# Abaqus/CAE Plug-In Utility to Automatically Create Honeycomb Structure Models

Honeycomb structures with hexagonal cell shapes, including a "rectangular" cell shape, can be efficiently modeled with the aid of a dedicated Abaqus/CAE plug-in. Using the plug-in, the honeycomb is explicitly modeled with conventional shell elements.

## Installation

Native CAE plug-ins are included with the Abaqus/CAE installation. External plugins (those installed after installation of Abaqus/CAE) should not be put inside the Abaqus/CAE installation. To install the plug-in, save the attached archive file to one of the following directories:

```
home_dir\abaqus_plugins

current_dir\abaqus_plugins
```

where `home_dir` is your home directory and where `current_dir` is the current directory.

The `plugin_dir` directory can also be used, where `plugin_dir` is a directory specified by the environment variable **`plugin_central_dir`**. This parameter is used to define a specific directory where plugins are stored. This is typically a central location accessed by all users at your site if the directory is mounted on a file system that all users can access. **`plugin_central_dir`** can be defined in the `abaqus_v6.env` file or the Abaqus solver `custom_v6.env` file. For example,

```
plugin_central_dir = '\\\\fileServer\\share\\AbaqusPlugins'
```

On Windows platforms, right click on the archive file and select WinZip → Extract to here. On Linux platforms, type **`unzip Hcore.zip`** at the command prompt. A folder named **`abq_Hcore`** and a file named **`hcore_plugin.py`** will be extracted.

Note that the plug-in will not function properly if the procedure described previously is not followed.

## Plug-in description

The plug-in can be used with any model included in an Abaqus/CAE database. The honeycomb structure is described in the plug-in by its: (a) material; (b) unit cell geometry; and (c) dimensions. Any material that has been created in the model can be accessed from within the plug-in. In addition, a new material can be conveniently created from within the plug-in by calling the material editor.

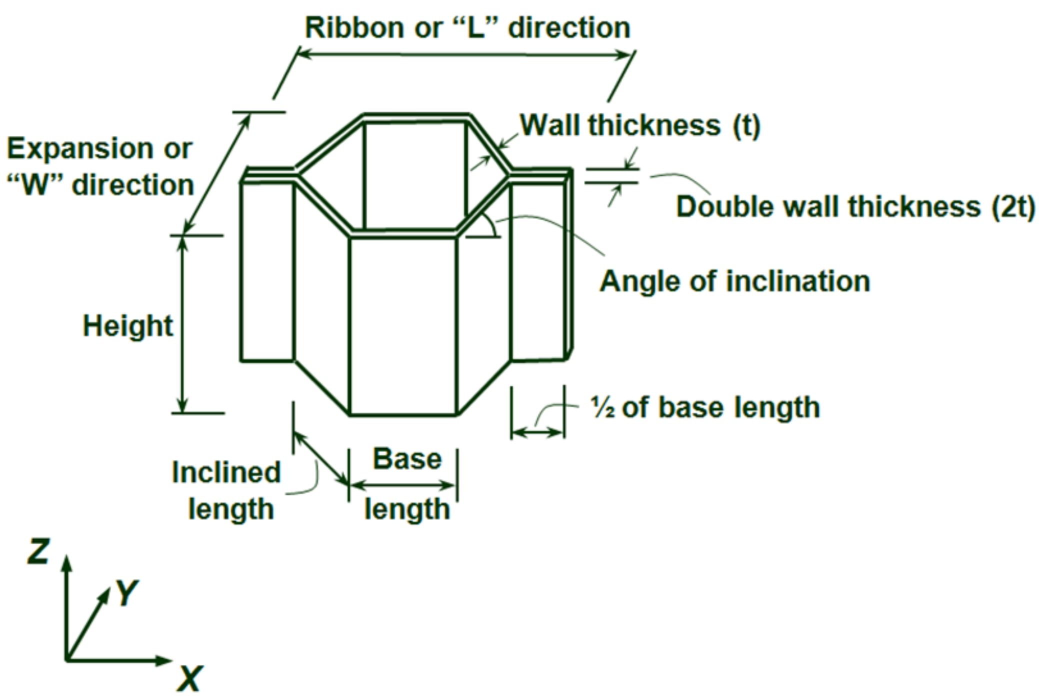


*Figure 1: Unit cell of honeycomb structure*

The honeycomb unit cell geometry is shown in Figure 1. To describe this geometry, the user is required to provide the base wall length, the inclined wall length and its angle of inclination, the height of the honeycomb, and the wall thickness. The honeycomb in-plane dimensions (Figure 2) can be specified either directly or by providing the number of unit cells in the X-direction (ribbon dimension) and Y-direction (expansion dimension).

