The concise guide to Nastran Rigid Elements

The Nastran group of elements often described as the "Rigid Elements" are very useful engineering analysis tools. "Rigid Element" is a slight misnomer, but the term is still used to describe the most commonly used items: the "RBE2" and the "RBE3".

This article describes some of the common uses and tips for using these tools. The guide is intended to be more practical than theoretical; however some basic theory is used to help better understand their practical use.

Firstly, what are rigid elements, and why might you want to use them?

A rigid element is a link from one node to another (or multiple nodes), where the motion of the node(s) is governed by the "degrees of freedom" you choose to connect. A rigid element is actually a constraint equation rather than an actual element, but for practical purposes that matters little, except for the tips to avoid common errors with rigid elements (described later in this article).

A few examples of useful applications of rigid elements include the following:

1. To model the dynamic behaviour of a vehicle, the engine can be modelled as a mass element connected by an RBE2 rigid element to the engine's multiple mounting locations. This makes the reasonable assumption that the engine is "very stiff" compared to the body structure and so the engine does not need to be modelled in detail. The mass is located at the centre of gravity of the engine, and the rigid element links the engine mass to the rubber mounts whose stiffnesses are typically much more relevant.

2. A large piece of rotating mining equipment operates in an effective "dynamic equilibrium" - the weight of the equipment and its ore is balanced by the pressure at the bearing pads. Standard constraints at the bearing journal could over-constrain the area, so the bearing reaction can be modelled as a pressure load. Similarly if the load is going to be rotated, then standard constraints would require a separate bearing constraint to match each rotation of load, resulting in excessive runtimes. If loaded correctly, the equipment is "balanced" and requires only nominal constraint (ie. constraints which produce negligible reactions). An RBE3 element connecting a ring of nodes at the bearing journal support to a single node on the rotating axis, allows a single constraint set to be used in conjunction with all of the rotating loads sets.

3. Bolt pre-load at a critical interface needs to be modelled, but does not need the bolt to be modelled with any more detail than as a "bar" or "beam" element. An RBE2 can be used to connect the end node of the "bolt" to the multiple nodes which represent the washer area over which the bolt load acts.

4. Masses are used to represent passenger/seating loads in a train or bus structure. The seating and passengers are assumed not to contribute any strength to the structure. A mass element could be used to represent one set of passengers/seat. An RBE3 element can be used to connect the mass element to the relevant area of the structure over which you wish to distribute the effect of the mass.

What is the difference between RBE2 and RBE3 elements?

Both elements "look" the same, in that they have a single node connected to one or (usually) multiple other nodes. The difference is that the RBE2 element adds (infinite) stiffness to the structure, while RBE3 elements "distribute forces" around the connected nodes, without adding any stiffness.

