the composite. Normally, the thickness of 3D spacer fabric is about 8-20 mm, and the maximum thickness dependent on the type of the woving machines can reach 60 mm [10]. The fabric is produced on a double needle bar Rachel warp knitting machine GE2298 from Wuyang Textile Machinery Co. Ltd. The detail characteristics of fabric are illustrated in Fig. 3. It can be seen from Fig. 3 that the surface layer of 3D spacer fabric consists of two types of fabrics: one is Mesh Fabric (MF), the other is Solid Fabric (SF); in between is spacer yarns, all the fibers used to weave the MF, SF and spacer yarns are made of Polyethylene Terephthalate (PET) filaments. As shown in Fig. 3, since the fabric density of SF is much higher than that of MF, the dry cement powder can easily pour into the 3D space fabric from the gap of the MF, and fill the space between the spacer yarns via vibration. The SF can prevent the cement powder from leaking through the bottom layers of the 3D space fabric. Once the mesh fabric is coated with PVC membrane, the cement powder is sealed inside the 3D spacer fabric without leakage. Obviously, the mechanical performance of the 3D spacer fabric depends on its structure. The fabric used in this study is warp knitted fabric, and there are three characteristic directions: warp, weft, and through-the-thickness directions. The warp yarns in the warp direction are inserted into the stitches and assembled together with the weft yarns in the weft direction, and then a grid net is produced and the meshes in the net are knitted in rectangle shapes. Additionally, oriented spacer yarns are inserted into the structure to the amount of 70/cm2. All warp/weft yarns between the two layers of 3D spacer fabrics are in twisted form. The yarns between the layers can enhance the adhesive strength between the fabric and the cement powders [2].



(a) global view



(b) local view

Fig. 3. Geometrical structure of 3D spacer fabric designed for CC application [3]

The N15 3D spacer fabric with thickness of 15 mm is produced on a double-needle-bar Raschel knitting machine with six guide bars (see in Fig. 4). The machine consists of two single needle bed fabrics from the front and rear sides and a yarn system, building loops on both side. The Front Guide Bars (GB 1 and 2) knit a base fabric on the front needle bar only, while the rear bars (GB 5 and 6) knit the other separate base fabric on the back needle bar. The middle bars (GB 3 and 4) carry the spacer yarns and knit on both needle bars in succession. The lapping code and threading. Polyethylene terephthalate (PET) is used for the fabrics, with spacer yarns being monofilament with the diameter of 0.18 mm, the solid surface yarns being 300D/288F DTY PET multifilament, and mesh surface yarns being 300D/96F FDY PET multifilament. The distance between the needle beds is kept constant at 15 mm [11].

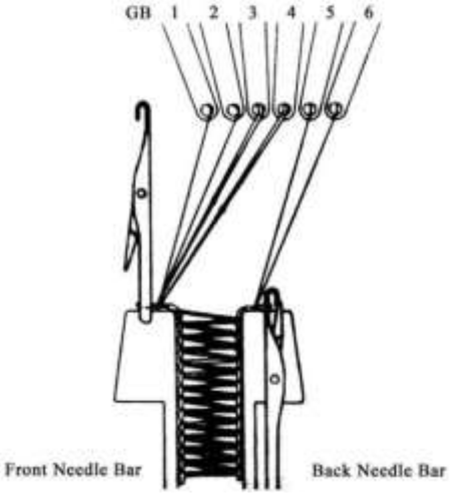


Fig. 4. Model of double-needle-bar Raschel knitting [12]

B. Cement Powders

The CC made in UK presents a good mechanical performance. Unfortunately, this product is not available yet in the market of China. In addition, calcium aluminate cement (CAC) is used in the UK-based CC product. It is well known as shown in Fig. 5 that the final strength of hardened sample decreases due to the transformation of hydration product with low density into high-density product [1]. To reduce the potential risk of long-term strength decrease, Han et al. (2014) developed gypsum modified calcium sulfophate aluminate cement (CSA) powders for the CC system. He studied the influence of geometrical pattern of fabric, mixture proportion on mechanical performance [13] as well as on drying shrinkage of the CC samples and Zhang et al. [14] comprehensively investigated the influence of types of fiber sheet on the mechanical behavior of fiber reinforced plastic (FRP) reinforced CC panels. Therefore, the optimized raw material and mixture proportion of cement powder is used in this study. The raw materials include anhydrite and 825 grade CSA cement from Tangshan Polar Bear Building Materials Co., Ltd (China). The CSA cement contains 65.5% ye'elimite and its Blaine specific surface area is 442 m^2/kg.