Based on the parameters described above, the plug-in automatically generates a honeycomb structure using 3D deformable shell features as shown in Figure 2. In addition, if the honeycomb structure is used as the core of a sandwich structure, the user can model an adhesive layer between the honeycomb and the face sheets. The adhesive layer is defined by its material, height, and thickness (Figure 3).

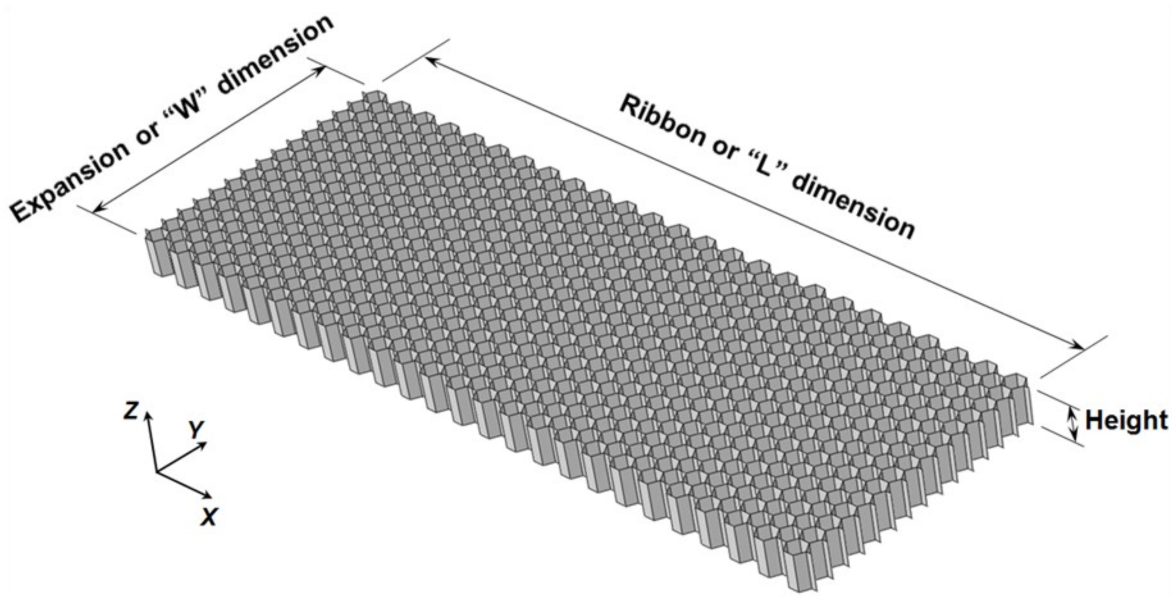


*Figure 2: Honeycomb dimensions*

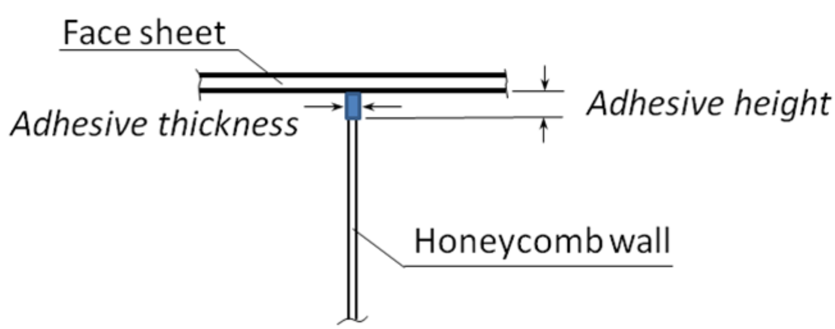


*Figure 3: Adhesive layer parameters*

## Plug-in usage

The plug-in is module-independent and can be launched by selecting **Create Honeycomb** from the **Plug-ins** menu. The **Create Honeycomb** dialog box appears (Figure 4) in which you can enter a model name, a name for the material, create or edit material properties, and enter the parameters describing the honeycomb structure and, optionally, the adhesive layer.