A rigid element can be as simple as two nodes connected at coincident locations (although it would be very unusual to use an RBE3 in that configuration), through to the more common appearance of a "spider" or "sea urchin" connection, or any arbitrary connection of one to multiple nodes.
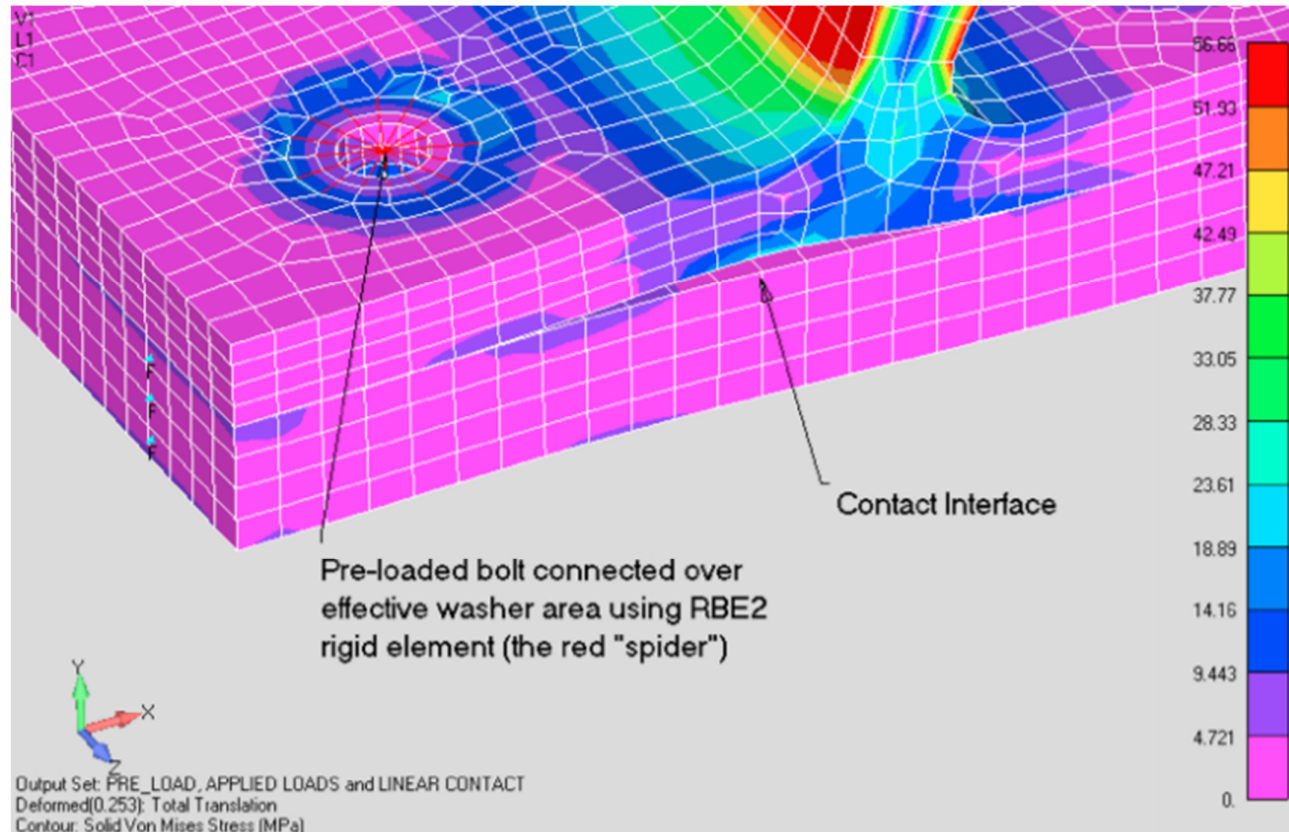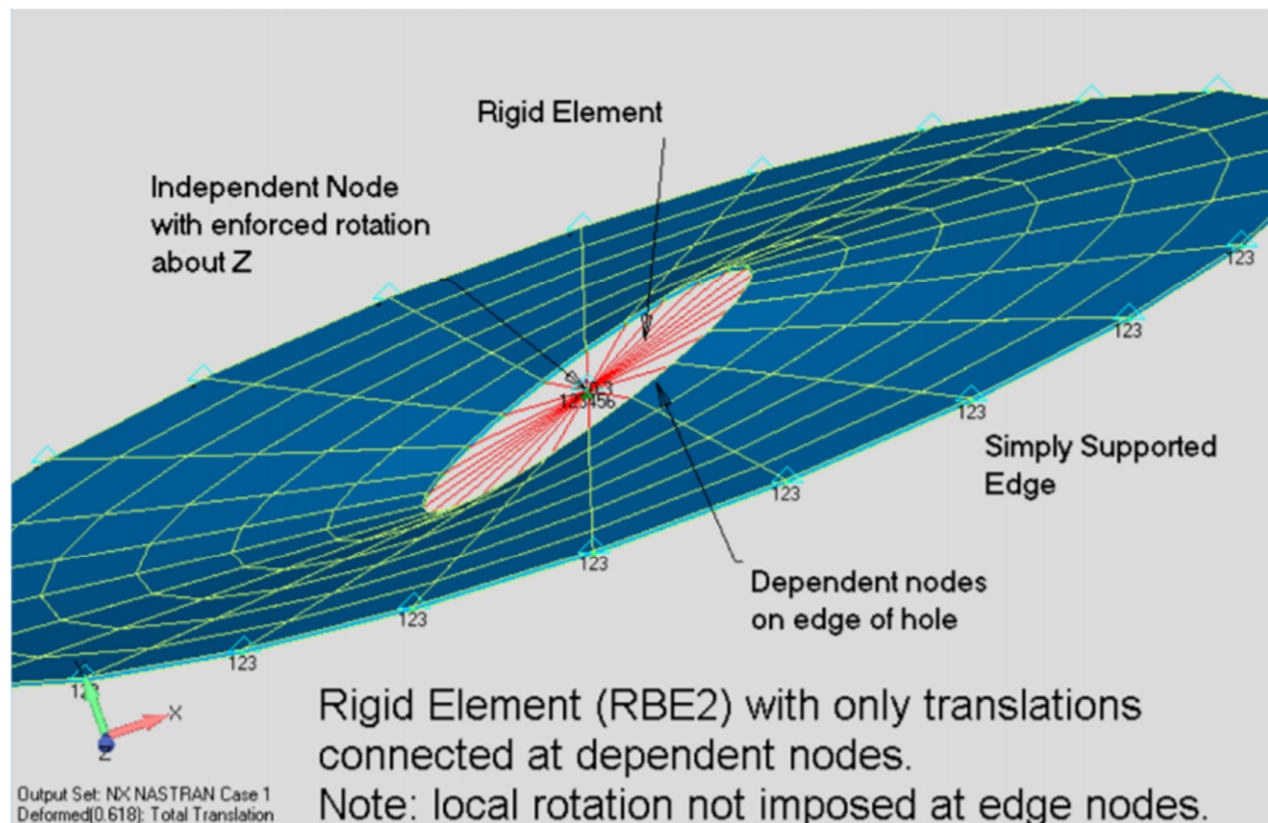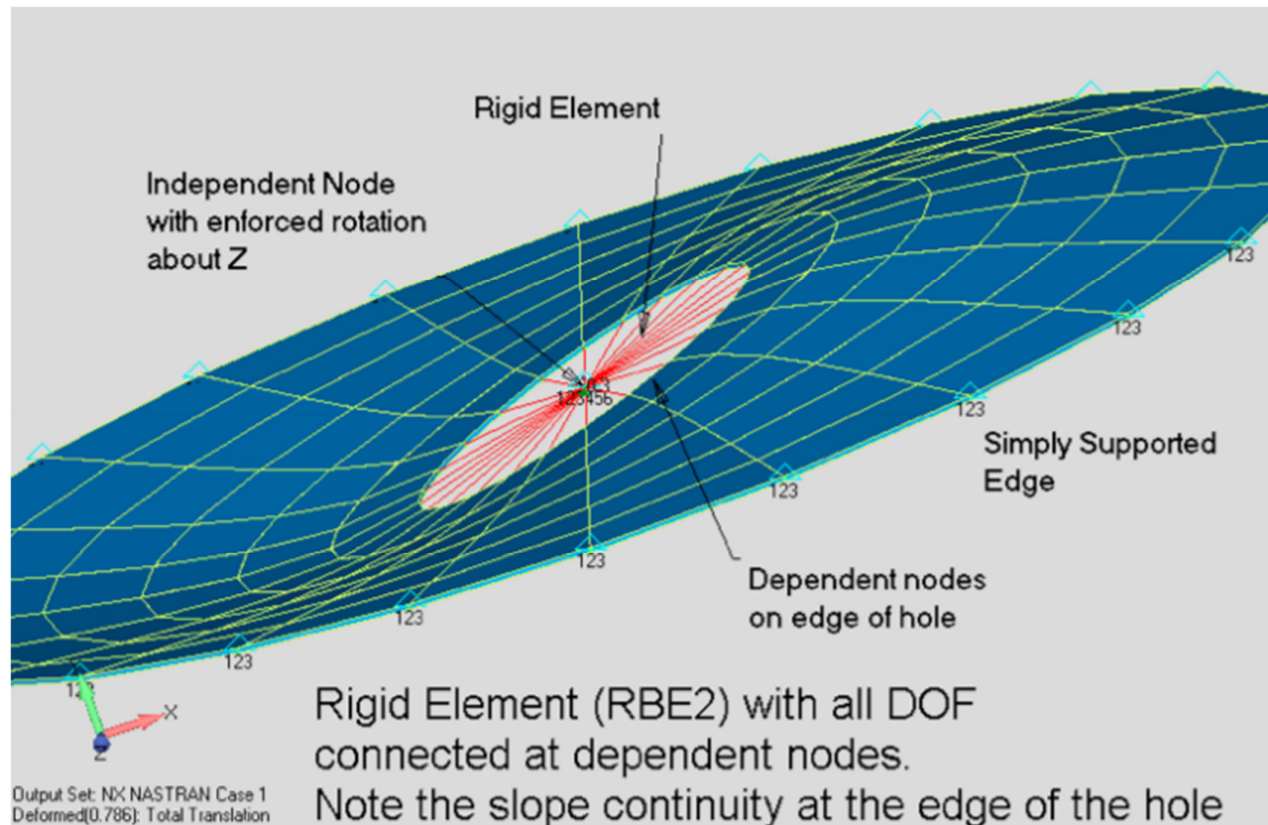

