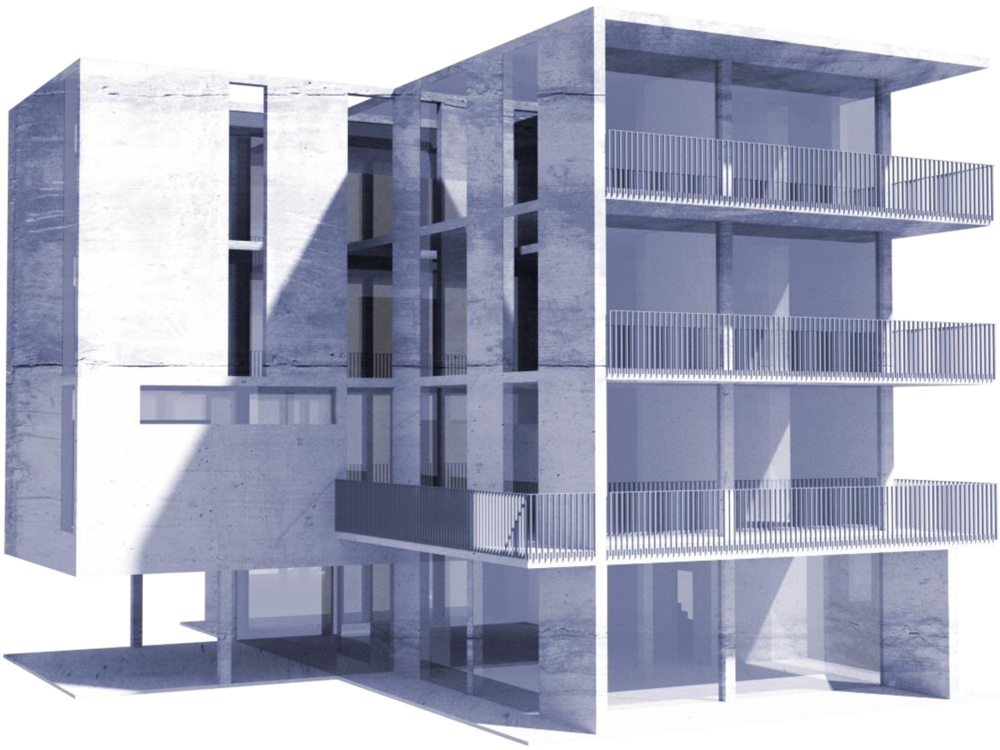
Bullet Constraints Builder
Tutorial

2/3

Guide to Simulate a Multi-Family House with Standard Blender



Laurea University of Applied Sciences
Kai Kostack & Oliver Walter

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List of content:

List of abbreviations:

Abbreviation	Description
BCB	Bullet Constraints Builder
BIM	Building Information Model
FM	Fracture Modifier
IFC	Industry Foundation Class
RC	Reinforced Concrete

1. Introduction

The Bullet Constraints Builder (BCB) was developed from scratch during the three yearlong R&D project INACHUS [1]at LAUREA, University of Applied Sciences [2]. The focus during this time was on improving the software, its accuracy and speed, therefore tutorials were time and again postponed. Due to the growing interest and requests from universities and engineers around the world, tutorials became indispensable. This tutorial is the second of three that have been written to gradually introduce the BCB basics:

BCB Tutorials:

1. Guide for BCB Installation & Simple Collapse Simulation
- installation instruction and introduction into a simple collapse simulation

2. Guide to Simulate a Multi-Family House with Standard Blender
- Introduction of the BCB fundamentals with standard Blender

3. Guide to Simulate a Multi-Family House with Fracture Modifier
- Introduction into a speed optimized variant with the FM

To follow this tutorial basic Blender knowledge is required.

[1] INACHUS. [Online] Institute of Communication and Computer Systems: https://www.inachus.eu/
[2] Laurea University of Applied Sciences, Wordpress. [Online]: https://inachuslaurea.wordpress.com/

2. About this guide

This guide introduces BCB simulations with standard Blender, you will acquaint yourself with some of the Preprocessing tools, the constraint concept and with the method to apply real-world element properties. The exercise is recommended for all those who want to get familiar with the BCB fundamentals in order to setup own simulation models from scratch. For a speed optimized alternative please refer to tutorial 3/3, “A guide to perform collapse simulations with the Fracture Modifier.” [3]

2.1.The BCB essentials

At first, three BCB sections are introduced that are essential to perform any simulation from scratch leaving aside most of the less substantial settings and commands. These sections are marked with A B C . The essential sub-steps are marked with 1 2 3 etc. Each of the sub-steps has a shortcut “***jump to exercise***” that leads to the step of the exercise where this tool is applied.

2.2.The exercise

The exercise can be shortened by loading predefined material settings that will spare you most of the manual work, see option 2 in Table 1.

Option 1: Create material settings manually,	**Option 2: Load predefined material settings**
Step1 Building model import	Load Blender model with stored configuration settings
Step2 Create groups from names	*Replace this step 2 with:* “Load configuration data” *see Tip in Step 6*
Step3 *Discretize*	
Step4 *Do all selected steps at once*	
Step5 *Element group list*	Skip this step
Step6 *Definition of element properties*	Skip this step
Step7 *Element Group Settings*, connection type	Skip this step
Step8 *Build constraints*	
Step9 *Define collapse scenario*	
Step10 Start simulation	

Table 1 Exercise diagram

[3] The simulations with standard Blender run relatively slow. In the third part of this tutorial series a speed optimized simulation approach is demonstrated that allows relatively big models to be simulated much more efficiently.

2.3.Downloads and software installation

The software, files and documents that are necessary for the exercise are listed in Table 2. The software is available for Microsoft Windows, Linux and MacOS systems. For detailed installation instructions refer to tutorial 1/3, “Guide for software Installation & a simple collapse simulation”.

Installations		
- Download and install standard Blender,		click “download Blender 2.79a”
- Download and install the BCB add-on,		click “download the BCB”
- Install the IfcOpenShell add-on [4],		click “download IfcOpenShell”
Trouble shooting:	Problem: *Not all BCB features are working as expected*	*Possible solution:* *- make sure that the BCB is compatible with the installed Blender version* *- Blender should be started as administrator: right click on the program icon and “Run as administrator”*
Documents		
- Download the building description,		click here
- Download the building model in ifc format (use “Save page”),		click here
- Download the Blender model with stored configuration settings,		click here

Table 2

To make sure a fluent workflow external building models should be produced by Building Information Modeling (BIM) software such as REVIT or ArchiCAD and made available as an ifc-data file[5].

2.4.System requirement

Minimum	Recommended
Hard Disk: 100 GB	Hard Disk: 1 TB
Memory 4 GB RAM	Memory: 8 GB RAM
Processor: Intel Pentium III	Processor: Intel Core i7-5820K or higher
Graphics Cards: Accelerated Open GL	Graphics Card: GeForce GTX 980 Ti or similiar

2.5. A general remark concerning simulation precision

Coherent looking simulations cannot be expected from coarse building models such as presented in this exercise. We have to bear in mind that single Blender elements are not breakable! Imagine a column in the middle of a rather large ceiling slab, this column will not be able to punch through that slab element. Breaks are only possible at the joint of two elements. To evaluate forces as authentically as possible object edges must be available close to the occurrence of the highest forces, this is increasingly the case in building models with higher discretization.

[4] Blender does not have an ifc-data import option, this option needs to be installed as an add-on
[5] Building models that are produced by AutoCAD or models in dxf-data format are not suitable

3. The BCB User Interface

After the BCB is installed Blender´s tool shelf in the 3D viewport is extended with a BCB tab. Clicking on it reveals the main BCB User Interface, Figure 1. At first, let us focus on three tool sections in this interface that are indispensable when performing any simulation from scratch in order of their execution. [6]