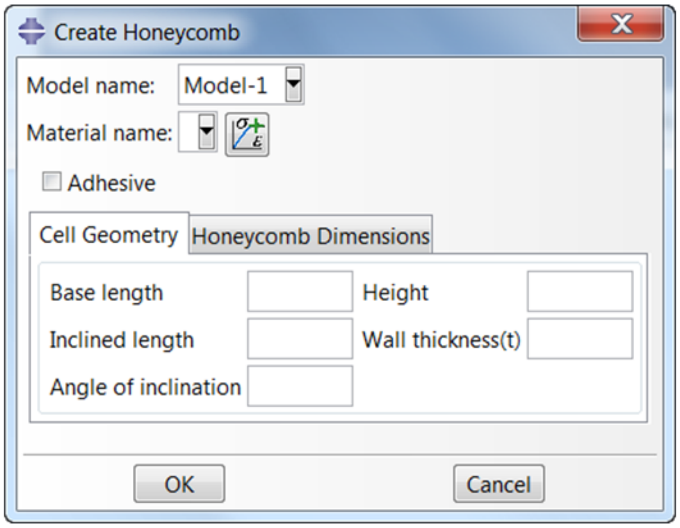


*Figure 4:* **Create Honeycomb** *dialog box*

The parameters describing honeycomb structure are specified using the **Cell Geometry** and **Honeycomb Dimensions** tabbed pages. A complete description of these parameters is given in the previous section. The **Number of Cells** and **In-plane Dimensions** radio buttons, which are located on the **Honeycomb Dimensions** tabbed page, allow you to switch between the two available choices for the definition of the in-plane dimensions as shown in Figure 5.

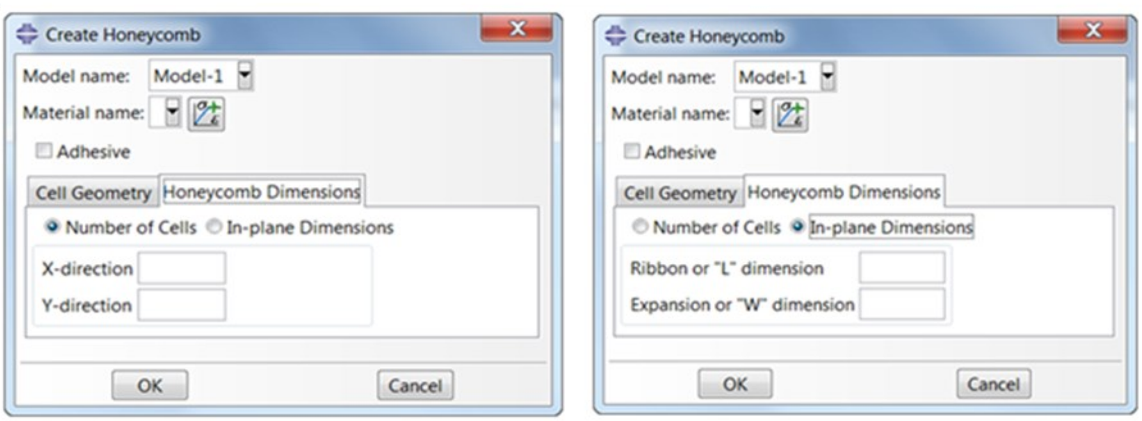


*Figure 5: Prescribing the honeycomb in-plane size: number of cells in the X and Y directions (left) and L and W dimensions (right)*

