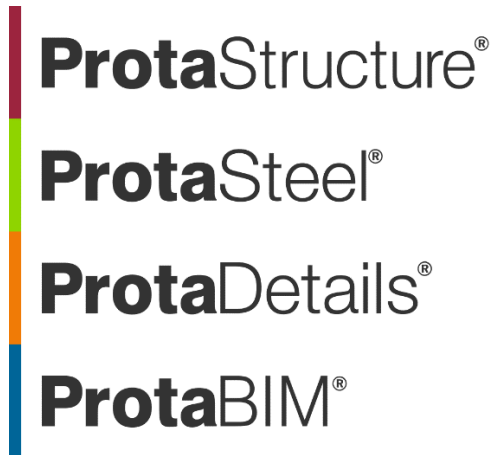




ProtaStructure Design Guide

Flat Slab and Raft Design with Slab Patch Panels

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Please contact us for your training and technical support queries

asiasupport@protasoftware.com

globalsupport@protasoftware.com

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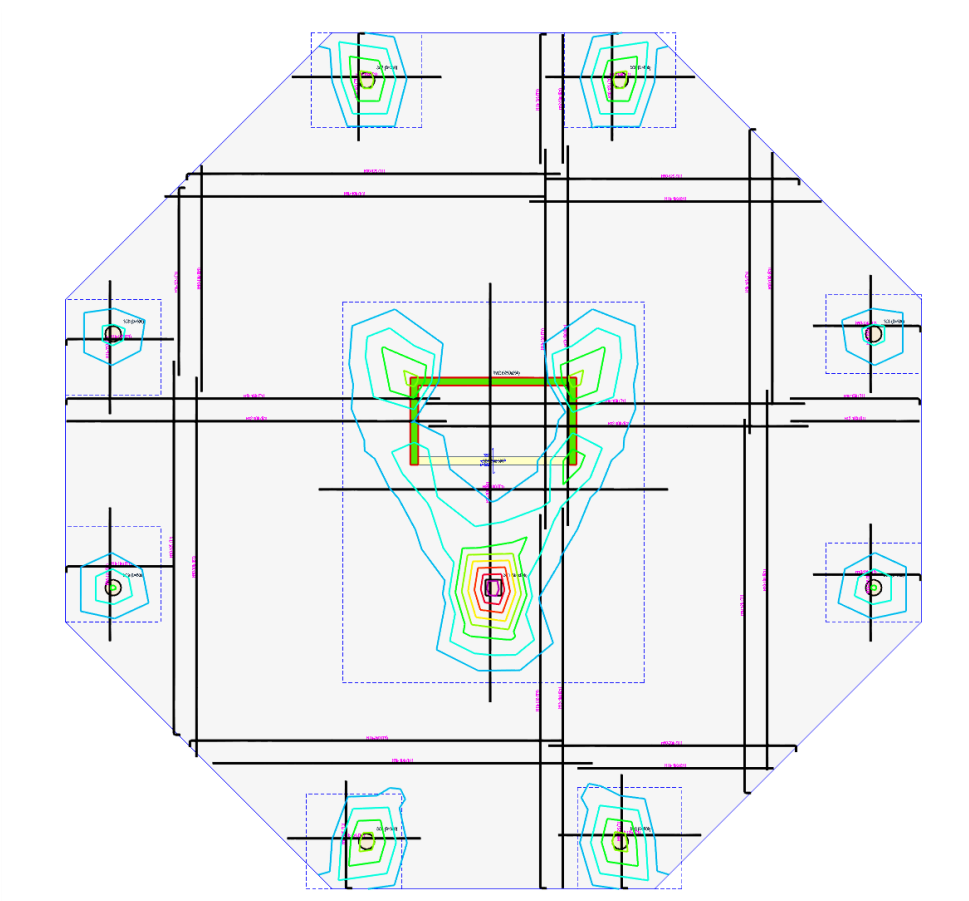
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Slab Design with Slab Patch Panels

A powerful feature in ProtaStructure for economical and practical design of flat slabs and raft foundations is to use a base reinforcement in the entire floor and calculate additional support bars at column regions. In **ProtaStructure 2024**, you can achieve this with the help of **Slab Patch Panels**. See the quick peek at what the final output looks like.