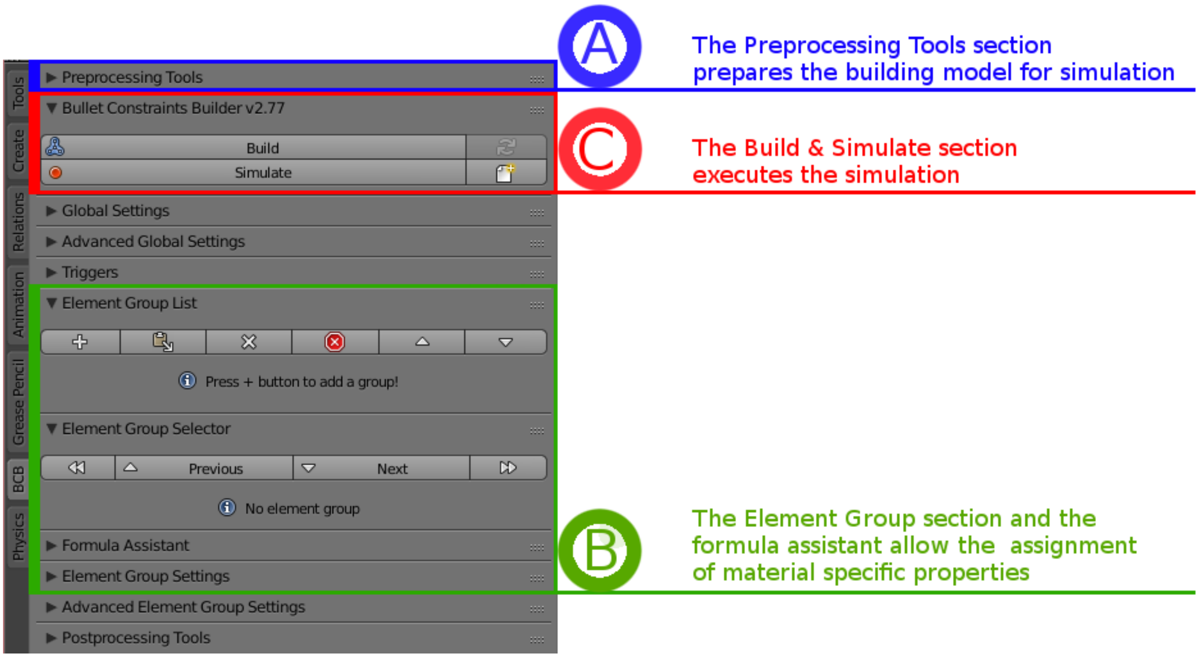


Figure 1 The main BCB- User Interface

3.1.The Preprocessing Tools section

A The execution of the Preprocessing Tools is the first of the three stages to prepare a building model in Blender for simulation. The BCB will run the activated sub-steps in the Preprocessing Tools panel as a batch. These steps will automatically analyse and prepare the model for the simulation. The sub-steps are all activated by default but they can also be executed separately. The mandatory sub-steps that need attention in the exercise are shown in Figure 2 and explained in the following section.

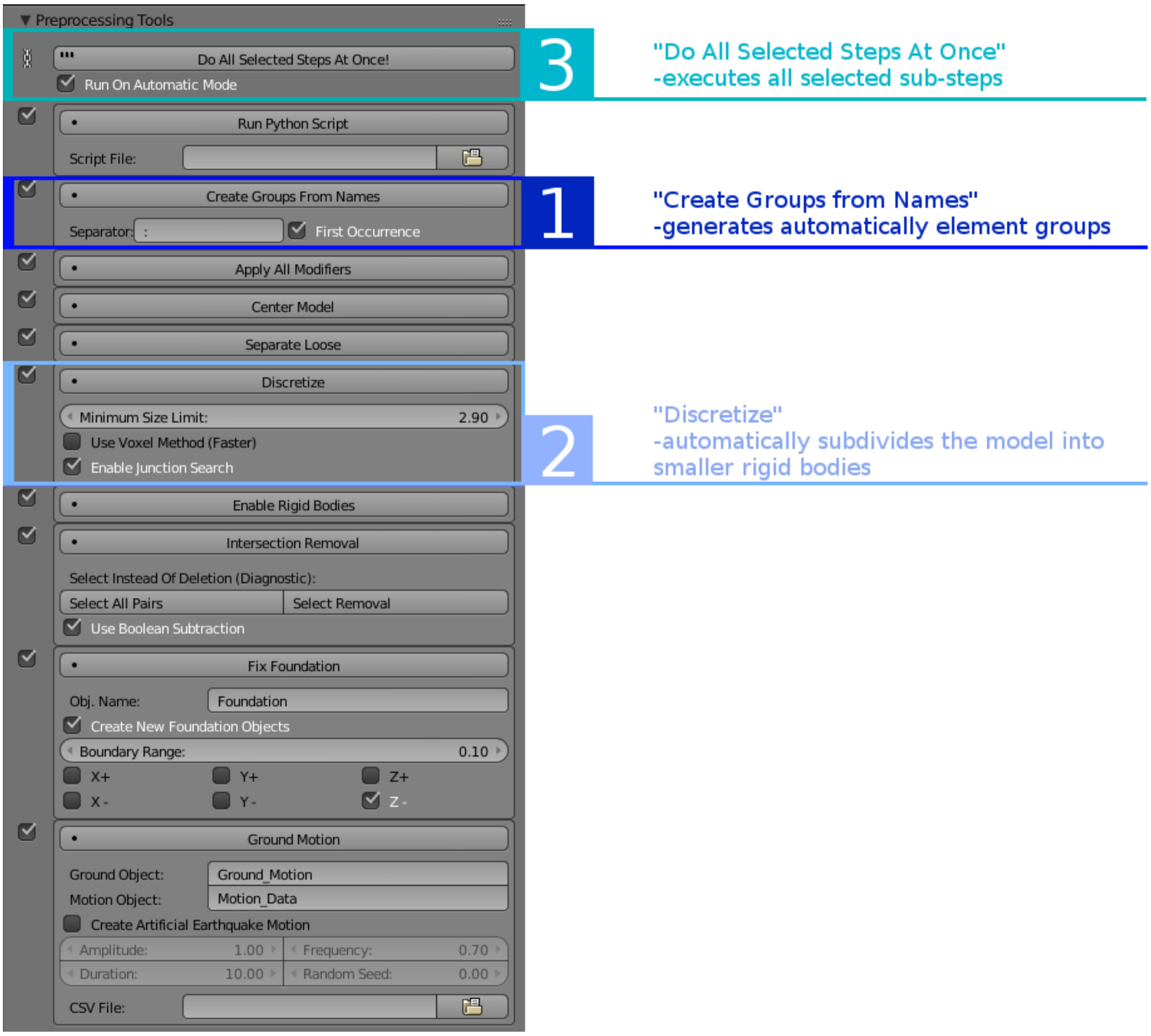


Figure 2 The mandatory Preprocessing steps

3.1.1. Create Groups from Names

1 This sub-step automatically creates element groups in Blender to which group specific strength values will be assigned later, see section 3.2.2. It is important that the elements in the building model are systematically named so they can be clearly categorized into groups with distinct labels. A reasonable naming convention always has a key character or a string of characters that separate the main element group name from the specific element number code.

Table 3 shows an example of a naming convention with ":" as a separator character and the resulting element group names.

Element name:	**Resulting element group name:**
RC-Girder-Rect-800x2000:391945	RC-Girder-Rect-800x2000
RC-Pillar-Rect-250x350:1201113	RC-Pillar-Rect-250x350

Table 3 Example of a naming convention

Jump to exercise

3.1.2. Discretize

This sub-step discretizes all selected elements into smaller segments by splitting them into halves until a predetermined minimum size limit is reached. If for example the Default Target Size of 2.9 m is used, the BCB will subdivide any dimension that is larger than 2.9 m. Lower discretization values will create smaller but much higher numbers of elements and the time necessary to solve the simulation will increase exponentially.

Jump to exercise

3.1.3. Do All Selected Steps At Once

This step will execute all selected sub-steps.

Jump to exercise

TIP:

-To monitor the execution of the Preprocessing Tools it is advised to have the system console window open. The system console gives also valuable indication for trouble shooting if commands do not work as expected, Figure 3.

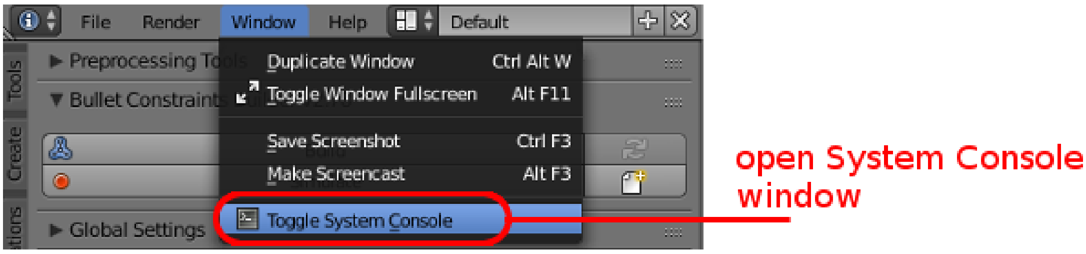


Figure 3

3.2.The Element Group and the Formula Assistant section

After the pre-processing routine has passed successfully the model is discretized (subdivided) into smaller physically active building blocks (rigid bodies) which are at this point still disconnected. The Preprocessing routine has also created a list with distinct element groups that are now visible in the Element Group List section. In the following step necessary to prepare the building model for the simulation we need to define the strengths for each of those newly created element groups. This is done with the help of the Formula Assistant, Figure 4. The mandatory sub-steps that need attention in the exercise are shown in Figure 4 and explained in the following section.

