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Modeling Floor Diaphragms in STAAD.pro 2007

By

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1.0 Introduction:

Based on support calls received by the STAAD.pro Technical Support Group, Engineers are interested in modeling the following types of roof in STAAD.pro.

1. ***Rigid Floor Diaphragm*** which assumes that the floor is very rigid to experience any in-plane and out-of-plane deformation. The rigid diaphragm action of floors assumes that the floor is stiff enough to undergo rigid body movement.

2. ***Semi Rigid diaphragm*** which assumes that the floor is very rigid to experience any in-plane deformation but no out-of-plane deformation.

3. ***Flexible diaphragms*** which assumes that the floor has no rigidity to resist lateral loads.

The rigid floor diaphragm assumption may not be appropriate if a relatively narrow building has closely spaced shear walls (i.e. the shear walls are stiffer than the floor diaphragm). In the case of a low rise building, the floor diaphragms may be flexible compared to the shear walls as in light wood framed construction. For long narrow buildings with deep beams the rigid floor diaphragm assumption has to be evaluated carefully. The presence of a slab opening for elevators or stairs can weaken the floor diaphragm action. Wood and metal decks without concrete fills may not be modeled as rigid diaphragms unless the floor system is braced properly. Hence, the use of these options in STAAD.pro requires good engineering decision making based upon the actual site conditions.

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2.0 Modeling Rigid Diaphragm Action in STAAD.pro

Let us assume that the top floor of the following 3D frame needs to be modeled using the rigid diaphragm action assumption.

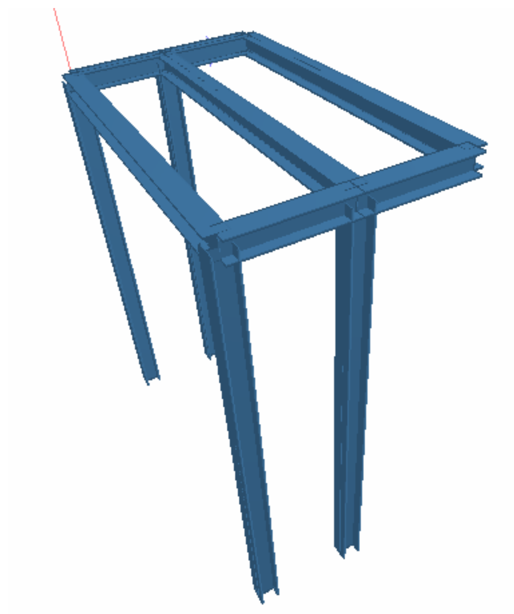

Figure 1: View of 3D steel frame

After the frame model has been created, click on the ***General->Spec*** tab on the control tab on your left hand side. Press the ***Shift+n*** key on your keyboard to see the node numbers of your structure.

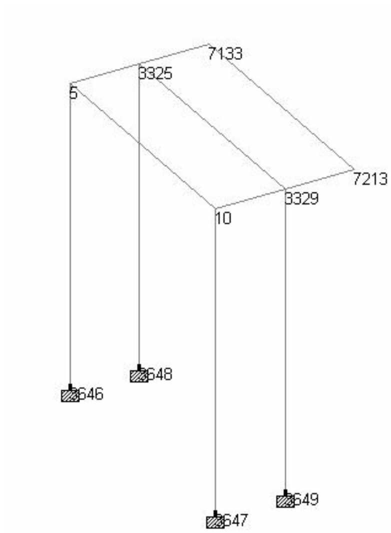

Figure 2: Stick model of the 3D Steel Frame with node numbers

Click on the ***Node*** button in the right hand side data area. The following dialog box will open.

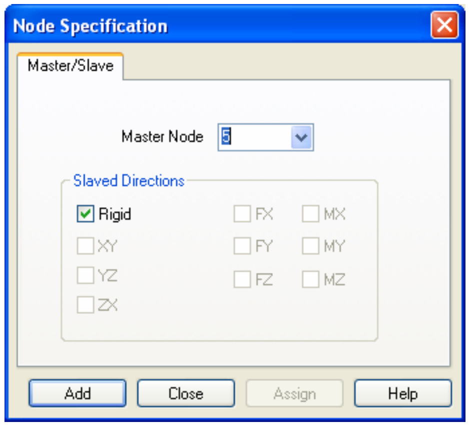

Figure 3: Master/Slave specification dialog box

Select Node 5 as the master node. This specification lets the STAAD.pro user create the master node in the floor diaphragm. The master node could be any node on the rigid floor (i.e. nodes 5, 3325, 3329, 7133, or 7123). Click the ***Add*** button to add the master node specification in the ***Specifications*** dialog box.