Flat Slab reinforcement design with Base Reinforcements and Additional Slab Patch Panel Reinforcements. FE Contours for Direction-1 Top Reinforcement (Asd1-Top) are also displayed on the floor plan.

A Quick Summary

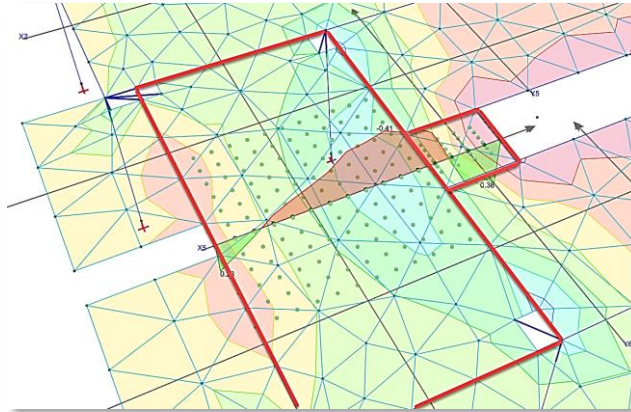
ProtaStructure provides powerful tools for the design of beam-slab, flat slab, rib/waffle slab, and raft foundation systems. The methods that you can use to design the slabs in ProtaStructure are:

- Beam-Slab Systems: Moment Coefficient Method and Finite Element Method
- Rib/Waffle Slabs: Finite Element Method
- Flat Slabs: Finite Element Method
- Raft Foundations: Finite Element Method

The Moment Coefficient method is an approximate method outlined in the design codes for beam-slab systems with regular geometry, spans, and loading. ProtaStructure automatically calculates the necessary coefficients by checking the slab continuities. Just stretch an **“Analytical Slab Strip”** across the slabs you want to design.

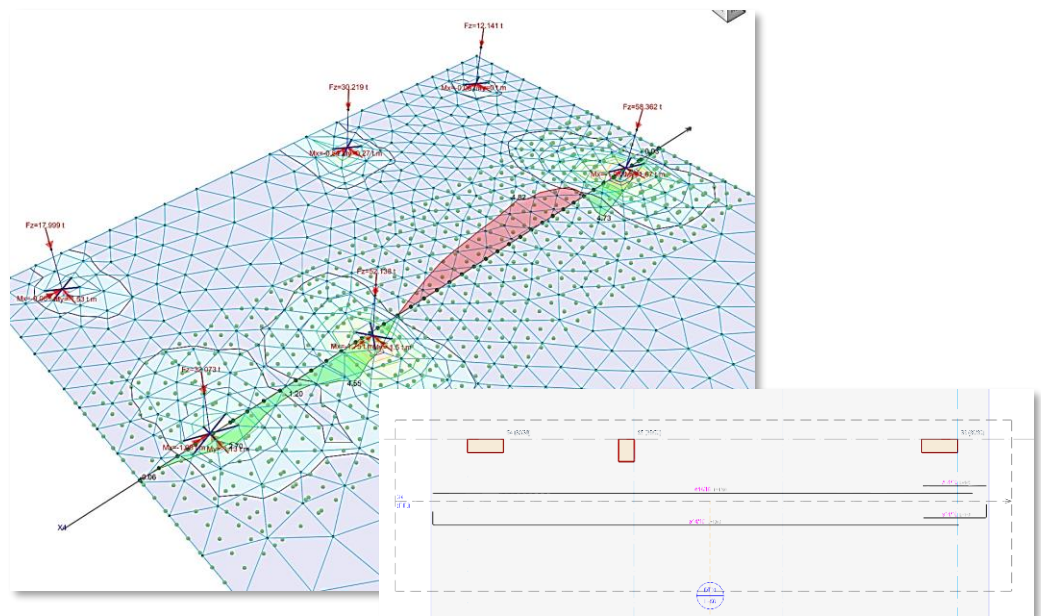
Finite Element method requires an “**FE Span Strip**” or “**FE Fixed Band Strip**” to be inserted across the slabs. Unlike an analytical slab strip, an FE slab strip collects results from its longitudinal and transverse station points and creates a bending moment diagram.