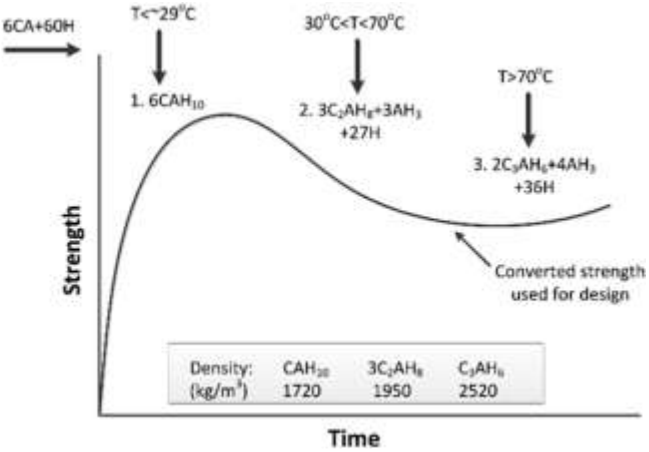


Fig. 5. Densification of hydrates leading to increased porosity and strength reduction [15]

Calcium sulfoaluminate cement (CSA) can be used as binder for CC due to its low porosity, high early strength, high frost resistance, low pH, high corrosion resistance, dimensional stability and good setting properties [16-19]. Furthermore, the production of CSA cement generates lower CO_2 emissions than that of CAC cement because of its lower calcination temperature in the kiln (around 1250–1350 ^{0}C), lower CO_2 release from the raw materials (low calcium carbonate content), and lower electricity consumption for grinding [20]. Typically, satisfactory setting properties, strength development and volume stability of products can be realized by the addition of calcium sulfate in CSA. By increasing the dosage of calcium sulfate, rapid hardening/high strength or more expansive cement can be produced [21]. In addition, the hydration of CSA cement and its properties depend on the reactivity of the applied calcium sulfate, such as the calcium sulfate fineness. If CSA is used as binder of CC, the optimal content and fineness of calcium sulfate would be two key parameters influencing setting times and mechanical properties. The contributions of calcium sulfate to the properties of CSA cement have been widely investigated and well documented under the condition of normal casting [21, 22]. The optimized dosage of calcium sulfate in this traditional system aiming to obtain highest strengths may not be suitable for the CC system where the water is spraying instead of mixing. This is attributed to the fact that the bulk density of dry cement power-filled CC system isaround 1250–1400 kg/m^3, after spraying water, its bulkdensity reached to 1800–1950 kg/m^3, which is lower than the average value of ordinary mortar (around 2200–2400 kg/m^3). So incorporation of extra amount of calcium sulfate may increase the mechanical strength of the CC product without introducing over-expansion cracks, whereas this is not true for the CSA cement with traditional mixing-casting procedure. Moreover, the mechanical properties of CC can be improved by increasing the fineness of calcium sulfate used, because the higher specific surface area of powders may increase the contact area between powder and water, and consequently accelerate chemical reaction progress and improves the early-age strength of CC. Therefore, for CSA-based CC, in order to make denser microstructure, the optimal content and fineness of calcium sulfate has to be investigated carefully.

Fig. 6. Over-expansion cracks induced by extra amount of calcium sulfate in CSA cement with mixing.