This specification has to be assigned to all the nodes on the rigid floor. Select the nodes cursor and select nodes 5, 3325, 3329, 7133, and 7123. Choose the ***Assign to Selected Nodes*** option and press the ***Assign*** button in the ***Specifications*** dialog box in the data area. Select the ***Highlight Selected Geometry*** checkbox and select the **SLAVE RIGID MASTER 5 JOINT** entry in the ***Specifications*** dialog box in the data area. You will notice the master/slave specification shown in the graphical user interface as shown below.

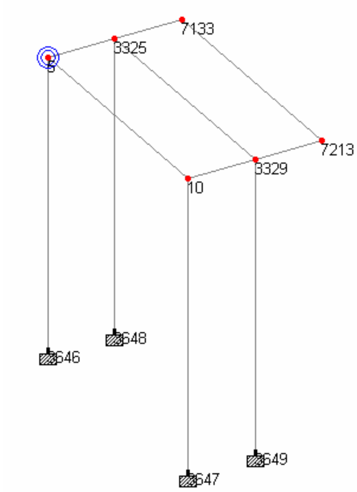

Figure 4: Graphical representation of Master/Slave specification in STAAD.pro

The double blue circles on node#5 indicate that node 5 is the master node and the nodes marked with the red dot are the slave nodes. To see the effects of this assignment, you have to assign a lateral load. You will notice the difference in the STAAD.pro post-processing mode as shown in Figure 5.

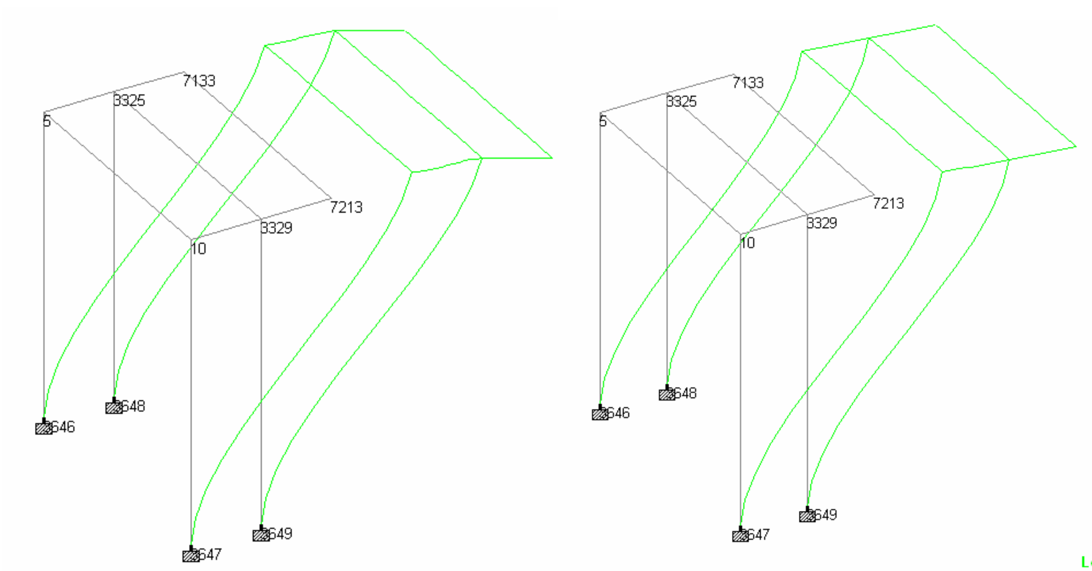

Figure 5: Deflected shape of the structure before using the master/slave specification (Left). Deflected shape of the structure after using the master/slave specification (Right)