You can use the **FE Span Strips** for beam-slab systems. It automatically collects bending moment results from the span of the slabs, it encompasses and designs the required support and span reinforcement.



FE Span Strip and the station points. FE Span strips collect results from the span of encompassing slabs

FE Fixed Band Strip is a general-purpose reinforcement design tool for flat slabs and raft foundations. An FE Fixed Band strip has a tributary area, and collects results from its longitudinal and transverse station points, creating a bending moment diagram along its length. The longitudinal stations consider the maximum or average value by integration, while getting transverse station results.



FE Fixed Band Strip and the station points for a raft foundation (column outlines included)

FE Fixed band strip is a powerful and handy tool. However, with every FE tool, one must pay special attention to some points emerging from the nature of FE analysis and design methodology. An FE Fixed Band strip designs the top and bottom rebar according to the maximum value obtained through the stations. In other words, when the FE Fixed Band strip encounters a column node, it picks up the

peak hogging moment and designs the top or bottom bars according to this critical support moment. It may yield an uneconomical design for the span where such a peak moment is unexpected.

ProtaStructure has several advanced tools to remedy this inevitable outcome:

1. Option to **exclude column nodes** from result collection,
2. Option to **average the column node results** with the adjacent shell nodes,
3. Option to use “**Integral Fixed Band Strip**” to use an area average of transverse points to smoothen out peak hogging moments,
4. Option to create the **floor mesh around the column outlines** (subtracting the column section from the FE Mesh)

In addition to these options, you must pay attention to keeping the strip tributary area **sufficiently narrow**. The larger the area, the lower the accuracy and feasibility of the design.

The New Feature: Slab Patch Panels

Knowing these facts about FE Fixed Band Strip, we introduced a new feature that allows our users to use a **Base Reinforcement throughout the entire floor** and design **additional top or bottom bars at column support regions**. This feature is called the **Slab Patch Panels**. Before delving into the details, the typical workflow is outlined below.