For an RBE2 rigid element, the single node is the "independent node". It has 6 degrees of freedom, regardless of what your FEA graphical interface looks like. The other node(s) are the dependent nodes. You decide which of their degrees of freedom you wish to connect. Note that it is important to understand the significance of your choices. Typical choices for the connected DOF would be either TX, TY, TZ. OR all 6 DOF (ie. translations and rotations).

Which DOF you connect is obviously dependent on the job which needs to be performed. It is critical to note that because of the "lever arm" effect of any distance between the independent node and its dependent nodes, rotations at the independent node produce translations at the dependent nodes and, therefore, translations at the dependent nodes affect rotations at the independent node.

The following figures show an example of a rigid element (RBE2) used to connect a central node to the nodes on the edge of a hole. In the first case, only translations at the dependent nodes (the ones on the edge of the hole) are connected.

In the second case, all 6 DOF are connected at the dependent nodes. An enforced rotation is applied at the central node (the independent node). Note the effect on the "local slope" at the ring of dependent nodes when all DOF are connected compared to just the translational DOF.

Rigid Element (RBE2) with all DOF connected at dependent nodes.
Note the slope continuity at the edge of the hole

Rigid Element (RBE2) with only translations connected at dependent nodes.
Note: local rotation not imposed at edge nodes.

Thus, be careful choosing the DOF to be connected at the dependent nodes, particularly for plate and beam models. Note that for "typical" FEA if the dependent nodes are on solid elements, then connecting only the translations vs all DOF will produce the same result – as most FEA packages' basic solid elements only have translational stiffnesses at each node .

A typical RBE2 rigid element is created as follows. in this case, only translational DOF at the dependent nodes are connected. *(Note that this user interface is Femap, but the concept is similar for other systems if rigid elements are available).*
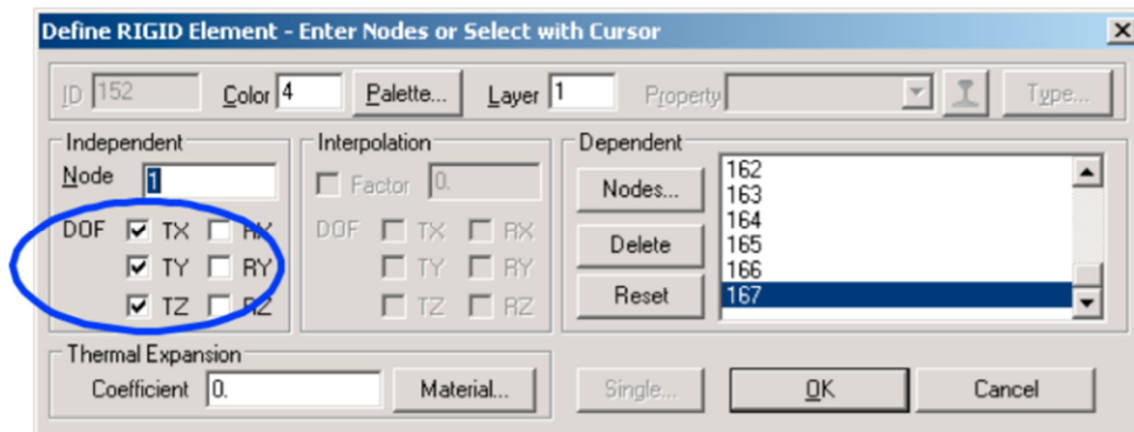
The RBE3 "rigid" element is not actually "rigid", however, it also is used to "connect" the DOF's at one or (typically) multiple independent nodes to a single dependent node. The motion of the single dependent node is a "factored interpolation" of the motion at the independent nodes – based on the DOF you choose to connect and the interpolation factor(s) you choose for the independent nodes.