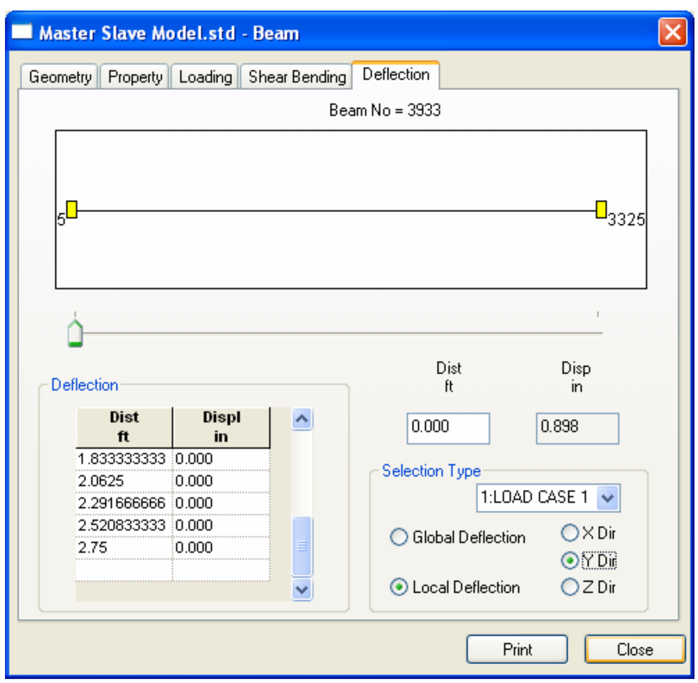

Figure 6: Local deflected shape of beam 3934 that connects node 5 and 10

3.0 Modeling Semi Rigid Diaphragm Action

Some engineers may want to consider their floor diaphragm as rigid in the global XZ plane but flexible about the weak axis of bending of the slab (slab action). In short when lateral loads are applied to the slab system, the slab acts as a rigid body in the global XZ plane but out-of-plane bending will be considered (i.e. the beam elements on the slab will be allowed to bend). This type of slab can be modeled using the XZ option in STAAD.pro. In the ***General->Spec*** tab, select the **SLAVE RIGID MASTER 5 JOINT** option. Click on the ***Edit*** button. The ***Node Specification*** dialog box will appear as shown in Figure 7.

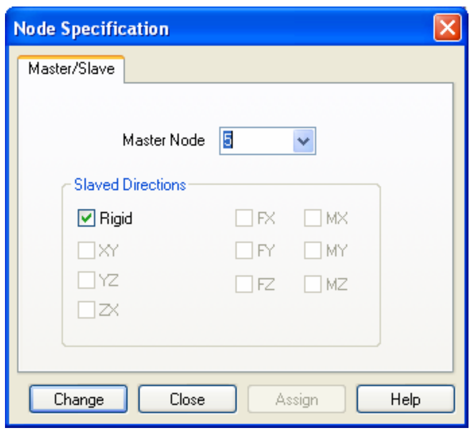

Figure 7: Node Specification Dialog box – Rigid Diaphragm Option

Click on the ***Rigid*** option and select the ***ZX*** direction as the slaved direction. Click on the change button.

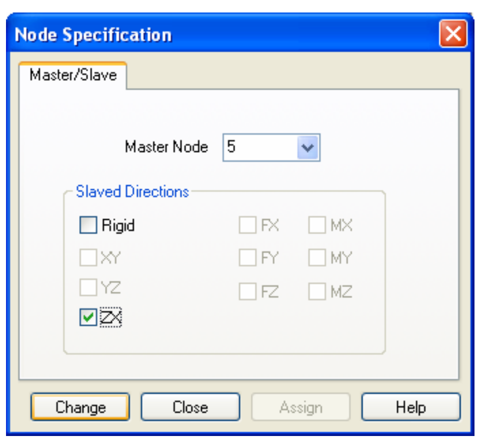

Figure 8: Node Specification Dialog box – Use of the ZX option

Figure 9 shows the effects of using the XZ master slave option. The beams now are deflecting in the global Y direction.