Recommended Workflow for using Slab Patch Panels

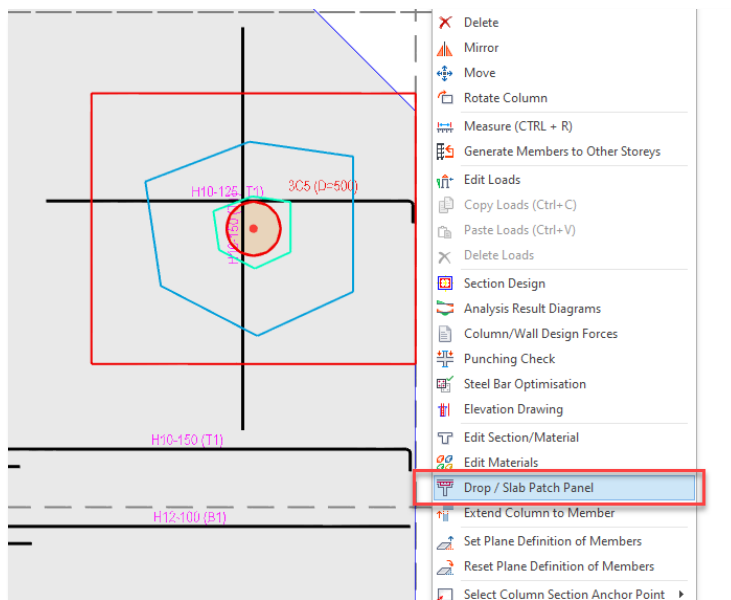
1. **(Optional Step)** Perform an **FE Floor Analysis** or a **Building Analysis** with the slabs meshed, and examine reinforcement contours to decide on the column patch areas where you will put additional rebars.
2. **(Required Step)** Insert **FE Fixed Band strips** for base reinforcement calculation. Fixed band strips allow you to decide and calculate the base reinforcement regions. Hence, it is important to first decide how many base reinforcement regions you will use.
3. **(Required Step)** Insert **slab patch panels**. Do not worry about the size of the patch panels yet. Ideally, they should cover the support moment contours. You can use an approximate size of 1.5x15 m or 2x2 m to start with. An FE Fixed Band strip should completely or partially cover slab patch panels in its tributary area.
4. **(Optional Step)** View the FE Reinforcement Contours on the physical floor plan view (such as $A_{sd1-top}$, $A_{sd2-top}$ for the upper floors, $A_{sd1-bot}$, and $A_{sd2-bot}$ for raft foundations). This will help you understand whether the patch sizes are large enough to cover the negative support moment regions.
5. **(Required Step)** Perform an **FE Floor Analysis** or a **Building Analysis** with the slabs meshed.
6. **(Required Step)** Design the slab reinforcements using the **Design > Slab** ribbon menu. The designed rebars will also be automatically drawn on the physical floor plan view with the correct lap splices and extensions. The additional bars in the patch regions will be automatically extended outside the designated patch area by anchorage length.

7. (Optional Step) Modify the size of slab patch panels if you need to. The most usual scenario would be to extend the patch region so that it covers more negative support moment contours. Optimizing the path region size can further reduce the base reinforcement (not less than the minimum required, A_{smin})
8. (Optional Step) Redesign the reinforcement using the **Design > Slabs** ribbon menu.
9. (Optional Step) Modify the base reinforcement and/or additional reinforcements on the **Design > Slabs** ribbon menu if you need to. If the edited reinforcement is not sufficient, ProtaStructure will issue a warning.

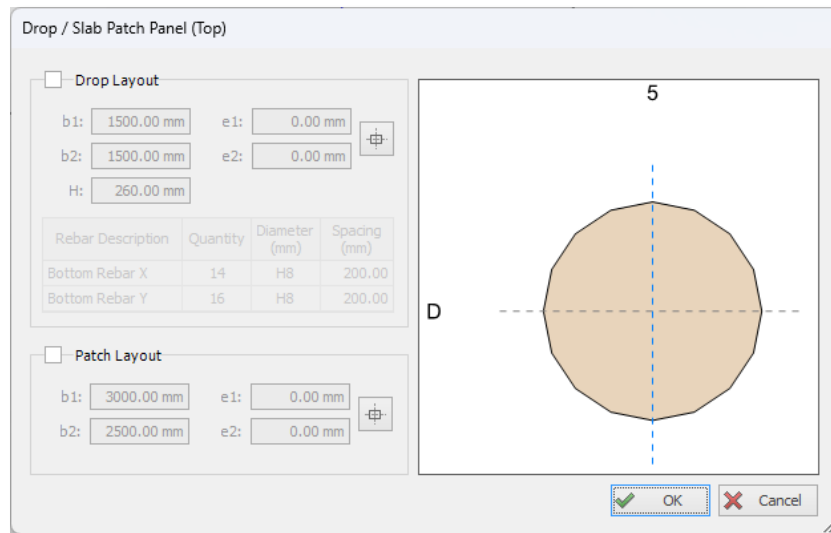
Assigning Slab Patch Panels to Columns

To insert a slab patch panel, follow these steps:

1. Select a column in the modeling environment.
2. Pick the “Drop / Slab Patch Panel” command on the Right-click menu.

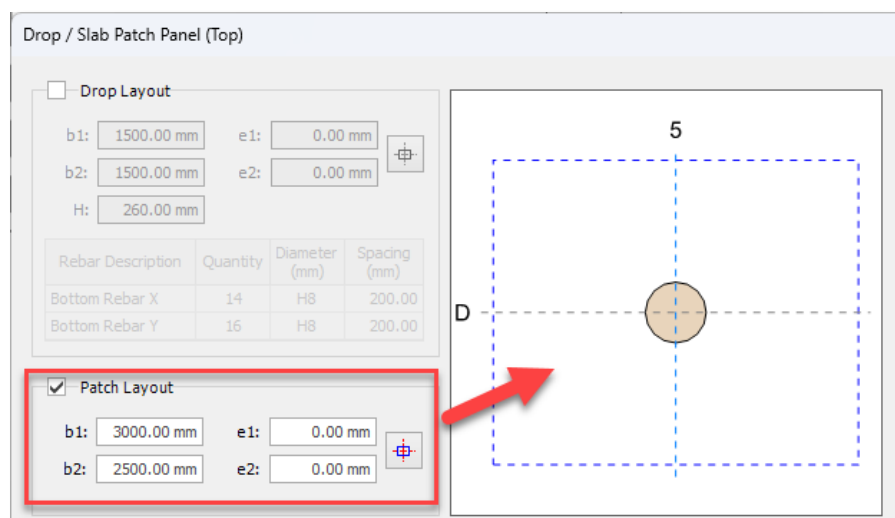


3. The “Drop / Slab Patch Panel” dialog will launch.
4. A **Column Drop** or a **Patch Panel** can be independently assigned to columns. In other words, column drop dimensions can be different than patch panels. Column drops are used to increase punching resistance and are irrelevant now. So, let’s continue with patch panels.



Drop / Patch Panel UI is used to assign a column drop or patch panel to a column. Initially, both options will be unchecked.

5. Check the **“Patch Layout”** checkbox and enter the patch panel dimensions and eccentricities. The schematic view on the screen will update and provide visual guidance as you change the values.



6. As soon as you check the **“Patch Layout”** checkbox, ProtaStructure automatically recognizes the **underlying Fixed Band strips** containing this patch panel and populates the **supplied steel information** on the window. You can see this information in the **“Slab Strip Base Reinforcement”** table.

☒ Patch Layout

b1: 3000.00 mm e1: 0.00 mm

b2: 2500.00 mm e2: 0.00 mm

Slab Strip Base Reinforcement

Slab Strip	Steel	Position	Supplied (mm ² /m)
X2	H10-150	Top	523.60
X2	H12-100	Bottom	1130.97
Y4	H10-125	Top	628.32
Y4	H10-100	Bottom	785.40

Patch Design Reinforcement

7. If the FE Analysis results are available in the memory, **ProtaStructure will automatically collect the FE results** from the designated stations within the patch panel and calculate the additional reinforcement inside the patch region. The design results will be presented in the “**Patch Region Reinforcement**” table. In this table, you can change the diameter and spacing of the rebars, as well as their extension styles and extension lengths. The design status will be updated upon your changes.

Y4	H10-125	Top	628.32
Y4	H10-100	Bottom	785.40

Patch Region Reinforcement

Rebar Description	Quant...	Dia...	Spacing	Left	Length	Right	Length	Moment	Provided/Required
		(mm)	(mm)		(mm)		(mm)	(kN.m...)	(mm ² /m)
Top Rebar X	21	H10	125.00	Lap	420.00	BOB	205.00	103.8	628.32>579.34 ✓
Top Rebar Y	21	H16	150.00	Lap	611.07	Lap	611.07	156.7	1340.41>1142... ✓