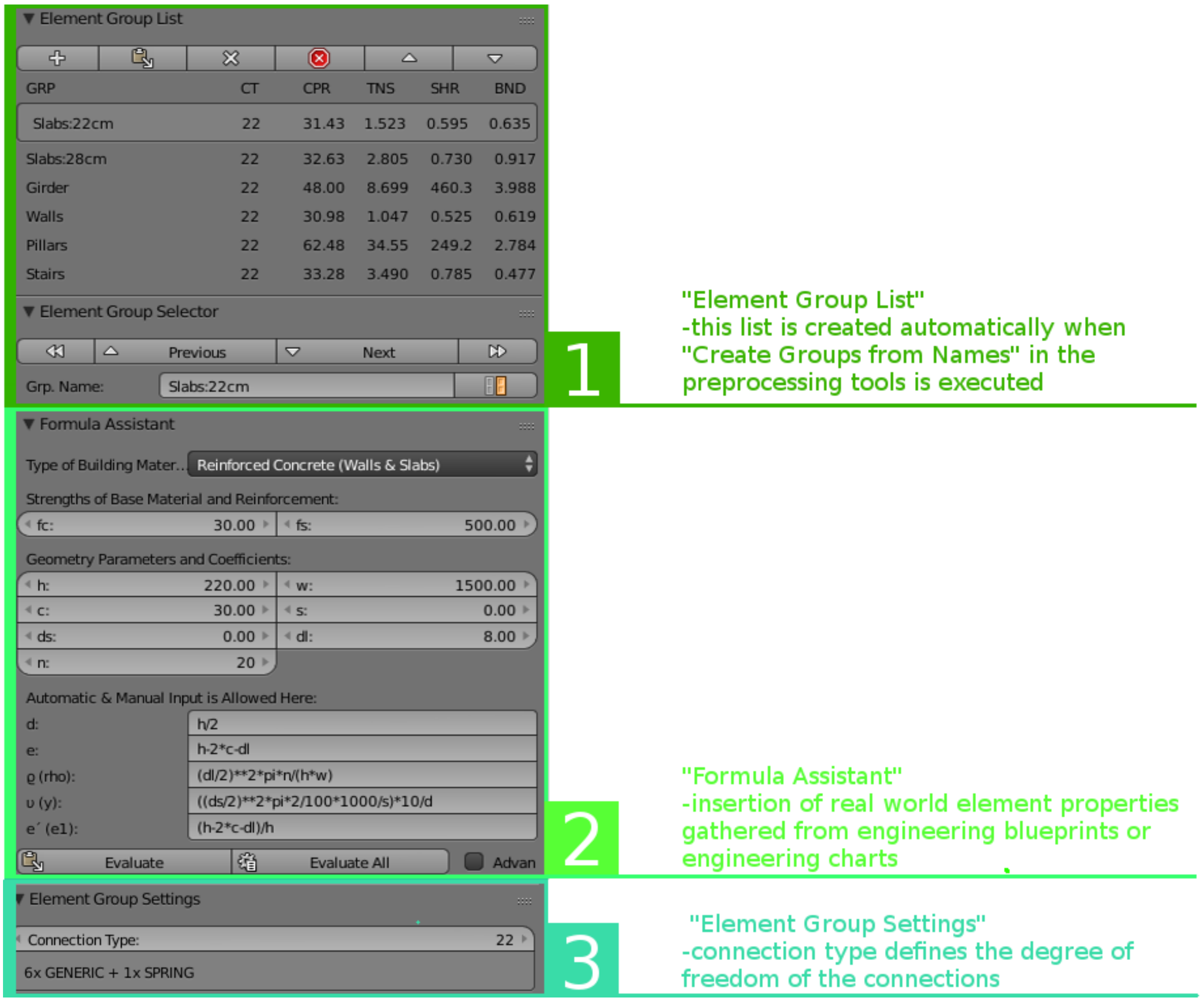


Figure 4 The Element Groups and the Formula Assistant

3.2.1. Element Group List

1 This list is populated automatically with element group names and default strength values after the sub-step “Create Groups from Names” in the Preprocessing Tools was executed. The Element Group List will be complemented with the correct strength values for each element group after the element properties have been filled into the Formula Assistant in sub-step two, 3.2.2. The types of strength that is evaluated is shown in Table 4.

	Maximum admissible forces			
CT	CPR	TNS	SHR	BND
Connection type	Compression in N/mm^2	Tension in N/mm^2	Shear in N/mm^2	Bending in Nm/mm2

Table 4

Jump to exercise

3.2.2. Formula Assistant

2 An element must be assigned to one of two categories: Reinforced Concrete (Walls & Slabs) -> these are elements without stirrups or Reinforced Concrete (Beams & Columns)-> these are elements with stirrups. The user must gather the detailed element properties from technical blueprints or from charts where engineers have compiled this information. The registering of the element property data in the Formula Assistant is one of the few steps in the simulation routine that requires relatively time-consuming manual input.

Based on this data the BCB will calculate the strength values for each degree of freedom, when "evaluate" is pressed, Figure 5.

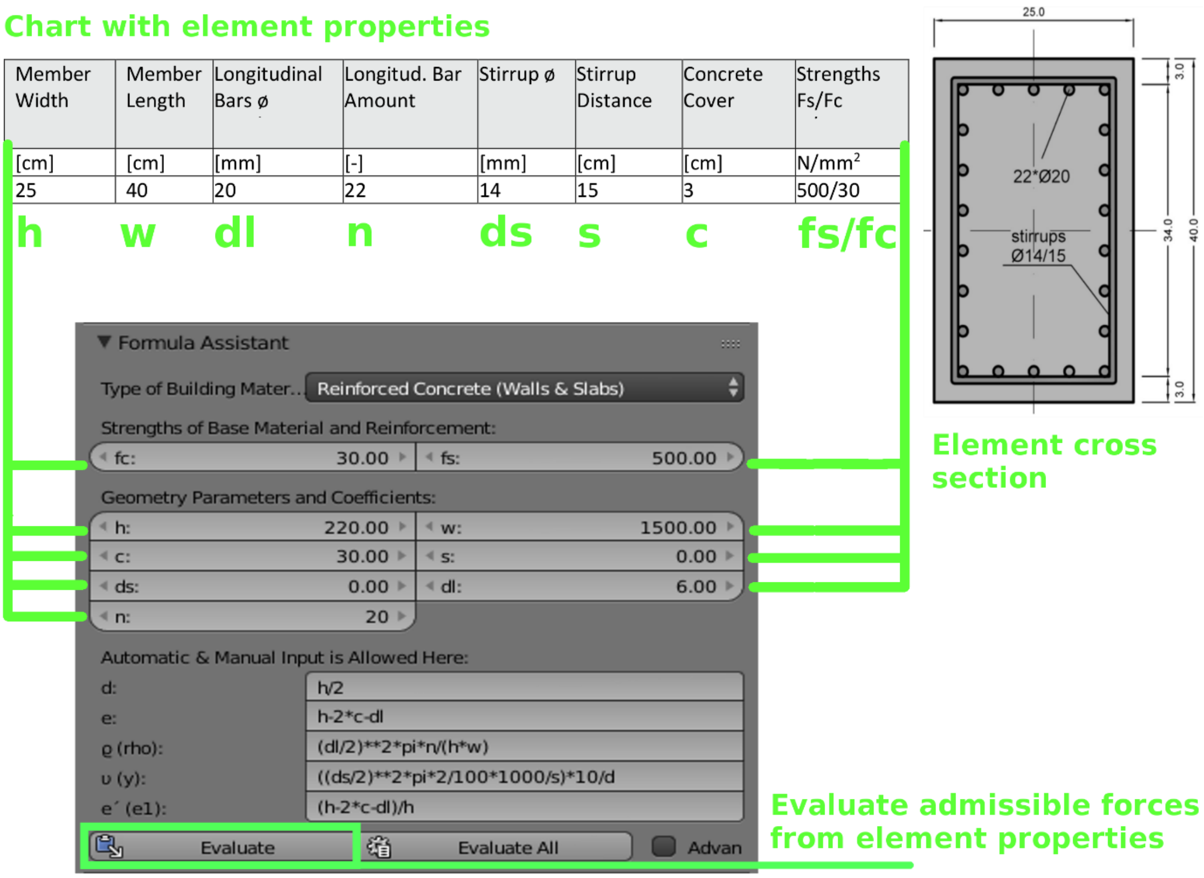


Figure 5 The element properties and the Formula Assistant.

Jump to exercise

3.2.3. Element Group Settings- connection type

3 The connection type influences how many degrees of freedom are considered for the element connection, connection type 22 is recommended.[7]

[7] The connections are comprised of various types of constraints, connection type 22 for example uses generic and spring constraints

Jump to exercise

3.3.The Build, Simulation section

After the BCB has calculated the maximum admissible forces based on the inserted element properties it is now ready to connect the still independent building blocks in the model with constraints. The simulation can be started after the building of the constraint setup is completed.

Figure 6 Building and Simulate

3.3.1. Build

The constraints building process is started by pressing “Build”, this can take from a few minutes up to several hours depending on the amount of building blocks in the model that need to be connected. The amount of total constraints also depends on the chosen connection type. The BCB places the constraints on the next free Blender layer which is turned off [8].

Jump to exercise

TIP:

- As it was suggested for the Preprocessing routine, it is also here advised to follow the progression of the building process via the system console as Blender will be not responsive for some time and will appear to have crashed. The system monitor can also provide vital information for trouble shooting.

3.3.2. Simulate

“Simulate” will start the simulation. The simulation will be solved over 250 frames. The simulation time length can be changed by adjusting the end frame of the playback range in Blender´s animation settings.

Jump to exercise

[8] *The vast amount of constraints that is created in this step is the reason for the relatively slow performance when standard Blender is used. Simulating with the Fracture Modifier, see tutorial 3/3, is much faster because the constraints don’t need to be represented as actual objects but are computed as numerical values.*

4. Exercise with standard Blender

step 1

Import building model

-open Blender and delete all objects in the scene.