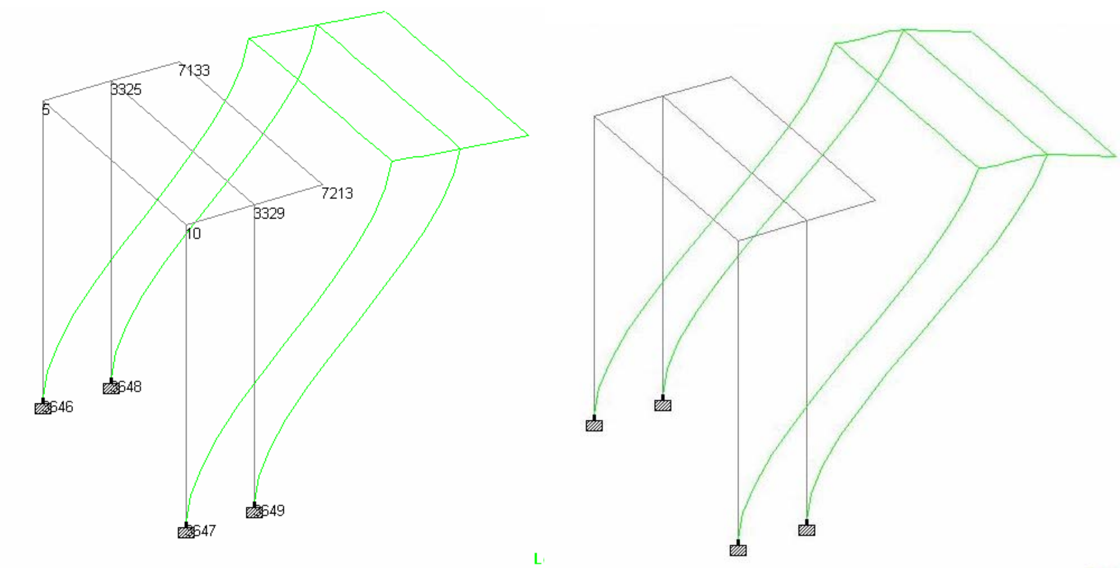

Figure 9: Deflected shape of the structure using the Rigid master/slave specification (Left). Deflected shape of the structure after using the XZ master/slave specification (Right).

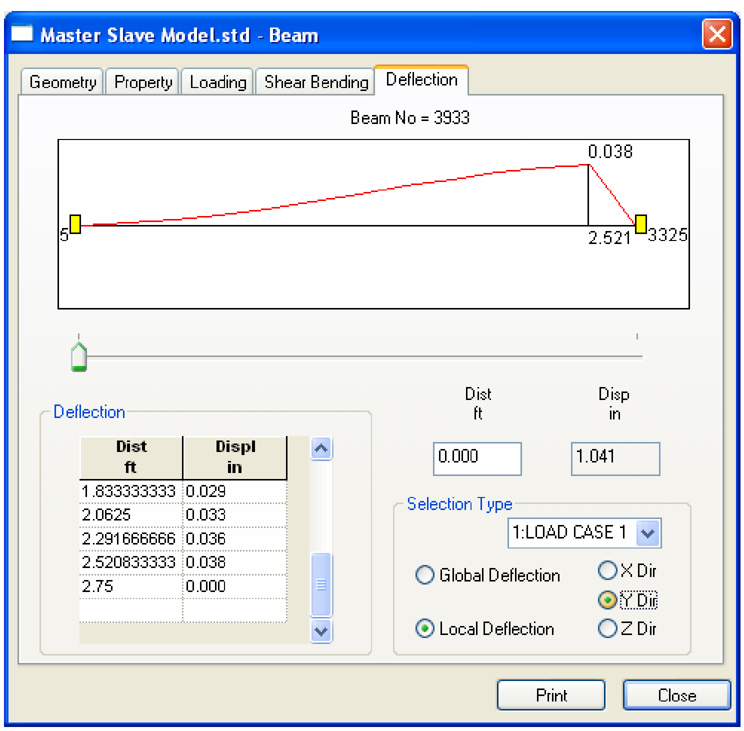

Figure 10: Local deflected shape of beam 3933 that connects node 5 and 3325

Another example of the different master slave options discussed above is well illustrated using the following loading scenario.