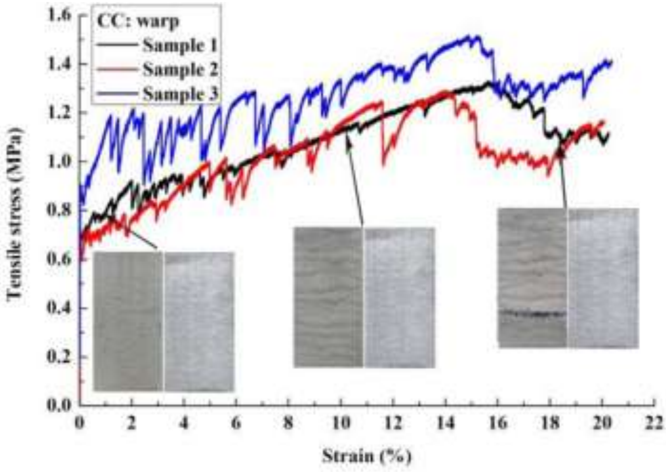
IV. Result & Discussion

A. Abrasion-Resistance

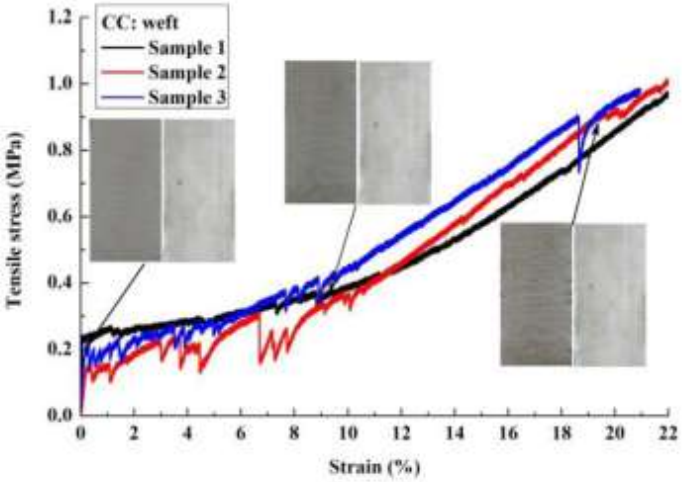
CC has good abrasion-resistance and anti-causticity. Because the matrix of CC is hardened cement paste, its weathering resistance and wearability are similar with conventional cement products. In addition, since the interlock and bridge effect of fabrics and fibre filaments prevent propagation of micro-cracks in cement matrix, CC has good crack-resistance. Therefore, the durability of CC may be better than conventional cement wall face, and the durability of CC retaining wall face need to be further investigated in the future. The results indicate the CC-faced retaining wall may meet the capacity requirements if the wall height is lower than 10 m. The spacing of reinforcement is 0.4 ~ 1 m when the carbon nanotube (CNT) modified ultra-high molecular weight polyethylene (UHMWPE) unidirectional fabric reinforced CC is used. And the connection between CC wall and reinforcement can be safe enough against bearing capacity failure,i.e., the local bearing capacity of the CC meets the design requirements. Finally, it is important to note that due to the limitation of thickness, the CC wall is a more flexible type of wall than the semi-rigid cement concrete-faced wall, and the horizontal displacement of the CC wall is slightly large (about 20mmwith 6m height retaining wall). Therefore, it is better to select high stiffness reinforcement (e.g. steel bar) when CC is applied as the retaining wall of the reinforced soil [1].

B. Tensile Strength

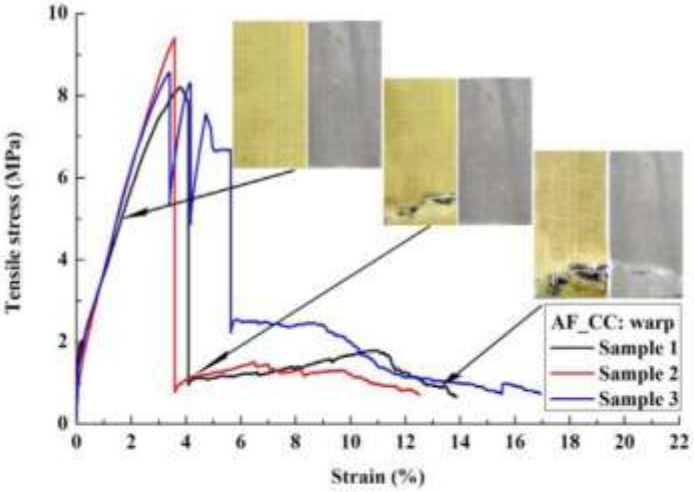
Fig. 6. shows the tensile stress-strain curves of CCs with and without AFRP reinforcement. Compared with the reference plain CC sample, the tensile strength of the AF_CC increases from 0.72 MPa to 8.74 MPa along the warp direction and from 0.17 MPa to 8.76 MPa along the weft direction [11]. The CC samples exhibit typical strain hardening behavior, whereas the tensile behavior of the AF_CC samples shows that tensile stress increases to the peak value under the strain of 4.06% (for warp) and 3.74% (for weft). Beyond the peak stress, the tensile stress shows a sudden decrease, accompanied by localized crack extension. We can also see that the warp CC samples show higher tensile stress at the first crack (0.72 MPa) than that (0.17 MPa) of the weft CC samples. However, beyond the first crack the weft CC shows a more rapid increase of tensile stress. When the strain for the warp and weft CC further increase to 15.1% and 22%, the maximal tensile stresses are 1.36 MPa and 0.99 MPa, respectively. The difference between the warp and weft samples could be caused by the large increase in the reinforcing efficiency factor when the orientation angle of the warp/weft yarns decreases. This is attributed to the larger contribution of warp/weft yarns’ strength with the decrease of orientation angle along the loading direction.