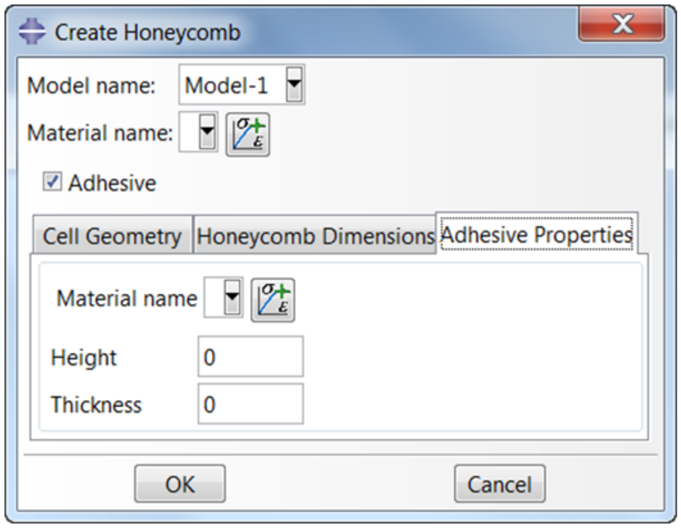


*Figure 6: Prescribing the adhesive layer*

You can toggle on the **Adhesive** check box to access the **Adhesive Properties** tabbed page where the adhesive's parameters described previously can be entered, Figure 6. Clicking **OK** in the **Create Honeycomb** dialog box creates a detailed three-dimensional part **honeycomb1** corresponding to the provided input. The generated honeycomb structure can be used either independently—to determine, for instance, the orthotropic material properties of honeycomb—or as the core of a sandwich structure. In both cases the usual model-building steps should be followed to complete the finite-element model. In the next section, an example is presented where honeycomb is used as the core of a sandwich beam.

## Example

A simply supported sandwich beam with a honeycomb core is subjected to a bending line load at its mid-span. The span of a sandwich beam is 500 mm (ribbon dimension) and its width is 100 mm (expansion dimension). The thickness of each face sheet is 1.5 mm. The height of the core is 12.7 mm, its hexagonal cell size is 6.35 mm, and the cell wall thickness is 0.0381 mm. The face sheets are made of aluminum A5083-H321 with the Young's modulus 71.070 GPa and the Poisson's ratio 0.33; and the core material is aluminum foil A3003-H19 with the Young's modulus 69.0 GPa and the Poisson's ratio 0.33 [1].

Using the magnitude of the cell size and the angle of inclination (60° for the hexagonal cell), the base and inclined length can be readily calculated to be 3. 666174 mm. Now the required data can be filled in the **Cell Geometry** and **Honeycomb Dimensions** tabbed pages of the plug-in, and the honeycomb structure similar to that shown in Figure 2 can be automatically produced. The resulting part **honeycomb1** should be meshed and attached to the face sheets. In this elastic banding example, it is sufficient to use just three shell elements through the core thickness.

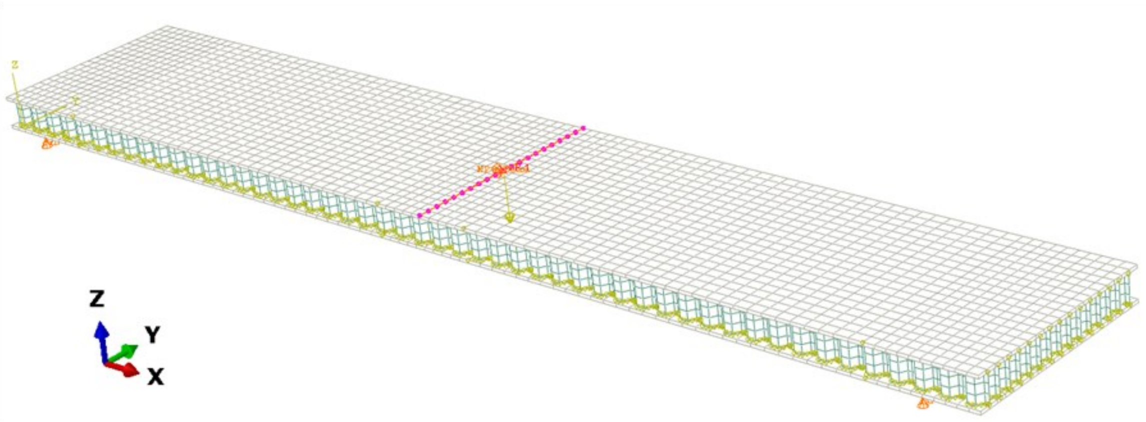


*Figure 7: Abaqus/CAE model of the honeycomb sandwich beam subjected to three point bending*