In practice, the RBE3 is used to distribute the effect of a force or mass (acting at the dependent node) over a number of other nodes (the independent nodes), without adding stiffness to the structure.

A typical RBE3 element looks as follows. In this case, the dependent (Reference) node has 6 DOF, governed by the interpolation of only the translations from the independent nodes (Nodes to Average), where the interpolation factor used for the independent nodes is 1.0 for each node:
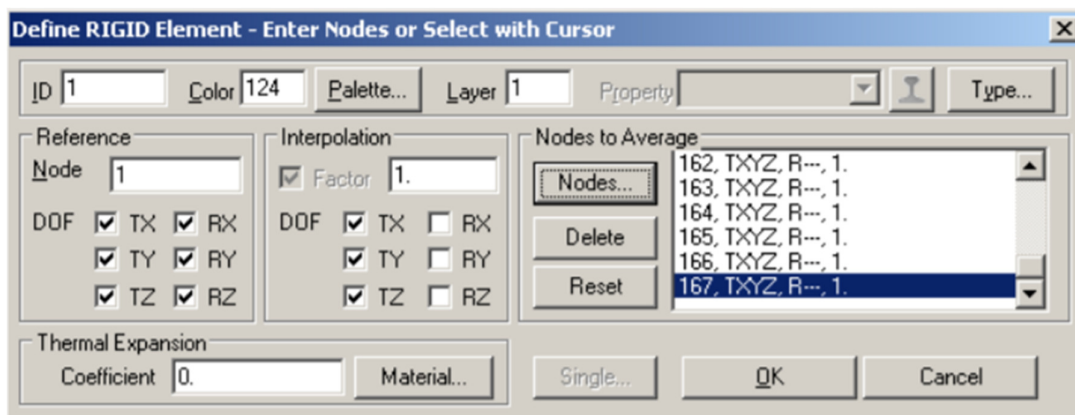
Again, this image is from Femap, but the concept is similar for other FEA packages if rigid elements are available.

A few key points when using rigid elements:

(Note that there are exceptions to the guidelines below, however, this guide is directed towards general/common usage rather than to cover every situation for the expert user).

1. If you have multiple rigid elements, do not have any node(s) as the dependent node(s) of more than one rigid element. Rigid elements can be nested (ie. the dependent node of one rigid element can be the independent node for another rigid element), however you should avoid a full circular dependency. (User Fatal 5289)

2. Do not apply constraints to the dependent nodes of a rigid element. If you do, you need to be sure that the DOFs that you constrain are not the same DOF's affected/connected in the element. (User Fatal 2101)

3. An important reminder is that rigid elements operate using small displacement theory. For example, if you use an RBE2 to rotate some structure, the initial (infinitesimal) vector of displacement at each dependent node does not change its direction irrespective of the magnitude of rotation at the independent node. In the case of basic non-linear analysis, this condition remains true. (Note, however, that in the case of eg. NX Nastran Advanced NonLinear option, RBE2s operate as large displacement elements which can be used to produce large scale rotations). However, for basic non-linear analysis it is trivial (in Femap at least) to convert multi-point rigid elements into multiple non-linear "stiff beams".

4. Also note that the connected degrees of freedom from the dependent nodes relate to their "output coordinate system" (if used) rather than the global coordinate system, as implied by some documentation. However, we strongly recommend, as with any capability that you may be trying out, that you run test model(s) to fully understand the principles that are described herein.