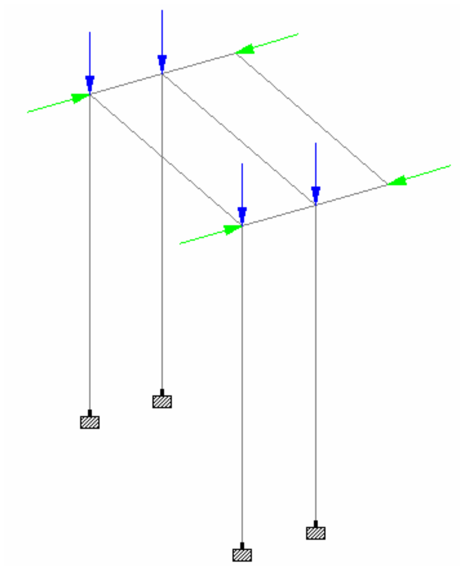

Figure 11: Loading diagram to illustrate effects of Master Slave Option

Using a displacement scale of 0.0048 the following displacement diagrams are obtained. The effects of using the master/slave option is clear but the difference between the rigid and XZ master/slave option is not seen.

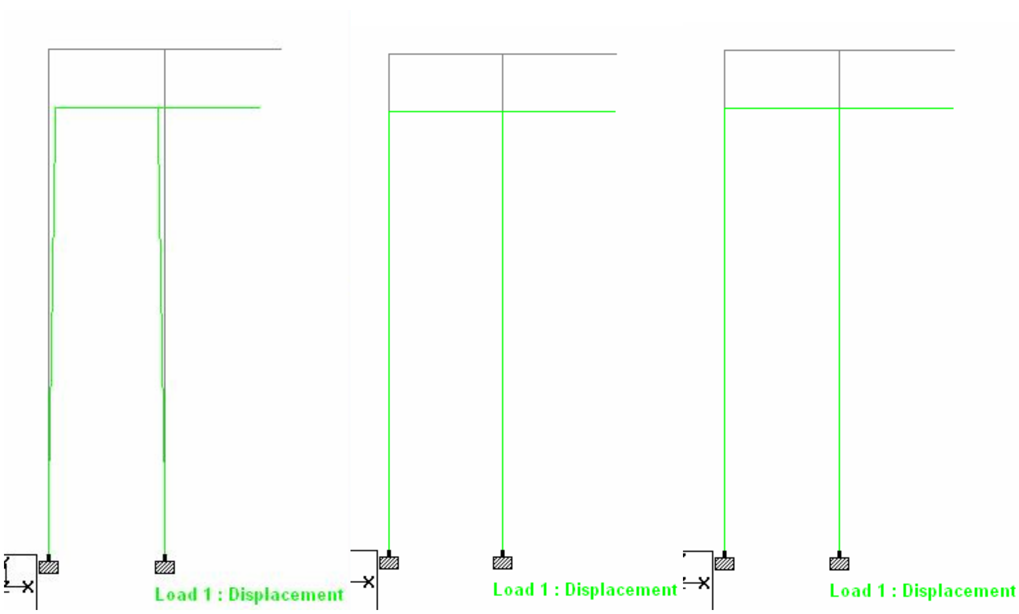

Figure 12: (Left) Without Master/Slave option, axial deformation is visible in the floor beams. (Center) With the rigid Master/Slave option, there is no axial deformation of the members. (Right) With the XZ Master/Slave option, there is no axial deformation of the members.

To illustrate the difference between the rigid and XZ master/slave option, let us modify the loading diagram as shown below.

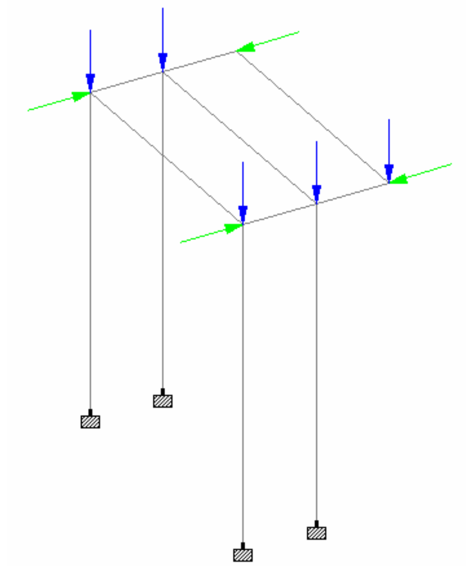

Figure 12: Loading diagram to illustrate effects of Master Slave Option

From the following deflection diagrams it is clear that the rigid master/slave option will maintain the slab rigidity in all directions (i.e. all nodes on the slab will lie on the same plane). However, the XZ option will maintain the slab rigidity only in the XZ plane.