It is assumed here that the core is rigidly connected to the face sheets, which are modeled with continuum shell elements. To model this rigid connection, tie constraint is used. The element edge-based surfaces created on the top and bottom of the honeycomb play the role of slave contact surfaces, whereas the contacting element faces on the top and bottom face sheets function as master surfaces. The bending load is applied via MPC constraint, with the slave nodes spanning the beam width at the mid-span and the control point restricted in the global *X*- and *Y*-direction. The resulting model is shown in Figure 7. It contains 15,900 linear quadrilateral S4 elements representing the honeycomb core and 3,600 linear hexahedral SC8R elements representing the face sheets.

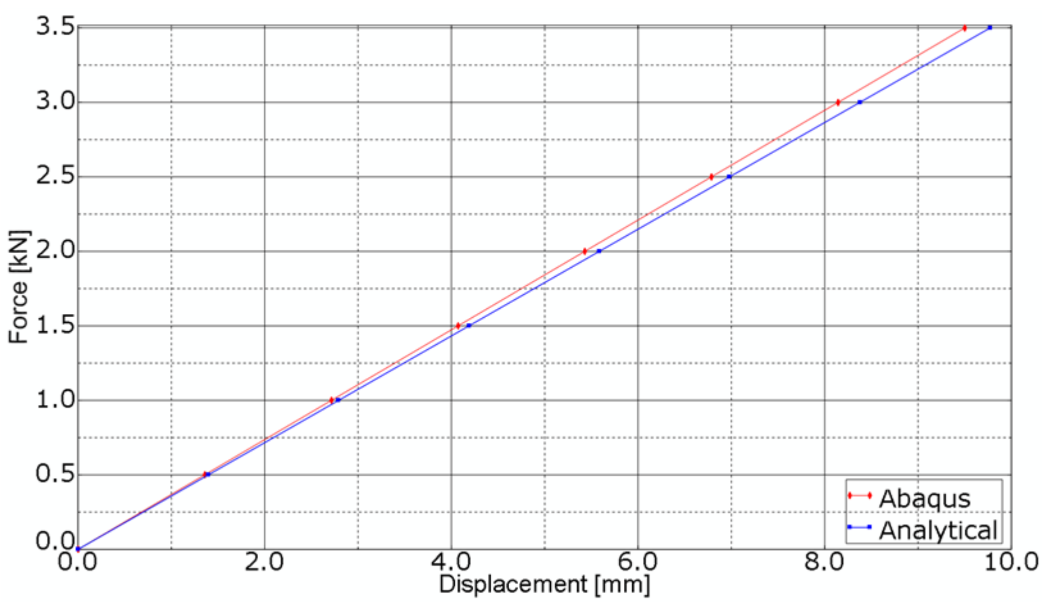


*Figure 8: Comparison between the Abaqus results for the linear mid-span deflection and an approximate analytical solution [2]*

The linear mid-span displacements of the sandwich beam resulting from the Abaqus linear analysis are shown in Figure 8 versus an approximate analytical solution in [2]:

$$w = \frac{1}{48}\frac{Pl^3}{D} + \frac{1}{4}\frac{Pl}{S} \tag{1}$$

where $w$ is the mid-span bending deflection; $P$ is the applied load; $l$ is the span of a sandwich beam; $D$ is the bending stiffness; $S$ is the shear stiffness. The bending stiffness is a product of the Young's modulus and the moment of inertia of the face sheets. The shear stiffness is a product of the core width and height and the elastic shear modulus of the honeycomb core in the ribbon direction (taking into consideration the sandwich layup in Figure 7).

## References


1. Paik, J.K., Thayamballi, A.K., and Kim, G.S., "The strength characteristics of aluminum honeycomb sandwich panels," *Thin-Walled Structures*, **35**, pp. 205–231, 1999.

2. HexWeb™ honeycomb sandwich design technology, Publication No. AGU 075b, Hexcel Co., Ltd., Duxford (UK), 2000.