# Shear Deformation of 3D Glass Woven Fabrics

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## ABSTRACT

**Much less has been done on failure characteristics of 3D (Three Dimensional) woven fabrics. This work is to attempt to this need. Shear behavior is key characteristic and play direct role to the performance of woven fabrics. In this study, three different 3D weave structures have been used to analyze the fabric shear rigidity. Shear analysis has been carried out in both directions using Kawabata evaluating system. Based on the results, a relationship of shear rigidity (G) and shear hysteresis are compared and analyzed in zero and 90$^o$ direction of fabric.**

**Key Words:** **3D Woven Fabrics, Kawabata Shear Test Method, Shear Rigidity.**

## 1. INTRODUCTION

The textile fabrics particularly 3D woven fabrics have penetrated into industrial and composites applications due to unique performance. However, the mechanical behavior is not fully understood yet; 3D fabrics are typical porous media (mixture of air and fibers). In industrial application, textile material experiences series of deformation which directly affect on the shear properties of woven fabrics. Various scholars [1-5] discussed a apparatus to measure thev shear properties of fabric. Later, qualitative method has been introduced to analyze the shear properties through model [6-7]. The method explains the hysteresis generated while shear properties were measured through frictional restraints increase in the movement of yarn from interlacing point of the fabric. The previous study confirms that the shear mechanism is directly influencing the draping, pliability, and handle of woven fabrics [1,6,9]. In addition, other properties such as bending and tensile are affected in various direction other than conventional directions -wrap and weft [2,10-11].

The mechanics of shear are highly dependent upon the geometric construction of the fabric. For example tightly woven fabric closes to the jammed condition and will be have elasticity, while loosely woven fabric behavior is more dependent on the frictional resistance between the yarns. It is generally assumed that the hystereses are the outcome of the frictional forces at the cross-over of yarns. In this research, authors analyze the shear performance of a woven fabric by comparing shear rigidity (G) and shear hysteresis with the KESF instrument. The data of different weave structures have been evaluated.

## 2. EXPERIMENT AND METHODOLOGY

### 2.1 3D Woven Fabrics

Three structures of 3D woven fabrics made of glass fibres are used in this study. The three weaves which are used in this study are orthogonal, Layer to layer and hybrid. The specifications of 3D woven fabrics are presented in Table 1.

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## 2.2 Method

Kawabata shear evaluating system has been used to analyze the shear deformation in 3D woven structures. Minimum five samples have been tested in warp as well as weft direction in each structure. The sample size was 20x5 cm.

## 2.3 Shearing

Shear properties are the measure of interaction of yarn friction force that represents the stability of fabric to withstand in plane mechanical distortion. In previous study, Long, et. al. [12] found that shear modulus is depending upon the fibre type and fabric construction. In addition, Collier, et. al. [13] and Kang, et. al. [14] analyzed the mechanical properties for characterization of textile fabrics showing the advantage of Kawabata evaluation system. In this research, the KES-FBI Tensile-Shear Tester has been used for such purpose. The parallel forces have been applied to the fabric up to the level of maximum offset angle. A pretension load is applied to the specimen. Shearing results provides G (shear stiffness), 2HG (hysteresis at θ=0.5°) and 2HG5 (hysteresis θ=5°) as shown in Fig. 1 to analyze the shear beaviour. G value is the shear stiffness or rigidity which defines the yarn movement in soft, pliable to stiff and rigid structures. Lower values of G exhibits the less resistance to the shearing process corresponds with better drape. 2HG is the shear hysteresis describes the measurement of energy loss during shear deformation. This energy loss is mainly caused by the yarn to yarn friction at cross over points.

# 3. RESULTS AND DISCUSSION

## 3.1 Shear Rigidity and Hysteresis

Shear rigidity gives values for the resistance of rotational movement of yarns at the interlacing point whilst the fabric undergo to minute shear deformation. Mahar, et. al. [15-16] analyzed linear relationship between warp and weft directions for the suiting fabric. In this research, shear rigidity is measured in both directions. The results of shear deformation of 3D woven structures are summarized in Tables 2-3.

**TABLE 1. SPECIFICATION OF 3D FABRICS**

| Fabric Structure | Areal Density (g/m²) | No. of Warp (per cm) | No. of Weft (per cm) |
|---|---|---|---|
| Orthogonal | 1846.00 | 16 | 3 |
| Layer to Layer | 2101.20 | 12 | 3 |
| Hybrid | 1841.6 | 15.3 | 8.66 |

Fig. 2 presents the comparison of shear rigidity among 3D woven structures along warp directions respectively. It is noted that the orthogonal weave exhibits higher resistant during shear pulling comparing other weaves. It is probably due to higher contact of the binder yarn which makes this weave more compact and stiff structure.