CC: warp
Sample 1
Sample 2
Sample 3
Tensile stress (MPa)
Strain (%)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
0
2
4
6
8
10
12
14
16
18
20
22

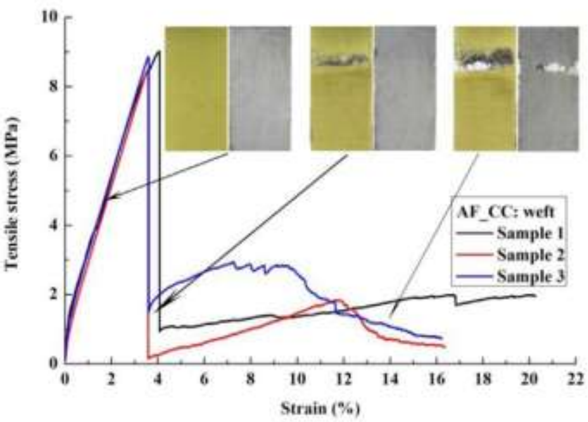
(a)


CC: weft
Sample 1
Sample 2
Sample 3
Tensile stress (MPa)
Strain (%)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
2
4
6
8
10
12
14
16
18
20
22

(b)


AF_CC: warp
Sample 1
Sample 2
Sample 3
Tensile stress (MPa)
Strain (%)
0
2
4
6
8
10
0
2
4
6
8
10
12
14
16
18
20
22

(c)

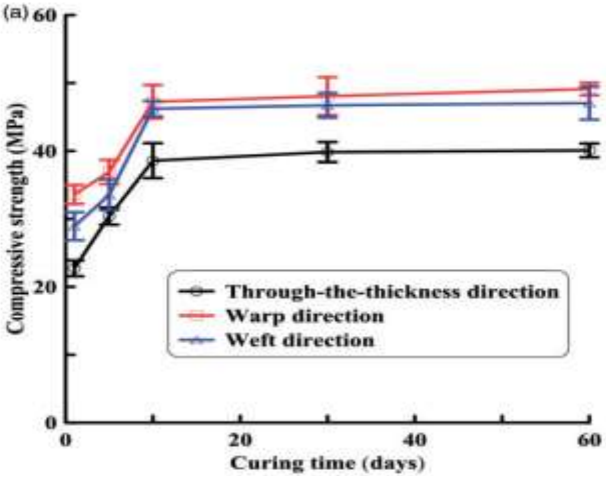


(d)

Fig. 6. Tensile stress-strain curves (a) CC: warp direction (b) weft direction (c)AF_CC: warp direction and (d)AF_CC: weft direction.

C. Anisotropy Of Mechanical Performances

The 3D spacer fabric presents an anisotropic geometric pattern, which clearly leads to anisotropy in the mechanical strengths of CC. Therefore, the anisotropic mechanical strength of CC with curing time is investigated and the results are presented in Figure 18. It can be seen from Figure 7 (a) that the highest compressive strength of CC is along the warp direction, followed by weft, and the through-thethickness directions. As shown in Figure 7(b), the flexural strength of CC in the warp direction is higher than that in the weft direction. After 10 days, the compressive strengths of CC in the warp and weft directions are improved by about 23% and 18%, respectively, compared with that in the through-the-thickness direction. These improvements can be attributed mainly to the confining effect induced by the outer textile substrates of the 3D spacer fabric. The outer textile substrates anchored in the paste of the CC are tightly connected by spacer yarns and can be considered as two additional strengthening layers. Due to the confining effect, a multi-axial stress state occurs in the CC and confinement is realized, improving the compressive strength of the CC. Another factor is the fiber reinforcing effect, which is dependent on the component properties and geometric pattern of the 3D spacer fabric. The effective orientation angle of spacer yarns in the warp direction is less than that in the weft direction due to the layout pattern. This leads to higher compressive and flexural strengths of CC in the warp direction. Therefore, according to the load situation to which CC is subjected, its laying direction should be logically chosen to effectively withstand unfavorable external stress and improve service life [16].



