Bullet Constraints Builder

Manual

USER INTERFACE

Main Settings

Build / Update

- If no old BCB constraint settings are being loaded:
  Starts building process and adds constraints to selected elements.
- If old BCB constraint settings are being loaded:
  Update old constraints with the new settings (faster).

Store / Get / Delete Scene Settings

- If no connections are being built yet:
  Stores actual configuration data in current scene.
- If BCB settings are stored within scene:
  Get settings from scene and update GUI.
- If BCB and constraint settings are stored in scene:
  Get settings and constraint data from scene and update GUI. One can update constraints after that instead of rebuilding constraints from scratch.
- If BCB and constraint settings are already loaded:
  Removal of all BCB related data from scene, including constraints, scaling and bevel changes, and additional facing meshes.

Bake

Starts baking of the rigid body simulation, a *Build* is invoked beforehand if not already done. Use of this button instead of the regular Blender baking is crucial if connection type 4 or above is used, because then constraints require to be monitored on per frame basis for the entire simulation.

Steps Per Second

Number of simulation steps taken per second (higher values are more accurate but slower and can also be more instable).

Enable Breaking

Enables breaking for all constraints.

Search Distance

Search distance to neighbor geometry based on the boundary box of the elements.

Cluster Radius

Search distance to neighbor constraints. Close constraint objects will be bundled into clusters. This can be important if connection types other than 1 are used to ensure rotation is possible as the cluster serves as pivot point. See also the *Technical Details* section of this document.

To automatically estimate an appropriate Cluster Radius from the selected elements in the scene the button next to the input field can be used.

Advanced Settings

Automatic Mode

Enables a fully automated workflow for extremely large simulations (object count-wise) were Blender is prone to not being responsive anymore. After clicking *Build* these steps are being done automatically:

1. Building of constraints
2. Baking simulation
3. Clearing constraint and BCB data from scene

Backup (for Automatic Mode)

Enables saving of a backup .blend file after each step for automatic mode, whereby the name of the new .blend ends with `_BCB´.

Distance Tolerance (for Baking)

Allowed tolerance for distance change between elements while baking, as relative change in percent (1.00 = 100 %). Smaller or greater distances will force the connection to detach completely.

Rotation or Bending Tolerance (for Baking)

Allowed tolerance for angular change between elements while baking in radian. Smaller or greater angles will force the connection to detach completely.

Vertical Alignment

Enables a vertical alignment multiplier for connection type 4 or above instead of using unweighted center to center orientation (0 = disabled, 1 = fully vertical).

Connection Count Limit

Maximum count of connections per object pair (0 = unlimited).

Minimum Element Size

Deletes connections whose elements are below this diameter and makes them parents instead. This can be helpful for increasing performance on models with unrelevant geometric detail such as screwheads.

Accurate Contact Area Calculation

Enables accurate contact area calculation using booleans for the cost of an up to 20x slower building process. This only works correct with solids i.e. watertight and manifold objects and is therefore recommended for truss structures or steel constructions in general. If disabled a simpler boundary box intersection approach is used which is only recommended for rectangular constructions without diagonal elements like reinforced concrete buildings.

Non-solid Thickness

Thickness for non-manifold elements (surfaces) when using accurate contact area calculation.

Element Group List

Element groups can be used to define different material properties to certain groups of objects. The order of the list defines the priority for conflicting connection settings in case two elements of different element groups needs to be connected.

The controls within the list box can be used to add, move and select element groups as desired. All settings below the list box belong to the selected group. A short overview of those settings is displayed in the list box as well.

Element Group Settings

Group Name

The name of the element group.

Connection Type

Connection type ID for the constraint presets defined by this script, see the *Technical Details* section of this document.

Breaking Threshold Compressive

Real world material compressive breaking threshold in N/mm^2.

Breaking Threshold Tensile

Real world material tensile breaking threshold in N/mm^2 (not used by all constraint types).

Breaking Threshold Bending (Hidden in UI)

The new connection type #5 currently uses a derivative from the tensile breaking threshold to calculate the breaking threshold for bending.

Required Vertex Pairs (Obsolete, hidden in UI and disabled in code)

How many vertex pairs between two elements are required to generate a connection.

Material Preset

Preset name of the physical material to be used from Blender's internal database. See Blender's Rigid Body Tools for a list of available presets.