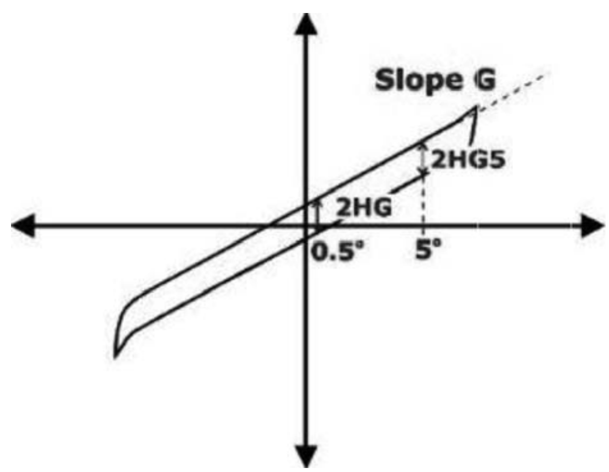


*FIG. 1. KAWABATA SHEAR MEASUREMENT UNITS*

**TABLE 2. SPECIFICATION OF 3D WOVEN FABRICS (WARP WISE)**

| Fabric Structure | G (gf/cm.deg) | 2HG (gf/cm) | 2HG5 (gf/cm) |
|---|---|---|---|
| Orthogonal | 8.33 | 51.2 | 47.9 |
| Layer to Layer | 3.55 | 23.4 | 25.4 |
| Hybrid | 7.75 | 25.4 | 56.9 |

**TABLE 3. SPECIFICATION OF 3D WOVEN FABRICS (WEFT WISE)**

| Fabric Structure | G (gf/cm.deg) | 2HG (gf/cm) | 2HG5 (gf/cm) |
|---|---|---|---|
| Orthogonal | 7.1 | 46.4 | 44.7 |
| Layer to Layer | 7.7 | 60.3 | 56.9 |
| Hybrid | 5.55 | 53 | 54 |

Layer to layer weave shows lowest resistant due to low count (per cm) of binder yarn. The 2HG and 2HG5 values of layer to layer and orthogonal shows almost similar behavior at both stages. However, hybrid weave takes higher energy at initial deformation and highest energy at 2HG5 stage.

Fig. 3 shows the shear rigidity and hystersis of 3D woven structures in weft direction. Layer to layer weave exhibit highest shear rigidity and hystersis in weft direction comparing other weaves mainly due to weave structures. In weft direction, the values between 2HG and 2HG5 presents almost similar behaviour in all structures.