✓ Design

✓ OK ✗ Cancel

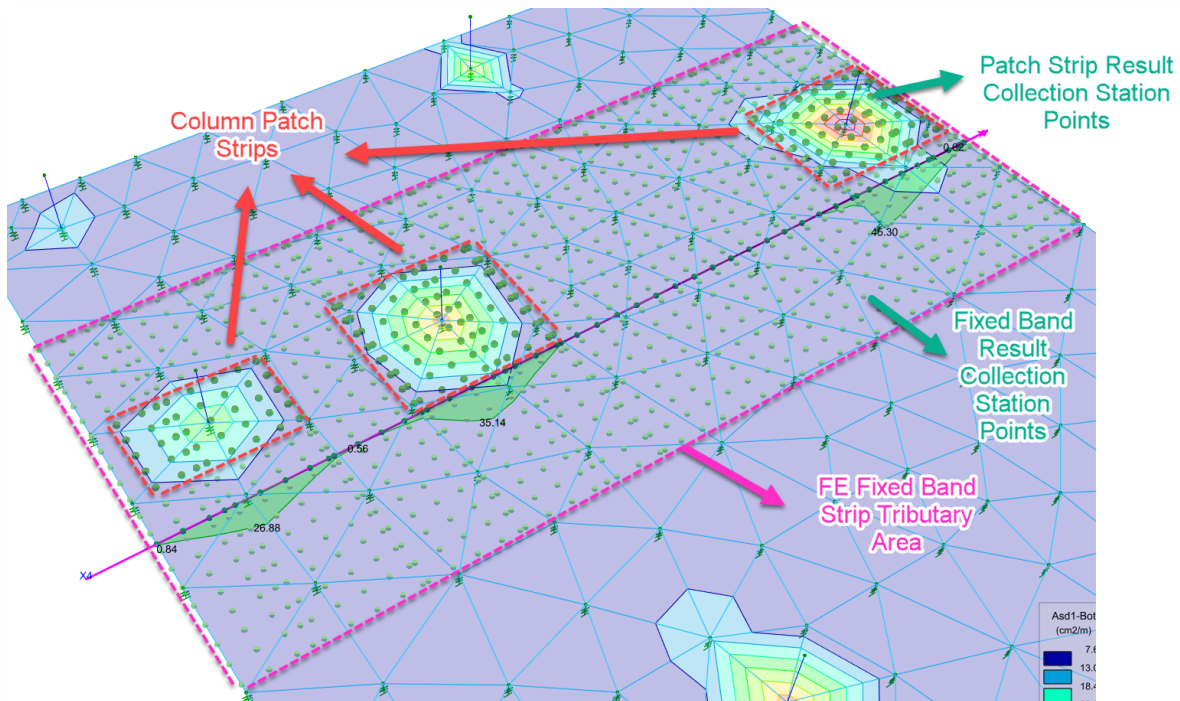
8. You can click on the “**Design**” button to reset the changes and do the design from scratch. ProtaStructure will redesign bar diameter and spacing. But, it will keep the bar extension style you have specified.

Assigning Patch Panels to Multiple Columns

If you want to assign patch panels to multiple columns, it is possible. Select multiple members on the screen and run the “**Drop / Slab Patch Panels**” command. The same window for a single member will open in a restricted mode, and you will be able to enter the geometric information only.

Base Reinforcement Design

An **FE Fixed Band Strip** is required for the design of base reinforcement. If the FE Fixed Band strip contains any slab patch panels in its tributary area, it will ignore the values inside the patch region and calculate the **top and bottom base reinforcement** using the **maximum values** collected outside the patch panel boundaries.



FE Fixed Band strip excludes the patch panels while collecting results from the mesh.