Material Density

Custom density value (kg/m^3) to use instead of material preset (0 = disabled).

Bevel

Enables beveling for elements to avoid `Jenga´ effect (uses hidden collision meshes).

Rescale Factor

Applies scaling factor on elements to avoid `Jenga´ effect (uses hidden collision meshes).

Facing

Generates an additional layer of elements only for display (will only be used together with bevel and scale option, also serves as backup and for mass calculation).

TECHNICAL DETAILS

Update / Rebuild

Most changes in material properties or in the element groups are covered by the update functionality. There are however changes that will make a rebuild of the whole structure necessary. The remove button has to be pressed before you can rebuild.

Here is a not conclusive list of changes that require a full rebuild:

- Adding or removing elements to or from the structure (it is however possible to put elements into another layer to make them invisible for the simulation)
- Adding or removing constraints to or from the structure

These changes outside of the BCB panel require an update:

- Changing of the simulation steps rate in the Rigid Body World panel of the scene properties, as it influences the breaking thresholds (but the constraint iteration rate can be changed)

Baking

Since the introduction of multiple constraints per connection a custom bake option has been implemented. As constraints shared by a connection have no knowledge of each other it has become necessary to manage these during the simulation and baking. Per each frame an event handler is invoked which is checking all connections if at least one constraint per connection has been detached and then it automatically detaches all other constraints within the particular connection as well. Individual left over constraints otherwise would heavily confuse the simulation, which can lead to very unstable behavior like exploding structures especially with higher step rates.

Detached connections are detected indirectly by measuring element to element relationships. More precisely, this is done by verifying changes in distance between elements and changes in their relative rotation to each other. Occurring differences are then compared to the *Tolerance* value. A change in distance which is only or mainly caused by a change in rotation will be recognized by the system as the tolerance threshold will be expanded accordingly to take this into account, so undesired detaching at least in this case should not happen.

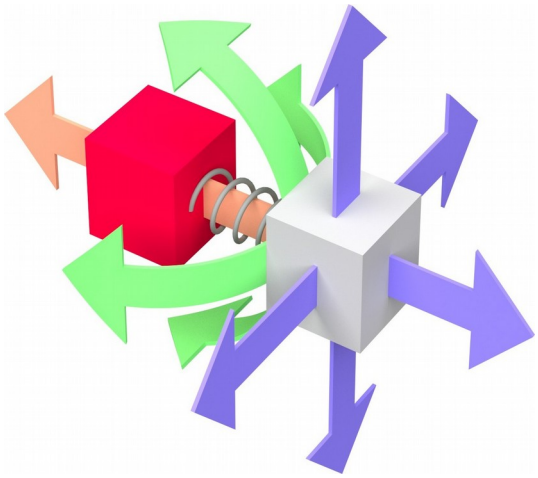
Connection types:

Constraints in connections are defined by presets, only the ID from the following list needs to entered into the *Connection Type* field to enable the respective connection type:

1. 1x 'FIXED' constraint per connection, only compressive breaking threshold is used (tensile limit stays the same, angular forces limit as well).
2. 1x 'POINT' constraint per connection, only compressive breaking threshold is used (tensile limit stays the same).
3. 1x 'FIXED' + 1x 'POINT' constraint per connection, compressive breaking threshold is used for the first one and tensile for the second.
4. 2x 'GENERIC' constraint per connection, one to evaluate the compressive and the other the tensile breaking threshold.
5. 3x 'GENERIC' constraint per connection, one to evaluate the compressive, another one for the tensile / lateral and the last one for bending / buckling breaking threshold.

Example for the connection type 5 structure

The red cube in the image is a fixed (passive) rigid body and the white cube is connected to the red one by connection type 5. This type uses three Generic constraints, each designated for locking different degrees of freedom with an own breaking threshold.



Legend:

1. Constraint, red - Compressive force
2. Constraint, blue - Tensile & shear force
3. Constraint, green - Bending force

Constraint placement specifications

Location

Constraints are placed at the center of the contact area boundary box. If bundling into clusters is enabled (Cluster Radius > 0) then all constraint locations will be bundled within a post process based on their previous locations.

Orientation

Constraints will be aligned to the center to center line of both connected elements.