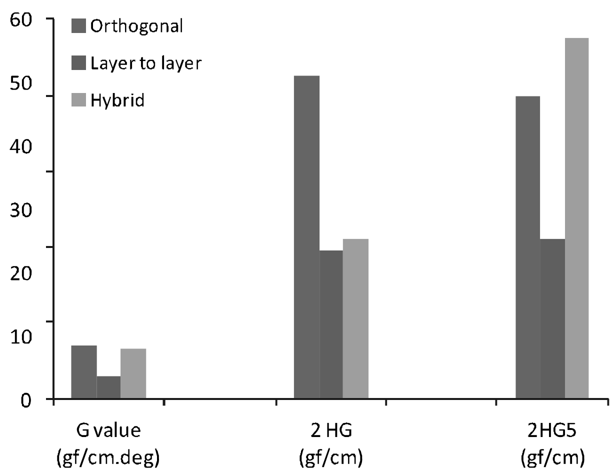


*FIG. 2. SHEAR RIGIDITY AND HYSTERESIS VALUES IN WARP DIRECTION*

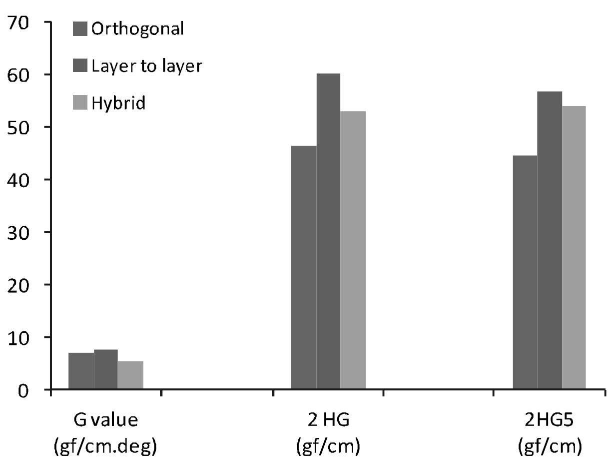


*FIG. 3. SHEAR RIGIDITY AND HYSTERESIS VALUES IN WEFT DIRECTION*

## 3.2 Shear Load and Angle Analysis

Fig. 4 presents the relation of shear load and angle for 3D woven fabrics in warp direction. Orthogonal and hybrid weaves perform similar behavior in warp direction when subjected to shear load. In addition, both weaves receive similar shear angle mainly due to compact and stiff nature of structure. Layer to layer weave carry least amount of shear load among all structures. This is probably due to fewer amount of binder and weft yarns which lead to low interaction between binder and weft yarns.

Fig 5 shows the relation of shear load and angle of 3D woven fabrics in weft direction. Almost all 3D woven structures carry similar shear load and angle except layer to layer which receive shear angle slightly higher as compared with other weaves.

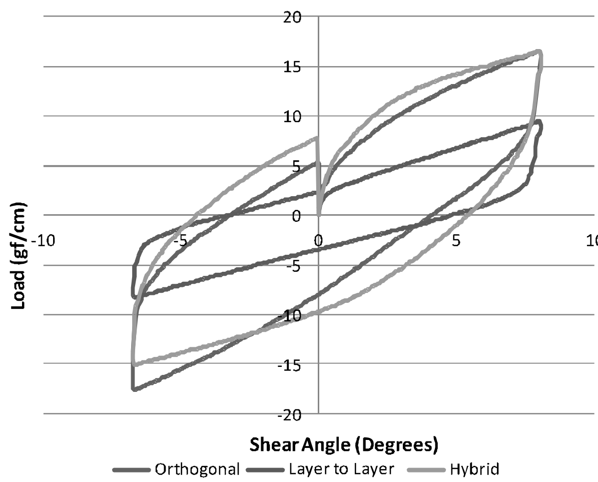


*FIG. 4. STANDARD LOAD AND ANGLE CURVE OF 3D WOVEN STRUCTURES ALONG WARP DIRECTION*

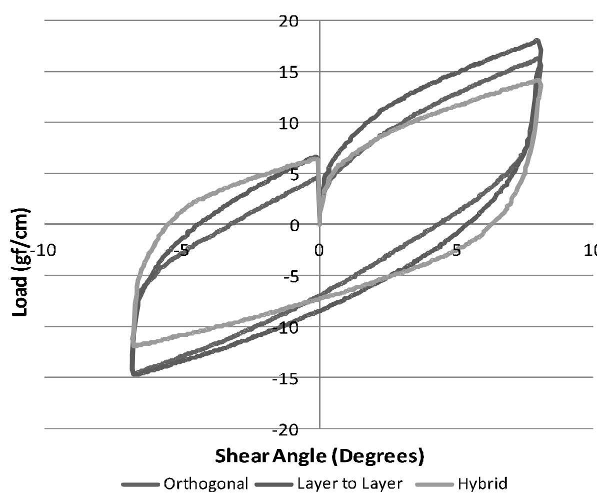


*FIG. 5. STANDARD LOAD AND ANGLE CURVE OF 3D WOVEN STRUCTURES ALONG WEFT DIRECTION*

## 4. CONCLUSIONS

In this research, the effect of 3D glass woven structures on shear deformation has been analyzed. Three different weave structures (orthogonal, layer to layer and hybrid weaves) were used to investigate the shear rigidity and shear hysteresis. Specimens of each weave have been tested in horizontal (weft) and longitudinal (warp) for shear analysis and results are presented.

It is observed that weave structure plays an important role in shear properties. The compactness of woven fabric also affects the rigidity of the fabric. It is observed that in orthogonal and hybrid weaves, number of binder yarn and its length of contact with weft yarns increase the stiffness of the fabric which may only deform with greater shear load and increase the shear angle.

Orthogonal and hybrid weaves presents almost similar shear deformation behavior in warp and weft direction. This is mainly due to stiff nature of structures. Layer to layer weave appeared with highest shear angle and load taking weave in weft direction. However, in warp direction, it receives lowest angle under similar load due to fewer binder and weft yarns in structure as compared with other structure.

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