The effect of shear blocks in OSB double layer gridshells

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Abstract
Bending active gridshells allow shell like forms to be built by bending a grid of initially straight components. Therefore the components used must be as flexible as possible. Increased strength and stiffness may be achieved by using multiple layers, each layer being bent independently. The layers are then locked together to form a single structure of significant depth. This research seeks to establish the degree of composite action after locking between individual layers in two layers gridshells made from Irish Oriented Strand Board (OSB). The short term and long term behavior of both unbent screwed and bolted double layer elements are examined and results are compared with test result from a previously constructed elliptical double layer gridshell.

Keywords:
Gridshells, Orientated Strand Board, Material Testing, Mechanical Testing

1. Introduction
Gridshells are three dimensional curved structures that have sufficient strength and stiffness to cross large spans using very little materials. Like shells, gridshells are efficient in their material use, they support applied loads mostly through “arching action” of their curved form [1]. There are practical and physical limitations on the tightness of curvature to which gridshell members of a particular cross-section can be bent. The depth of member required in a single layer gridshell to achieve relatively large spans may be too deep to permit easy bending without fracture of the initially flat lattices to a final shape with tight radii of curvature. The solution to this problem is to use multiple layers to form the gridshell. A double layer gridshell is, in simple terms two single layer gridshells one placed on top of the other but locked together after forming to curve to create the composite action required to develop greater out-of-plane bending strength and stiffness, even though individually each layer uses smaller section sizes [1]. The layers are initially un-coupled, therefore they deform independently of each other and because of their small section size they can be formed with tight curvatures. A single layer gridshell (Fig 1-a) is one that has a single lath in each direction whereas a double layer gridshell (Fig 1-b) has two laths in each direction. When the double layered gridshell approaches the target shape, the nodes and the shear blocks are locked, enforcing a degree of compatibility of translation and rotation between layers thereby generating composite action between the two layers in respect of any subsequent loading.

Fig 1: Single layer gridshell using timber member

Fig 2: Cs value in different shear blocks connection

2. Methodology
This research seeks to establish the degree of composite action [represented by a coefficient (Cs)] between two 8mm thick OSB layers in a double layer element tested individually [i.e. not as part of a gridshells]. For two single layers (Fig 2(b)) Cs=0 and the expression for the stiffness becomes simply, the sum of the individual layer stiffnesses. For two fully composite layers (Fig 2(d)) Cs=1 and the stiffness becomes the stiffness assuming a continuous linear strain profile. Value of Cs between 0 and 1 give intermediate stiffness and reflect some slip or discontinuity of strain at assembly interfaces (Fig 2(c)). Double layer elements can be modelled by using an equivalent second moment of area which depends on Cs [2]. The increase in stiffness after locking due to the presence of shear blocks and the node connections must be taken into account in any analysis. The double layer elements are tested as
straight elements subject to a four point bending test (Fig 3) loaded in increments to destruction to establish Cs for the test specimen.

Fig 3: Four point bending test

3. Results
The Cs coefficient of the double layer bolted beams and the double layers screwed beams are similar (see Fig 4). When tested in a (four point bending test).

The Cs factor value measured for unbent (i.e not curved) double layer elements is much higher than the effective Cs value for similar double layer elements loaded as part of a fully formed gridshell [4]( see Table1).

![Fig 4: Cs value between Bolted & Screwed Beams](Image)

<table>
<thead>
<tr>
<th>Beams position</th>
<th>Materials</th>
<th>Structure shape</th>
<th>Cs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bent Beams</td>
<td>OSB</td>
<td>DL Gridshell</td>
<td>0.4</td>
</tr>
<tr>
<td>Unbent Beams</td>
<td>OSB</td>
<td>DL Gridshell</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Table 1: Cs value between bent beams & unbent beams

In addition, Cs value of double layer bolted beams and double layer full glued beams were compared. The Double layer bolted beams have a higher Cs value (higher bending stiffness) than the double layer fully glued beams (See Fig 5). This result is contrary to expectation.

Fig 5: Cs value between Bolted & Fully Glued Beams

5. Conclusions
The two central themes to this research were the OSB material properties and the degree of composite action (Cs) between coupled grid layers in gridshells made from Oriented Strand Board. The stiffness properties of bolted and screwed double layer gridshell elements made from 8mm thick OSB were established. Preliminary results have been established for glued elements.

6. Recommendation for Future Research
Current research is examining the time dependent flexural behavior of the material and of double layer assemblies for a range of thicknesses. Future research will examine the flexural behavior of pre-curved assemblies to better understand the influence of the material properties, connection details, connection contact prestress and flexural prestress due to curvature on the composite action between layers.

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References