-import the building model “Multi Family House.ifc” into Blender, Figure 7.

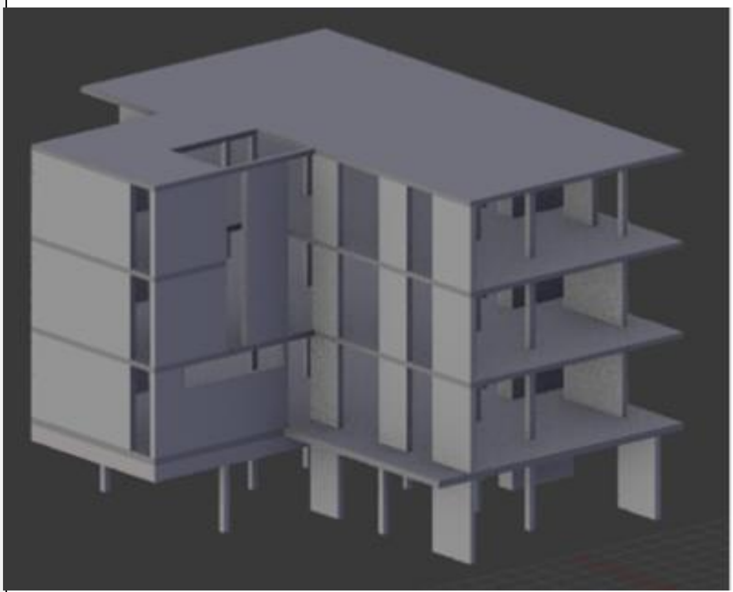


Figure 7

Trouble shooting	Problem: *There is no ifc import option in Blender*	*Possible solution: Install the fcOpenShell add-on, see paragraph 2.3. The add-on needs to be activated in Blender´s User Preferences*

step 2

Create groups from names

- navigate to Blender´s outliner to check the name convention of the imported building elements. As you can see there are two occurrences of the colon characters “:” The second separates the main element group from a reference number. The word stem defines the name of the element group. In Figure 8 the word stem is “Basic Wall:25cm”.

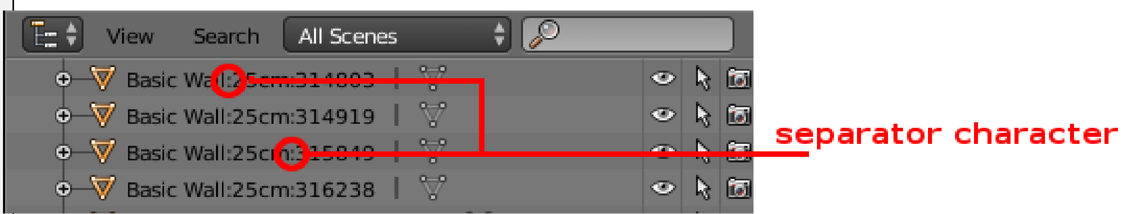


Figure 8

- next, click on “Preprocessing Tools” in the main BCB UI. This will open the Preprocessing tool panel and reveal the Preprocessing sub-steps.

- notice the field “Create Groups from Names”. Leave the default “:” character and uncheck the First Occurrence field, Figure 9.

Figure 9

step 3 A 2 ***Discretize***

- now pay attention to the field "Discretize", Figure 10. Let´s keep the default Minimum Size Limit value at 2.90. The resulting discretization will be relatively rough with a modest amount of building blocks which will allow fast simulations.

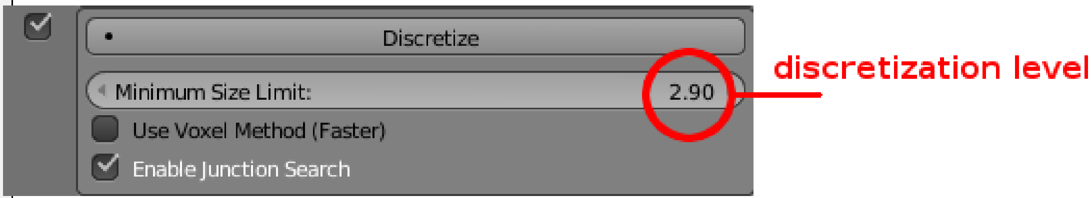


Figure 10

TIP:

-Lower the Minimum Size Limit value when you feel that you handle the simulation routine by heart and if you aim at more detailed simulations.

step 4 A 3 ***Do all selected steps at once***

- select the entire model by pressing the "A"- key on your keyboard.

- keep all the other fields in the Preprocessing Tools panel checked and press "Do All Selected Steps At Once", Figure 11.

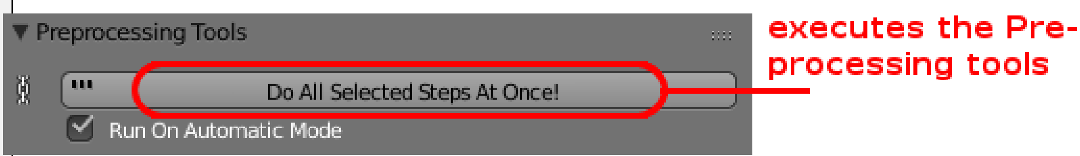


Figure 11 Do All Selected Steps At Once

-after a short while the model is discretized, a ground plane and foundation objects are added and the model is moved to the origin of Blender´s coordinate system, Figure 12.

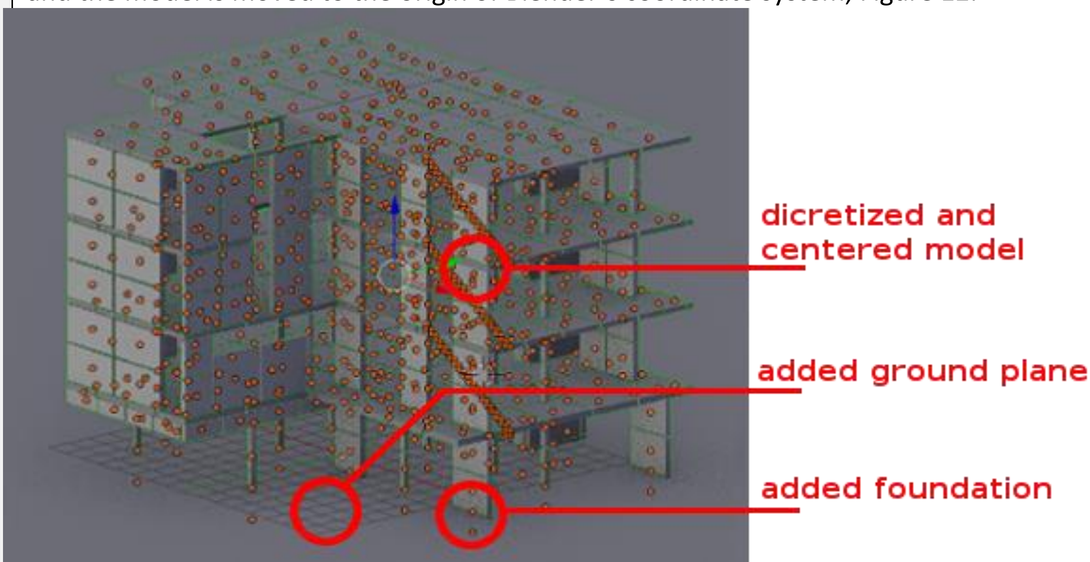


Figure 12 Discretized building model after the pre-processing tools have been executed

- close the Preprocessing Tools by clicking on the Preprocessing Tools header.

- save the Blender model

step 5

B

1

Element group list

- the model is now ready for the input of the element properties. Notice that the element group list is populated with the names of the newly created element groups, Figure 13. The values for the admissible forces (CPR, TNS, SHR, BND) as well as the connection type (CT) are default values and will be replaced in the following steps. Notice also the group “Foundation”. The foundation elements in this group where created automatically by the Preprocessing routine. Altogether you should have seven groups in your list.