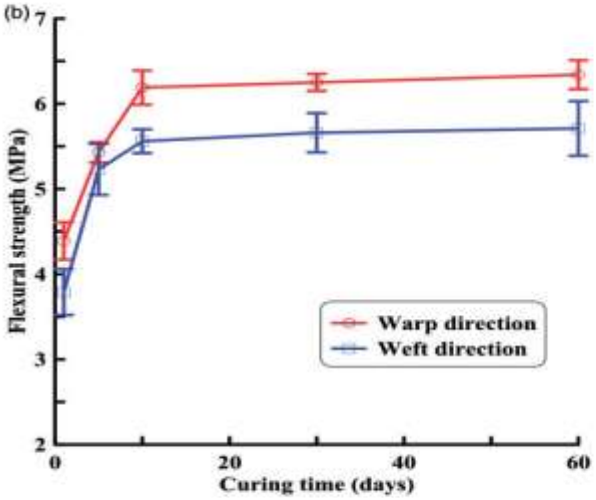


Fig. 7.

Mechanical Strengths Development Of Ccs In Different Loading Directions:

(A) Compressive Strength;

(B) Three-Point Flexural Strength [16]

D. Drying Shrinkage

The drying shrinkage strain versus curing age curves of CC and control samples are shown in Figure 8. In all cases, the drying shrinkage strain increases with curing age and develops fast within 10 curing days. After 30 curing days, the drying shrinkage curves are prone to flatten. Compared to the control samples, the drying shrinkage strain of CC samples becomes lower due to the restraint provided by 3D spacer fabric. In addition, the drying shrinkage of CC samples in warp direction is less than that in weft direction. It revealed that the restraint provided by 3D spacer fabric in warp direction is stronger than that in weft direction, which is consistent with the result of mechanical anisotropy of CC samples [23]. This is attributed to the layout pattern of spacer yarn, the orientation angle of spacer yarn in the warp direction is lower than that in the weft direction after transforming. Consequently, a greater restraint was obtained with a lower orientation angle of spacer yarn.

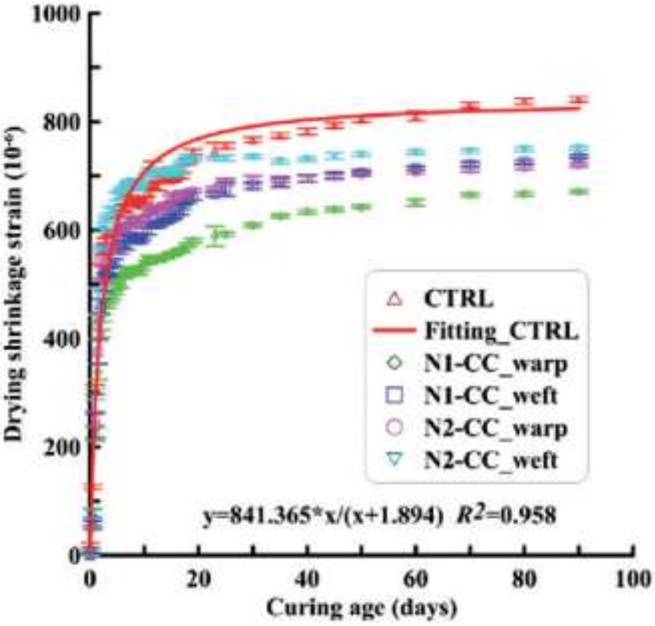


Fig. 8. Experimental results of drying shrinkage of CCs and control samples [23]

V. Conclusion

Canvas Concrete has good abrasion-resistance and anti-causticity. Because of the matrix of canvas concrete. Concrete canvas owing to its easy manufacturing process, better flexibility property, a higher a degree of water proofing and easy to customized use can prove a boon for the construction industry. Concrete canvas is made up of ceramic material which expand its utilization in the fire resistance purpose.

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