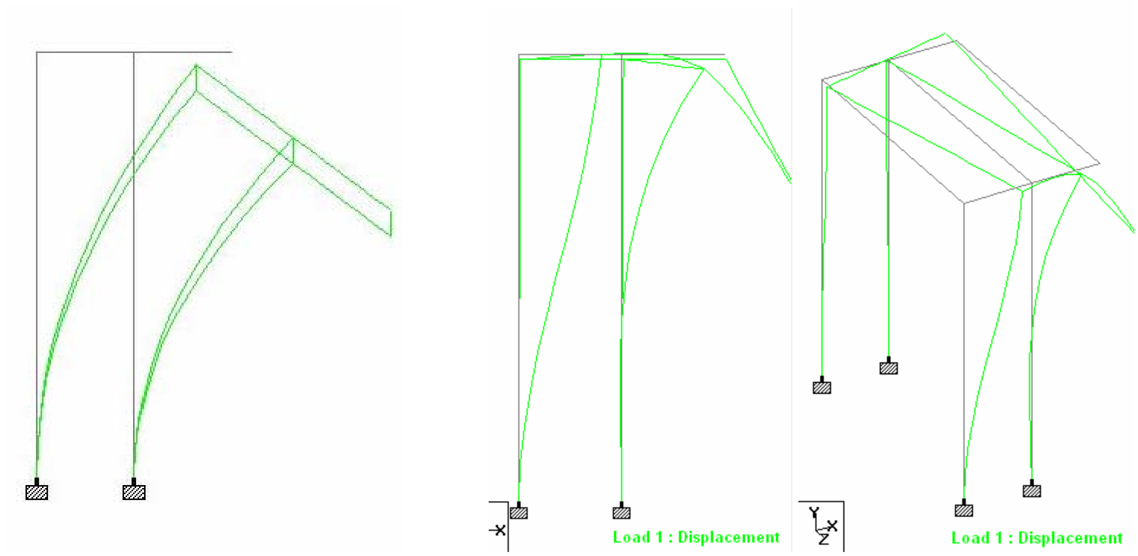

Figure 13: (Left) Deflection diagram with the rigid Master/Slave option. (Center & Right) Deflection diagrams with the XZ Master/Slave option

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4.0 Modeling Flexible Diaphragm Action

Flexible diaphragm action can be in STAAD.pro using two methods. The engineer in this case could implement one of the following methods to analyze and design the structure:

1. Plate modeling of the slab.
2. Completely ignore the slab and use the floor load generation to take the dead weight of the slab into account.

Both these methods are discussed below.

<u>Method 1</u>:

Suppose a w_r=1.5" and h_r=1.5" corrugated steel deck is placed on top of the structure shown in Figure 1. Modeling such a steel deck is possible, however, it will become very difficult for the engineers to run the analysis on these types of structures and make changes because of the large size of the models. For example, Figure 14 shows the steel deck modeled using about 7,000 plate elements.