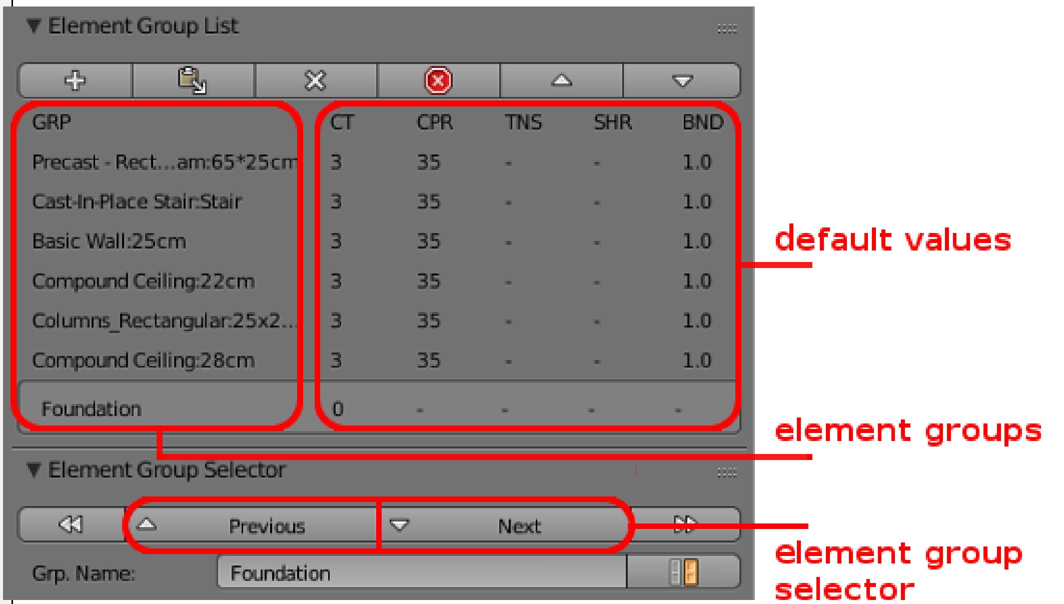


Figure 13 Element Group list with default strength values

step 6

B

2

Definition of element properties

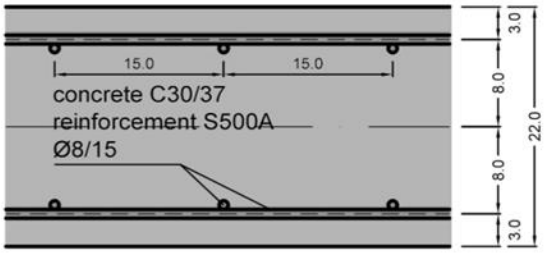
TIP:

-to bypass the following laborious input of element properties in this step 6, you can open the blender model with stored configuration settings in which the properties are already defined, refer to download section 2.3. The properties will be loaded by pressing the “Load config data” button, Figure 14.

Figure 14

- please continue with step 8 of this exercise.

- open the document “Multi-Family House Description.pdf” and refer to the specification charts of each group of reinforced concrete elements: ceilings, beams, walls, columns and stairs. Figure 15 shows the specifications of the first group “Compound Ceiling:22cm” from which we will gain the properties. Notice that this element does not have stirrups! Let´s write the element properties into the Formula Assistant.



Level	Member Thickness	Member Width(part)	Bars ø	Bar Distance	Bar Amount 2*(width/Dist)	Concrete Cover	Strengths Fs/Fc
[-]	[mm]	[mm]	[mm]	[mm]	[-]	[mm]	N/mm^2
2,3,4	220	1500	8	150	20	30	500/30

Figure 15 Specifications of the element group “Compound Ceiling:22cm”

- to choose the element group in the element list press the “Previous” respectively “Next” arrow in the Element Group Selector, see Figure 13. With the element group “Compound Ceiling:22cm” selected go to the Formula Assistant section click on “Type of Building Material” and choose “Reinforced Concrete (Walls & Slabs)”, Figure 16.

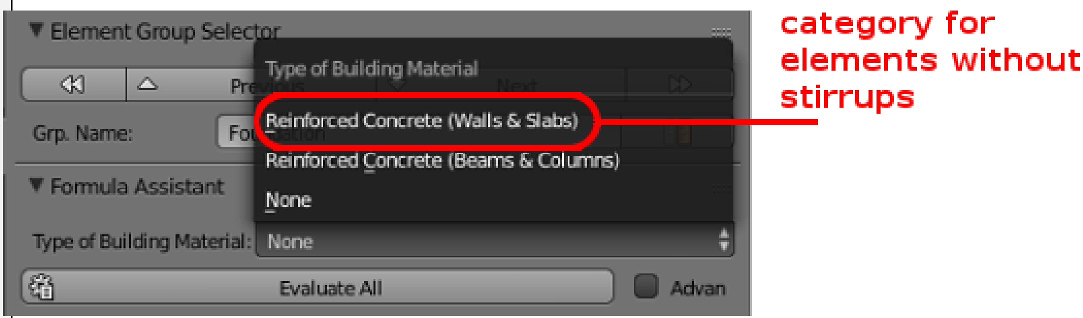


Figure 16

- this will open the fields where we need to insert the element parameters. Replace the default values with the values you find in the ceiling chart. After the default values are replaced the values in the Formula Assistant should look as in Figure 17.

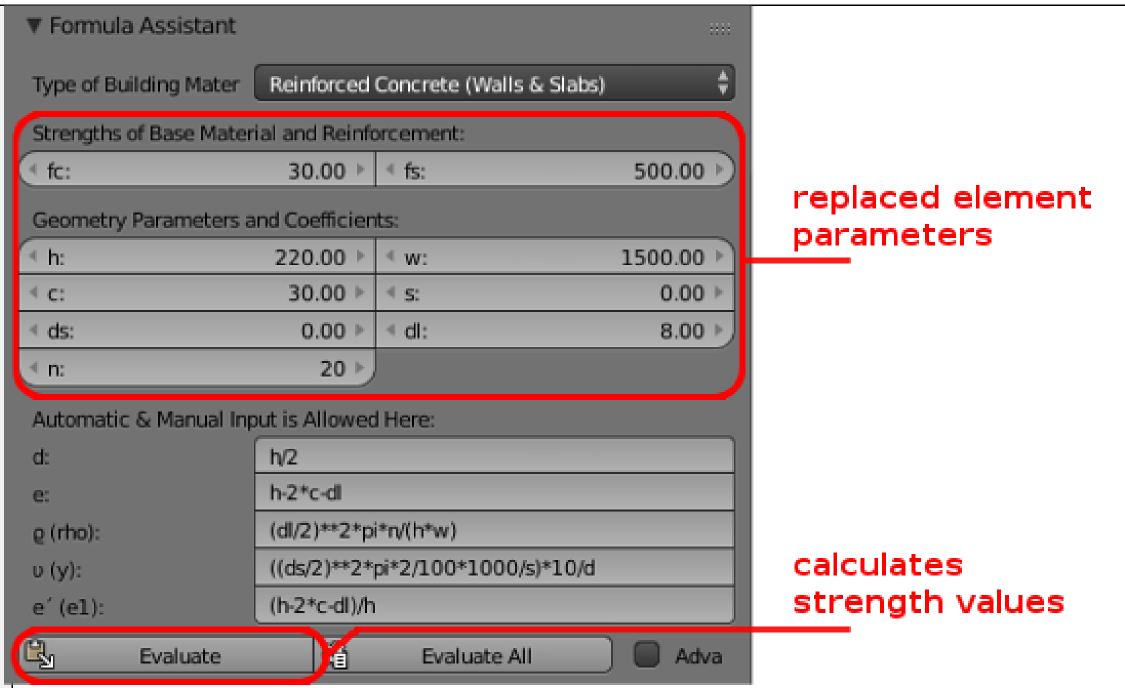
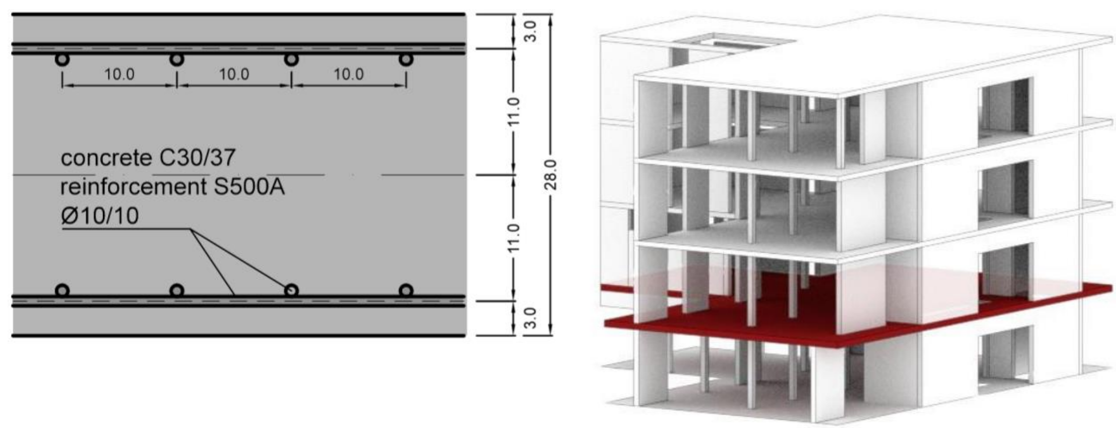


Figure 17 Formula assistant with specific element parameters for the group "Compound Ceiling:22cm"

- now click on "Evaluate" in the bottom of the Formula Assistant section (Figure 17) this will calculate the admissible strength for this group.

- we need to repeat step 6 for each of the other element groups. Refer to the next group "Compound Ceiling:28cm" in the document building description.



Level	Member Thickness	Member Width(part)	Bars ø	Bar Distance	Bar Amount 2*(width/Dist)	Concrete Cover	Strengths Fs/Fc
[-]	[mm]	[mm]	[mm]	[mm]	[-]	[mm]	N/mm²
1	280	1500	10	100	30	30	500/30

Figure 18 Specifications of the element group "Compound Ceiling:28cm"

- after the default values for this group are replaced, the values in the Formula Assistant should look as in Figure 19.