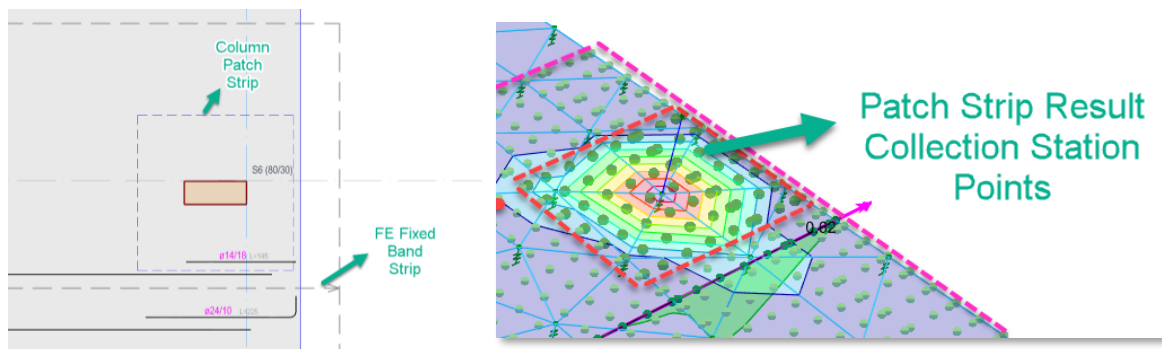
Important Remark

Fixed band strips should completely or partially cover the column patch panels. Otherwise, the Fixed Band strips will continue to collect bending moment results from **column nodes**, which may yield an uneconomical design. If you think a column support region does not have a significant negative moment, you have the freedom not to insert a patch panel for that column.

If you choose not to insert patch panels around a column, you must cover the column area with an FE Fixed Band. If you leave a particular column region uncovered by a Patch Panel or an FE Fixed Band Strip, the results in the column region will not be considered, and that column region will not be designed. **You may end up with an unsafe design.**

Additional Top or Bottom Reinforcement Design

A patch panel automatically collects results **from its interior points**. See the following figure:



A Slab Patch Panel already knows its associated FE Fixed Band Strip. Hence, the additional reinforcement is simply the difference between the maximum required by the patch region minus the provided reinforcement by the FE Fixed Band.

Important Information:

The Additional Reinforcement Calculation is different between the upper floors and foundation floors.

For the **upper floors**, only the additional top reinforcement is calculated by the formula:

$$A_{s \text{ TOP (Additional)}} = A_{s \text{ MAX TOP (Patch Region)}} - A_{s \text{ PROVIDED TOP (Fixed Band Strip)}}$$

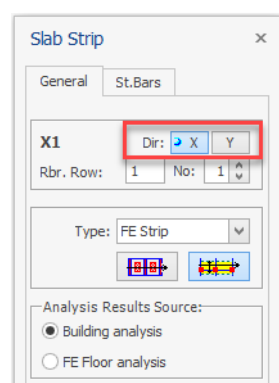
For the **foundation floors**, only the additional bottom reinforcement is calculated by the formula:

$$A_{s \text{ BOTTOM (Additional)}} = A_{s \text{ MAX BOTTOM (Patch Region)}} - A_{s \text{ PROVIDED BOTTOM (Fixed Band Strip)}}$$

Only the top additional bars are designed for the upper floors, whereas only the bottom additional bars are designed for foundations.

Important Remark:

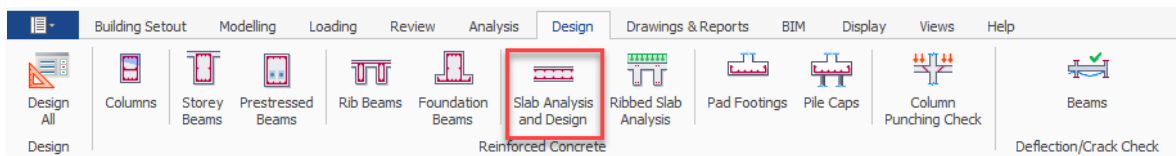
It is important to specify the **FE Fixed Band Direction** correctly. If the fixed band strip is along direction X (or direction 1, so to say), you should check **the X button** on the strip properties window. Similarly, if the fixed band strip is along direction Y (or direction 2), you should check the **Y Button**. Otherwise, patch panel reinforcement directions will be wrong.