The *Vertical Alignment* setting can be used to make sure skewed but mostly vertically oriented constraints will be rectified. This is done by reducing the X and Y components of the directional vector by a custom factor in range from 0 to 1. This way horizontal oriented constraints will stay horizontal and more diagonal ones will be corrected towards upright. This can help for buildings where one wants to avoid undesired diagonal oriented constraints.

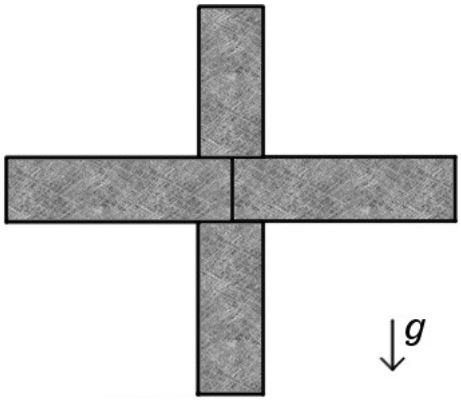
Hints for better construction modeling

The `Jenga´ effect

The `Jenga´ effect this document refers to describes the characteristic of rigid bodies of not being able to give in or break away if they were stacked upon each other like the wooden blocks of that popular game.

Rigid bodies are by design incompressible and indestructible so one needs to make sure they being hold together only by the connection constraints and that they are able to move away and to collapse, especially if that is the desired outcome of the simulation.

To deal with this issue in a convenient way BCB offers two options, beveling and rescaling, to change the collision shape accordingly. This can help to give all elements of the corresponding group more freedom of motion in all directions.

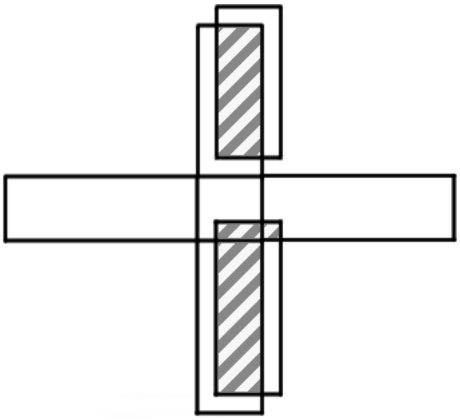


Bad: Elements will not collapse even if all constraints are broken

It is also possible to add an optional facing layer of element duplicates which will hide the visible changes of the underlying collision objects.

Element intersections

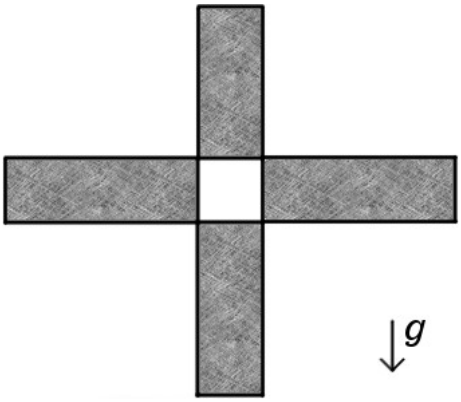
It is important that no active rigid body elements are intersecting each other, this would lead to an explosion like repelling reaction during simulation. Passive rigid body elements however can intersect each other, like for footings of a building that can intersect with a ground plane.



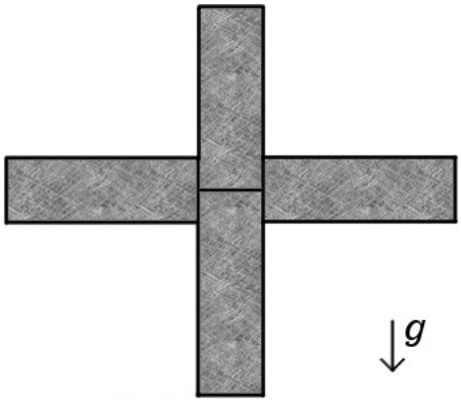
Bad: Elements overlapping others

Connection evaluation

The search for connections starts by finding boundary box intersections of all mesh elements. Then for every found element pair the contact area will be calculated and only the contact area is > 0 then a connection is created. You can have gaps between the elements as long as the distance between surfaces lies within *Search Distance*, all boundary boxes will be extended by this value.



Bad: No contact area



Optimal structure modeling