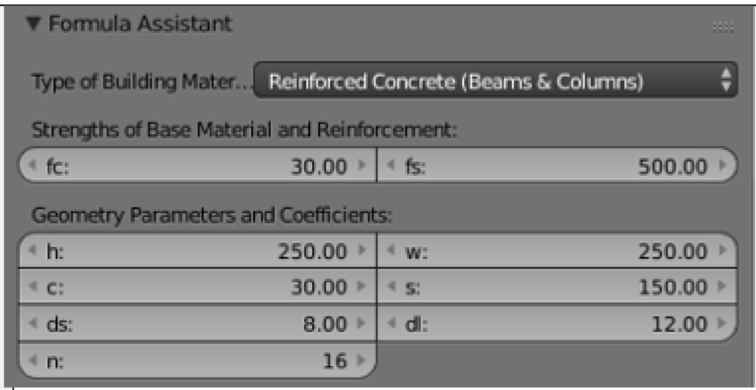
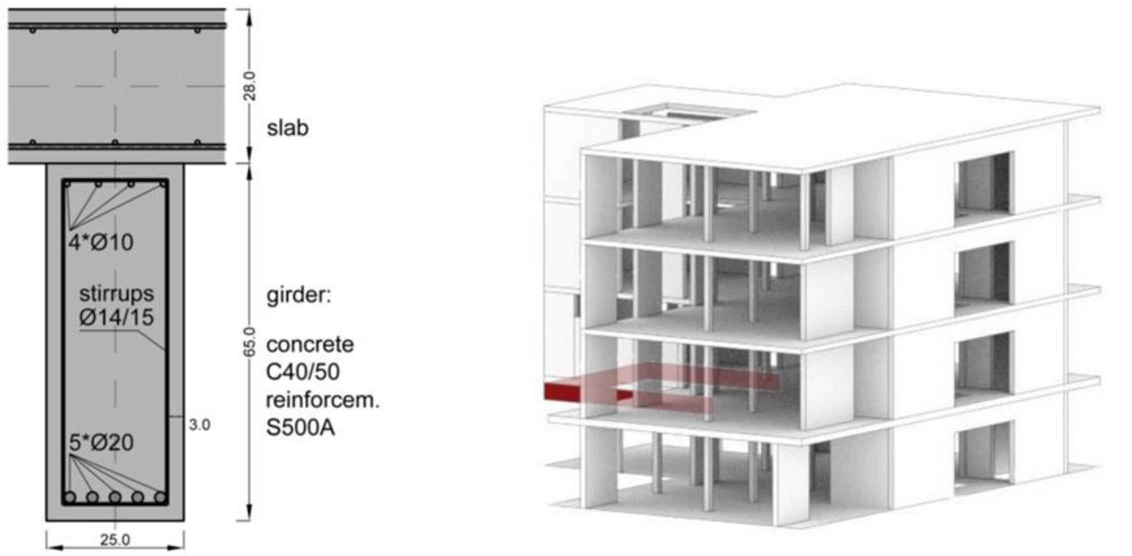


Figure 19 Formula assistant with specific element parameters for the group ""Compound Ceiling:28cm"

- click on "Evaluate" in the bottom of the Formula Assistant section this will calculate the admissible strength for this group.

- refer to the next group "Precast - Rectangular Beam:65*25cm" in the document building description.



Member Width	Member Height	Lower longitu-dinal Bars, ø	Lower longitudi-nal Bars, Amount	Stirrup ø	Stirrup Distance	Concrete Cover	Strengths Fs/Fc
[mm]	[mm]	[mm]	[-]	[mm]	[mm]	[mm]	N/mm^2
250	650	200	5	14	150	30	500/40

*Figure 20 Specifications of the element group "Precast - Rectangular Beam:65*25cm"*

- please note that this element has stirrups go to the Formula Assistant section click on "Type of Building Material" and choose "Reinforced Concrete (Beams & Columns)", Figure 21.

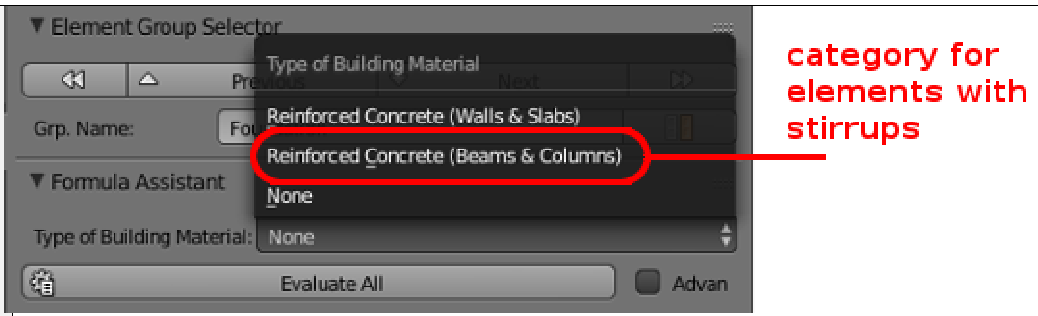


Figure 21 Type of building material, choose Beams & Columns for elements with stirrups

- after the default values for this group are replaced, the values in the Formula Assistant should look as in Figure 22.

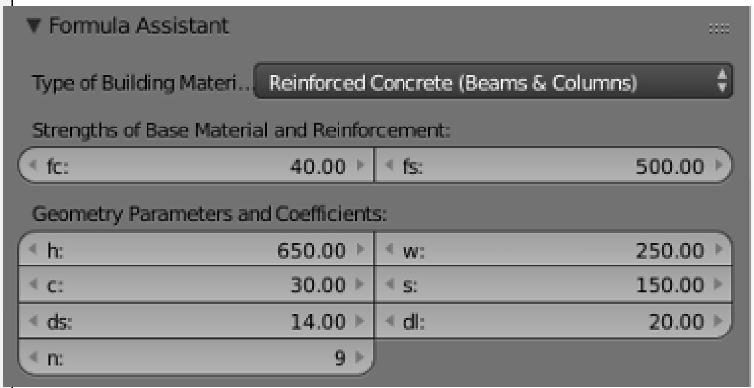


*Figure 22 Formula assistant with specific element parameters for the group "Precast - Rectangular Beam:65*25cm"*

- click on "Evaluate" in the bottom of the Formula Assistant section this will calculate the admissible strength for this group.

- refer to the next group "Basic Wall:25cm" in the document building description.

Member Thickness	Member Width(part)	Bars ø	Bar Distance	Bar Amount (width/Dist)	Concrete Cover	Strengths Fs/Fc
[mm]	[mm]	[mm]	[mm]	[-]	[mm]	N/mm^2
250	1500	10	150	10	125	500/30

Figure 23 Specifications of the element group "Basic Wall:25cm"

- please note that this element has no stirrups go to the Formula Assistant section click on “Type of Building Material” and choose “Reinforced Concrete (Walls & Slabs)”.

- after the default values for this group are replaced, the values in the Formula Assistant should look as in Figure 24.

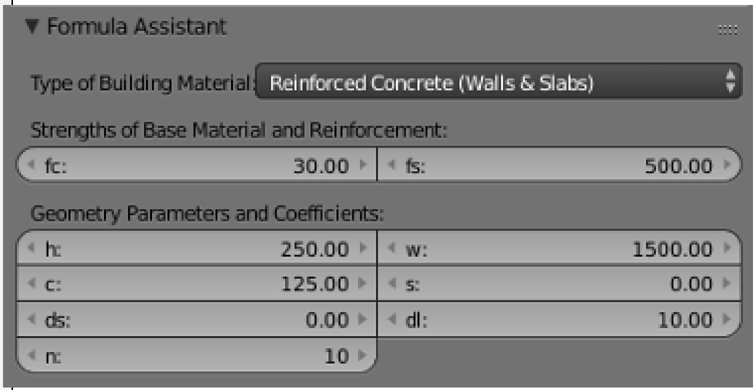
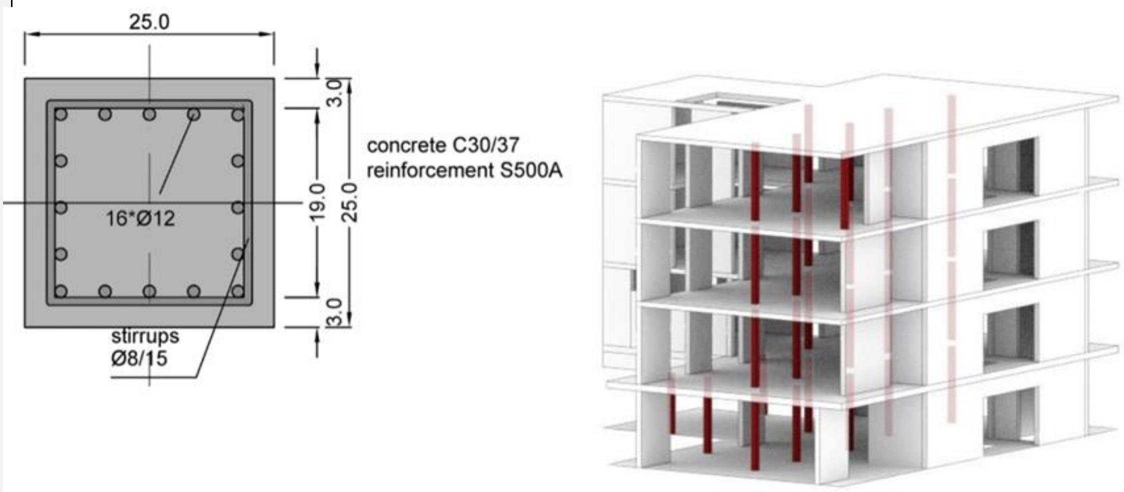


Figure 24 Formula assistant with specific element parameters for the group “Basic Wall:25cm”

- click on “Evaluate” in the bottom of the Formula Assistant section this will calculate the admissible strength for this group.