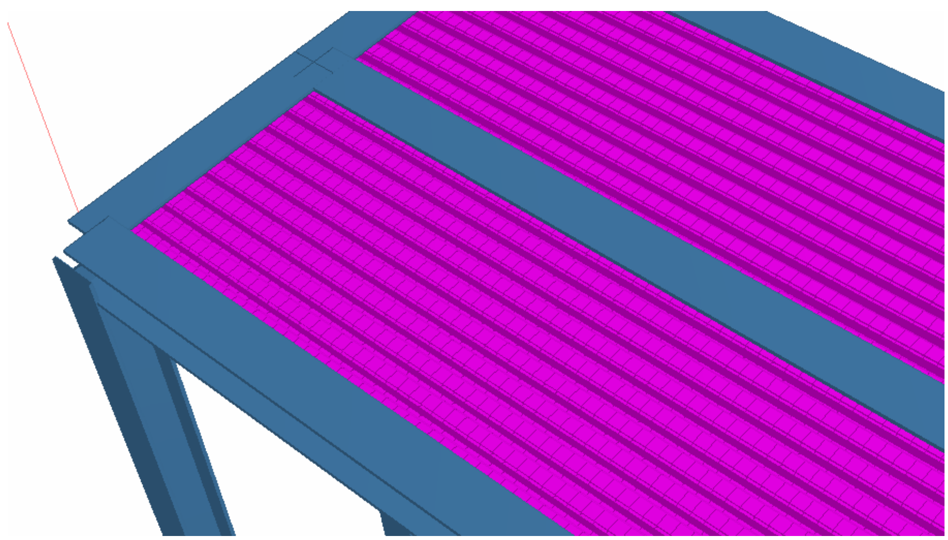

Figure 14: A 1.5" steel deck modeled using plate elements

This model will take about five minutes to perform the analysis. When the deflected shape of the structure is obtained, it is noted that the global X and Y displacement of node#5 is 1.078in and 0.013in respectively. The maximum moment (Mz) in beam 3933 is 54.691 kip-in.

Method 2:

In this case, the slab will be ignored however the weight of the slab and the loads acting on the slab will be taken into account using the floor load option.

Select the ***General->Load*** control tab on your left hand side select the ***Load Case details*** in the data area. Click on the ***Add*** button. Enter the title of the load case and the loading type. In this case, let us add *Dead Load* as the ***Title*** and *Dead* as the ***Loading Type***. Click on the ***Add*** button and then click on the ***Close*** button.

To create the floor load, click on the *1:Dead Load* entry that has been created in the ***Load*** dialog box in the data area. Click on the ***Add*** button in the data area. The ***Add New: Load Items*** dialog box will appear. Select the ***Floor Load*** item. Enter in the parameters as shown in Figure 15. Click the ***Add*** button and then click on the ***Close*** button.

