

# Screencast 002

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## RAM Structural System: Pseudo-Flexible Diaphragms

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Hello, and welcome to the **Bentley Structural Team** screencast. I'm *Jason Coleman*; a Senior Technical Writer with Bentley Systems.

Today, I'm going to demonstrate for you how to use the new Pseudo-Flexible Diaphragms feature in the version 12 release of **RAM Frame**.

First, let's briefly discuss diaphragm types and when to use them. A flexible diaphragm is defined by the 2003 International Building Code as any diaphragm whose maximum deflection is more than twice that of the average drift of the adjoining vertical elements. In practice, a large number of diaphragms are stiff enough to fall below this threshold, including many cold-formed roof decks as well as most concrete floors. However, some diaphragms may be more flexible. For example, the roof deck of a building whose plan has a high aspect ratio or a concrete floor diaphragm with a large number of openings.

A diaphragm is analogous to a deep beam, with the lateral load resisting elements below as its supports. As stated, most diaphragms are sufficiently rigid that the force received by each supporting lateral load resisting elements is proportional to its relative stiffness. However, should a diaphragm be considered flexible, the supporting lateral load resisting elements receive load based on a tributary amount of the structure. This tributary is an exposure area for wind loads or a tributary mass area for seismic loads.

So, why then is it referred to a *pseudo*-flexible diaphragm? That's because when this option is selected, the diaphragm is actually ignored by RAM Frame all together. The story loads are distributed as nodal loads at the vertical elements. The user must then specify what percentage of the total diaphragm load will be applied at each vertical element.

The relative deflections can be approximated by first running a model with all diaphragms in RAM Frame as "Rigid," which remains the default diaphragm type. The drifts at adjoining vertical elements are compared to the maximum diaphragm deflection between them. Diaphragm deflections are usually calculated using tabulated material and stiffness properties in vendor catalogs. If it is found that a diaphragm is indeed flexible, then the pseudo-flexible diaphragm can be used in the analysis.

Let's take a look at an example of how to use a pseudo-flexible diaphragm for the analysis of a building in the RAM Structural System. Here is a fairly long, two story concrete building modeled in RAM Modeler. The building has braced frames in either direction. I've determined that the steel deck roof diaphragm is flexible for loads in the Y direction.

Let's open up RAM Frame to perform the lateral analysis of the structure. We see that the wind, seismic, and notional loads have been previously generated for this particular structure. The diaphragm type is specified under the **Criteria** menu; **Diaphragm....** Now, for the pull-down menu for each diaphragm, pseudo-flexible has been added. We'll select this option for the roof diaphragm and click **OK**. We get a brief warning dialog explaining that the frame load percentages have changed. Click **OK**.

Let's turn off all gravity members to make the next step a bit easier to see.

We now must assign frame numbers to each frame. While this is an optional step for rigid diaphragms, it is required in for using pseudo-flexible diaphragms as we have to assign load distributions manually. I'll assign the Y-direction frames as one through three, and the X-direction frames as four and five. Let's skip on ahead to assign diaphragm properties.

All the frame numbers assigned. Next, under the Loads menu, we'll select **Pseudo-Flexible Diaphragm Properties...** In this dialog, we will set the frame load percentages for each floor, load type, and diaphragm. Note, that any assignments made to diaphragms of type Rigid or None will be ignored when the analysis is run. Effective percentages are distributed equally to each frame in the X or Y direction by default for Wind, Seismic, Notional or User defined loads. This model doesn't any Dynamic loads.

Here, I'll change the load percentages for frames 1 and 3 to 25% and for frame 2 to 50%, as its tributary for all loads is essentially  $\frac{1}{2}$  the building's length. You can see that when the sum of the load percentages is less than 100%, the total is displayed in red. However, we do have the option of having more than 100% of the load applied. Let's change frame 3 to 30%. This is a conservative loading and can be used to create an envelope condition, accommodating code-required torsional effects. When the summation is greater than 100%, the total is displayed in blue. You can specify different percentages for each load type, but I'll simply click **Apply These Percentages to Other Load Types** to copy the changes made on the current table.

There is also an option for applying the loads equally to each node or to distribute them based on nodal stiffness. Since the nodes in my braced frames have similar stiffness, I'll just leave this set to apply the load equally. Click **OK** to save the changes.

Now, we run the analysis for all loads. We get a warning message if the pseudo-diaphragm loads are not equal to 100% for a diaphragm, which we would certainly want to go back and correct if this was less than 100%. We're using a conservative loading, so we'll click **OK** to continue with the analysis.

There are two handy places to review the results for pseudo-flexible diaphragms. First, let's go to the **Process** menu, select **Results**, and then select **Applied Story Forces...** Here, I'll select Wind in the Y direction, turn off **Show Coordinates** and select **Display**. Click **Apply** and we can see the loads applied for this load case. Note that the roof loads are now nodal loads on each frame. The second floor load is a story shear, applied at the center of the building's length. The loads at frames 1 and 3 differ since I increased the percentage to 30% at frame 3. The nodes at frame 2 have twice the load as those at frame 1.

Next, let's take a look at the results in report output. Select the **Reports** menu and then **Loads and Applied Forces**. In this report, pseudo-flexible diaphragm loads show up for each load case, under the Applied Diaphragm Forces. The total diaphragm force still is presented under this table, but a new table appears immediately following with the applied nodal loads. Note that if a set of percentages totally more than 100% was used, the numbers may differ.

Another item to consider is that in a building such as my example, though the roof diaphragm was flexible in the Y direction, it was rigid in the X. Loads in that direction should be proportioned using ratios taken from a rigid diaphragm analysis, which we would have performed in our assessment of the vertical elements' relative drifts.

This has been a screencast for using pseudo-flexible diaphragms in version 12 of the RAM Structural System. If you'd like to get additional information, sign up for training courses, or learn more about our licensing programs, please visit [Bentley.com](http://Bentley.com). Thank you for watching.

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