- refer to the next group “Columns Rectangular:25x25cm” in the document building description.



Member Width	Member Length	Longitudinal Bars ø	Longitud. Bar Amount	Stirrup ø	Stirrup Distance	Concrete Cover	Strengths Fs/Fc
[mm]	[mm]	[mm]	[-]	[mm]	[mm]	[mm]	N/mm^2
250	250	12	16	8	150	30	500/30

Figure 25 Specifications of the element group “Columns Rectangular:25x25cm”

- note that this element has stirrups go to the Formula Assistant section click on “Type of Building Material” and choose “Reinforced Concrete (Beams & Columns)”.
- after the default values for this group are replaced the values in the Formula Assistant should look as in Figure 26

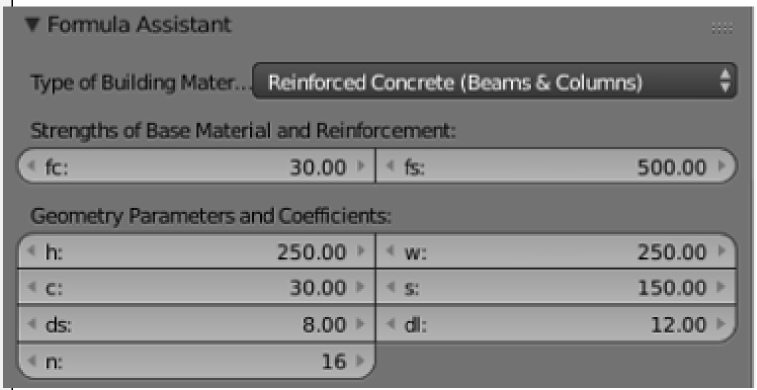
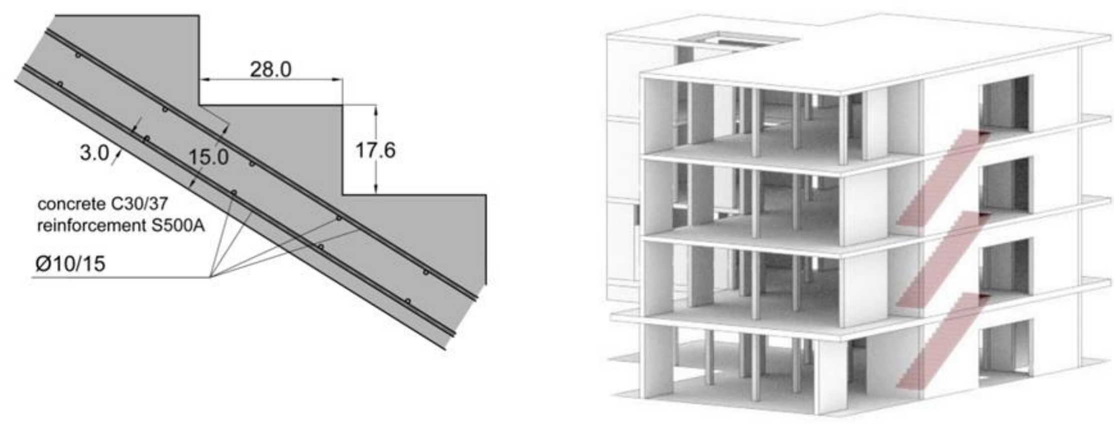


Figure 26 Formula Assistant with specific element parameters for the group "Columns Rectangular:25x25cm"

- click on "Evaluate" in the bottom of the Formula Assistant section this will calculate the admissible strength for this group.

- refer to the last group "Cast-In-Place Stair:Stair" in the document building description.



Member Thickness	Member Width(part)	Bars ø	Bar Distance	Bar Amount 2*(width/Dist)	Concrete Cover	Strengths Fs/Fc
[cm]	[cm]	[mm]	[cm]	[-]	[cm]	N/mm^2
15	150	10	15	20	3	500/30

Figure 27 Specifications of the element group "Cast-In-Place Stair:Stair"

- please note that this element has no stirrups go to the Formula Assistant section click on "Type of Building Material" and choose "Reinforced Concrete (Walls & Slabs)".

- after the default values for this group are replaced, the values in the Formula Assistant should look as in Figure 28.

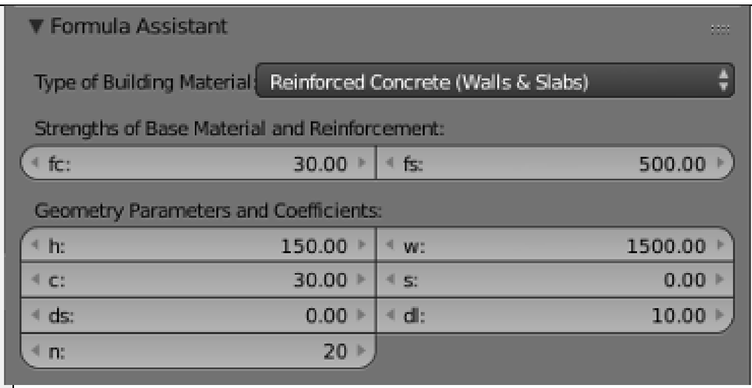


Figure 28 Formula assistant with specific element parameters for the group "Cast-In-Place Stair:Stair"

-click on "Evaluate" in the bottom of the Formula Assistant section this will calculate the admissible strength for this group. We are now done with the definition of the element properties.

step 7

3

Element Group Settings- connection type

- next we need to determine the connection type for each element group. Open the Element Group Settings. In the field Connection Type replace the default value with 22, Figure 29. (With this connection type the BCB will place six generic constraints and one spring constraint at each of the element connections.) For the Element groups "Compound Ceiling:28cm" and "Compound Ceiling:22cm" add a Live Load of 250 kg/m2, Figure 29.

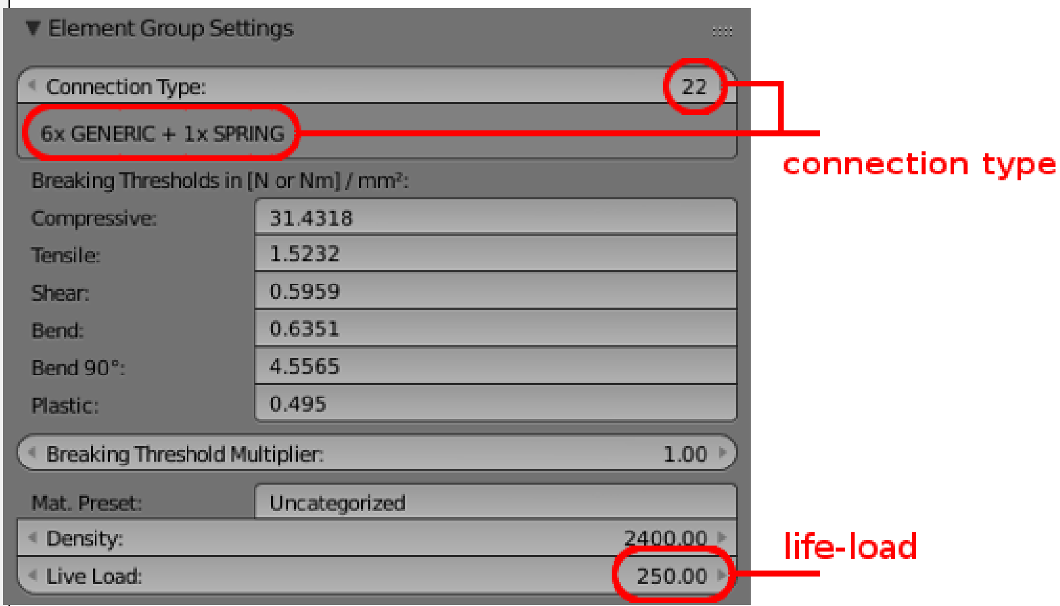


Figure 29 Connection type 22 and life load

- to close this step it is advised to save the element configuration, Figure 30 and then save the Blend file. The settings can now be reloaded each time the Blend file is opened.