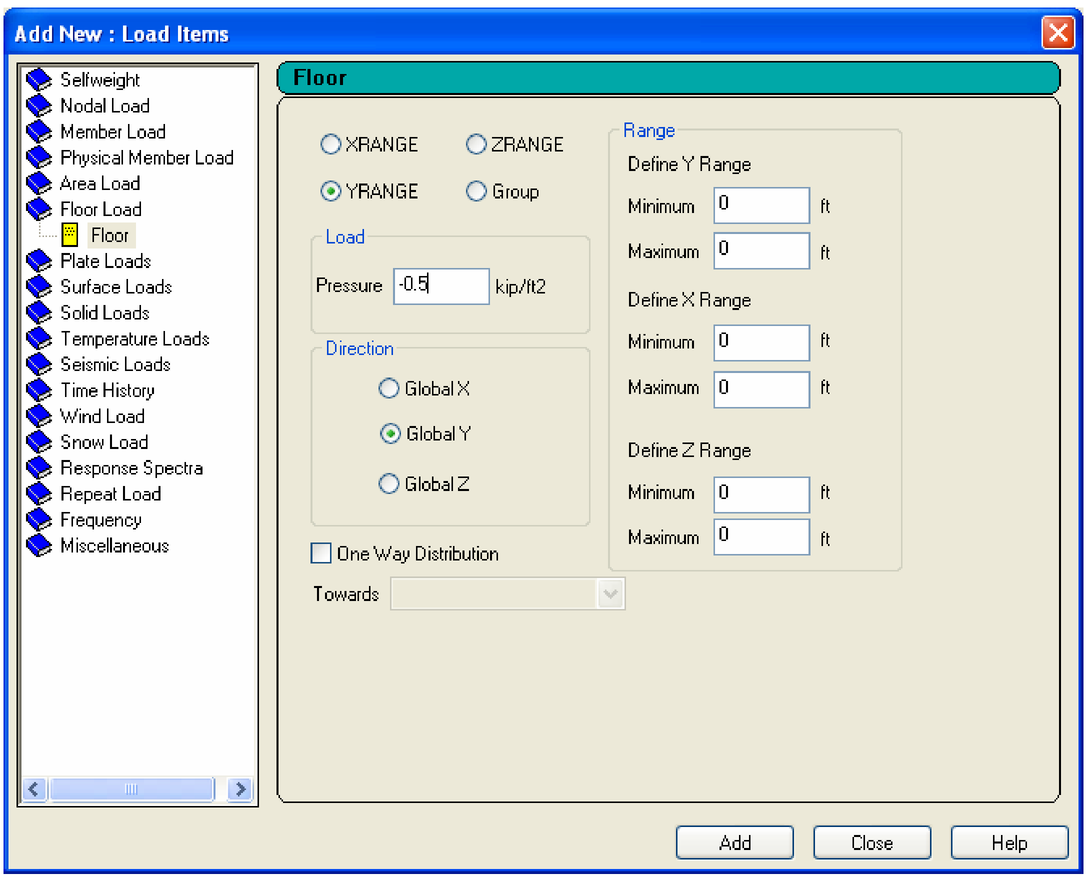

Figure 15: Floor Load Generation Parameters

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Click on the *YRANGE 0 0 FLOAD -0.5 GY* entry in the data area under the *1:Dead Load* entry. The tributary widths and load distribution will be displayed in the graphics window as shown in Figure 16. In the example shown in Figure 16, two nodal loads on 10 kip magnitude are added to the load case to compare results of Method 1 and Method 2.

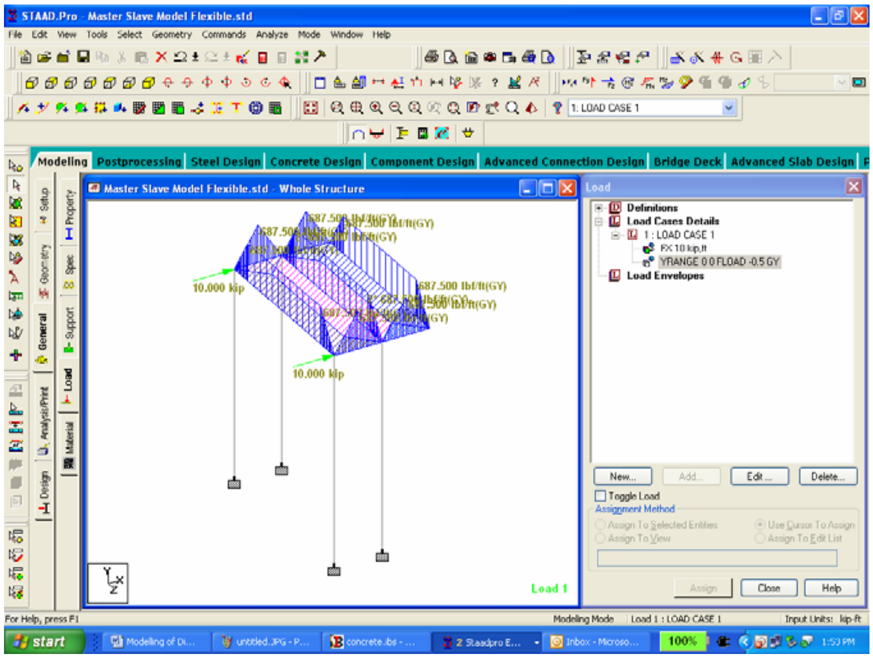

Figure 16: Floor Load has been generated and applied to the beam members as distributed load.

This model will take about five seconds to perform the analysis. When the deflected shape of the structure is obtained, it is noted that the global X and Y displacement of node#5 is 1.083in and 0.013in respectively. The maximum moment (Mz) in beam 3933 is 77.697 kip-in.

6.0 Conclusion

It is possible to model rigid, semi rigid, and flexible diaphragms in STAAD.pro. Rigid diaphragms are modeled using master/slave option. Semi rigid diaphragms can be modeled using XZ master/slave option. Engineers could do complete plate modeling of a slab to model flexible diaphragms; however, in some cases this approach could become very difficult to manage because of the increasing size of the models. In such cases, an engineer could completely ignore the slab but take the dead weight of the slab into account using the floor load generation method. Again, the use of these diaphragm modeling options in STAAD.pro requires good engineering decision making based upon the actual site conditions.