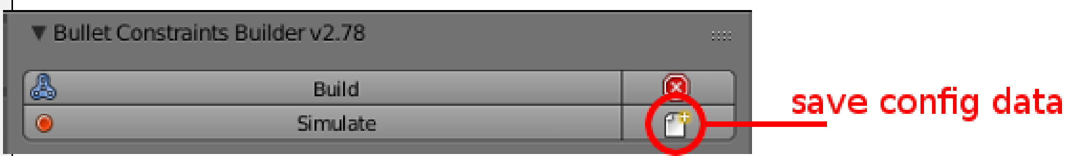


Figure 30 Saving the element setting configuration

TIP:

- element configurations can be stored globally so they can be exported to other building models. To store an element configuration globally open the Global Settings tab and export the configuration data. To reuse this configuration in another model just import this data, Figure 31*.*

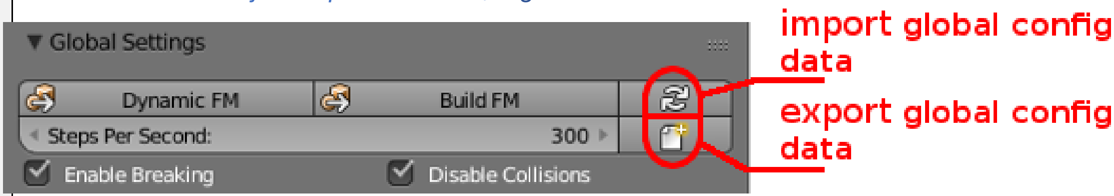


Figure 31 Saving and loading element setting configurations for use in other models

TIP:

- in absence of predefined Element Groups and engineering blue prints or if the building is modelled in Blender and element groups have been created manually, pre-set properties can be applied. After the element groups have been created manually add a pre-set element groups to the Element Group List, Figure 32, then choose a pre-set element type from the list, Figure 33. Type the name of the manually created element group into the Group Name field, Figure 34.

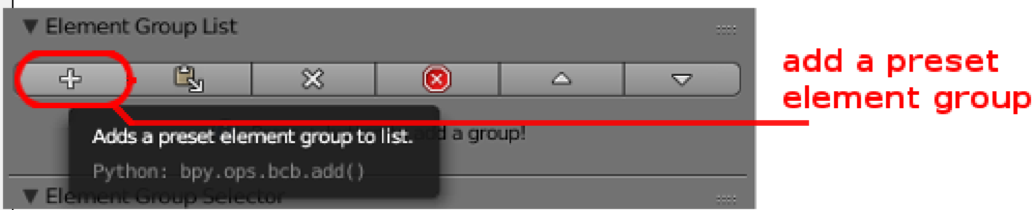


Figure 32 In the header of the element group list add a pre-set element group

Figure 33 Choose from the available element presets

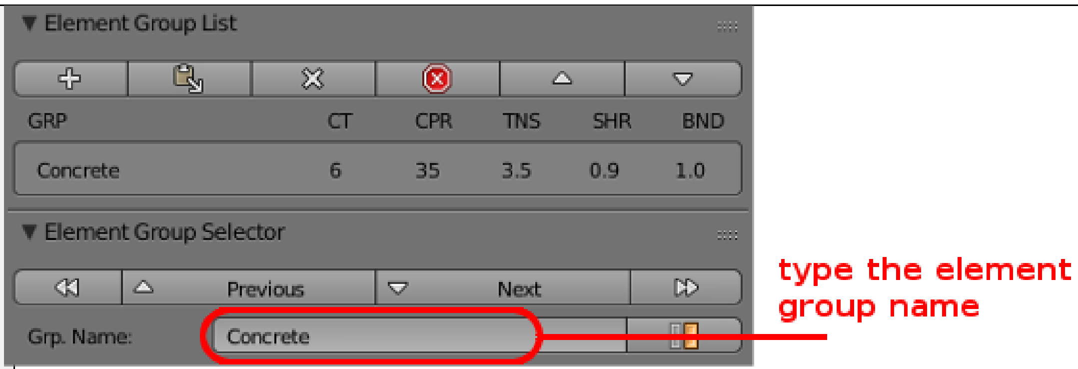


Figure 34 Type the element group name

step 8

1

Build constraints

- the BCB has now all the necessary information to connect the building elements with each other. Select the entire model by pressing the "A"- key on the keyboard, then press "Build" in the main BCB user Interface, Figure 35. After around two minutes the connections have been created.

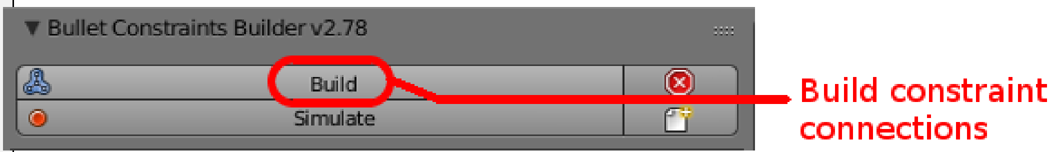


Figure 35 Building will create the connections between the elements

- note that there are now gaps between the elements, the newly created constraints are placed in between. The BCB moved the constraint setup on the next available Blender layer, Figure 36. Keep this layer switched off as the constraints don't need further consideration.

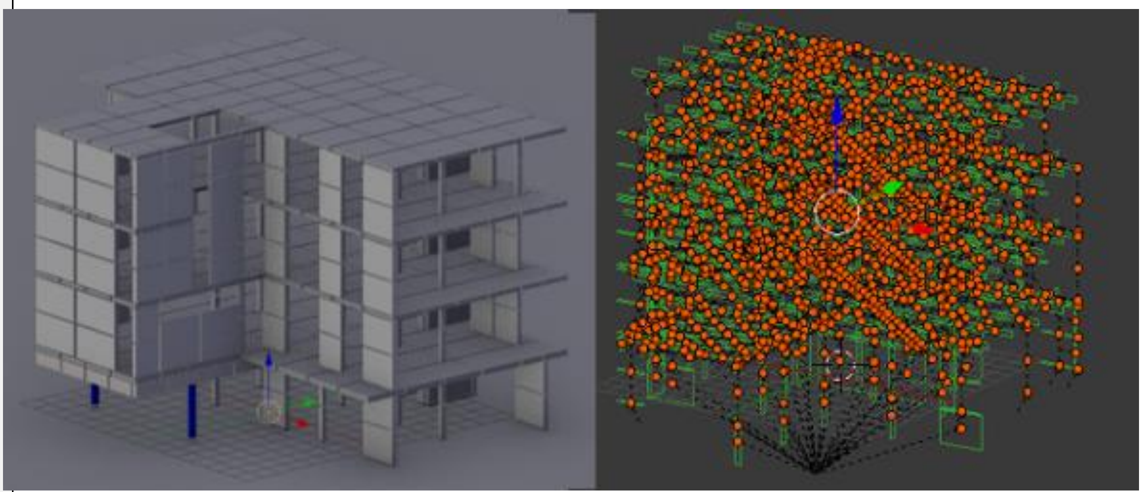


Figure 36 The connection setup, the BCB moved the constraints to the next free Blender layer

- Save the Blender model. Use this model for any subsequent simulation.

Trouble shooting:	Problem: When pressing "Build" nothing happens.	*Possible solution:* *-Are there element groups in the Element Group List?* *-Are all elements selected when pressing "Build"?*

step 9

Define the collapse scenario

- now, we will define the collapse scenario. Let´s assume that this house is located beside a busy road and a truck got of that road, hit and destroyed the two basement pillars that support the cantilever extension. Delete the two pillars shown in blue in Figure 36.

step 10

2

Start simulation

- we are ready for simulation. Press “Simulate” in the main BCB interface, Figure 37. For this it is advised to have a viewport with the timeline open. The simulation will stop at frame 250.

Figure 37 “Simulate” will start the simulation

- the progress of the simulation can now be followed in the 3D viewport. The collapsed model is shown in Figure 38. The simulation can be replayed in real time by pressing “`alt`”+ “`A`”-key.

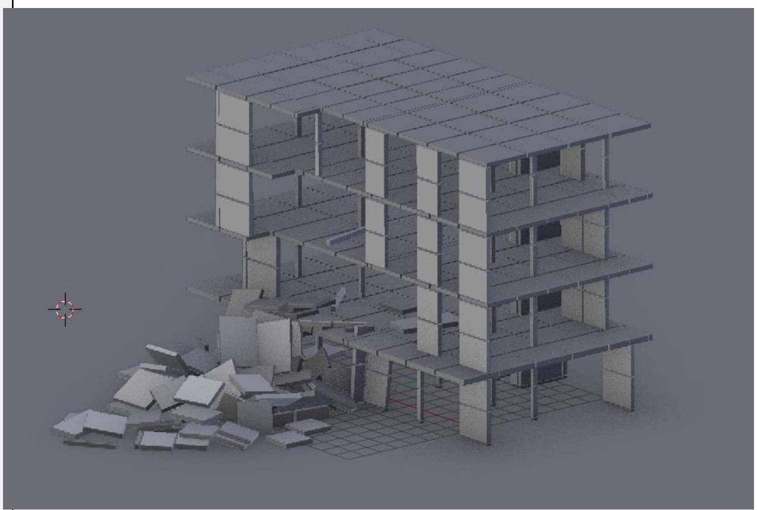


Figure 38 Model after simulation

- to repeat the simulation with another collapse scenario it is advised to use the Blender model that was stored in step 8. However, reversing the deletion of the columns in the previous step by pressing `ctrl`”+ “`Z`”- key might work in many cases as well.