Batch Design of All Slab Patch Panels and Strips

As soon as you insert **Fixed Band Strips** and **Slab Patch Panels**, the FE analysis results will be automatically collected behind the scenes, and reinforcement design will be automatically performed. The calculated reinforcements will also be drawn on the floor plan. In addition to this automated workflow, you can always **design all strips from scratch** or **perform a check design** from a central design interface. To open the batch design window:

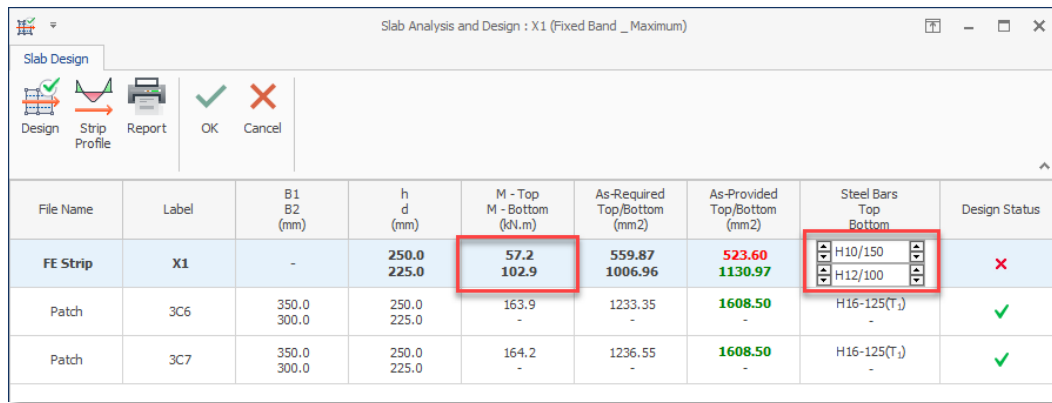
1. Insert all FE Fixed Band Strips and Slab Patch Panels.
2. Click “**Design > Reinforced Concrete > Slab Analysis and Design**” on the ribbon toolbar. The batch design window will open.



3. The batch design window displays all the slab strips (not the slab patch panels) in the model. You can review the strips’ **Storey, Type, Analysis Result Source, Encompassing Slabs, Design Status**, and **Rebar Information**.
4. Double-click one of the strips or click the **Interactive Design** button to see the details of the design.
5. If a Fixed Band Strip contains Slab Patch Panels, the **enclosed patch panels will be listed** under the Fixed Band Strip in the table.

Slab Analysis and Design : X2 (Fixed Band _ Maximum)								
Slab Design								
    								
File Name	Label	B1 B2 (mm)	h d (mm)	M - Top M - Bottom (kN.m)	As-Required Top/Bottom (mm ²)	As-Provided Top/Bottom (mm ²)	Steel Bars Top Bottom	Design Status
FE Strip	X2	-	250.0 225.0	45.9 108.0	448.64 1058.79	523.60 1130.97	H10-150 (T ₁) H12-100 (B ₁)	✓
Patch	3C1	950.0 1200.0	250.0 225.0	267.1 -	2774.10 0.00	3141.59 0.00	H20-100 (T)	✓
Patch	3C4	300.0 250.0	250.0 225.0	116.7 -	731.43 0.00	785.40 0.00	H10-100 (T)	✓
Patch	3C5	300.0 250.0	250.0 225.0	103.8 -	579.34 0.00	628.32 0.00	H10-125 (T)	✓
Patch	3C8	300.0 300.0	250.0 225.0	103.7 -	578.94 0.00	628.32 0.00	H10-125 (T)	✓
Patch	3C9	300.0 300.0	250.0 225.0	116.7 -	730.74 0.00	785.40 0.00	H10-100 (T)	✓

6. The FE Fixed Band Strip row will present the details for the calculated base reinforcement, such as **Design Moments M-Top** and **M-Bottom**, **As-Required Top/Bottom**, **As-Provided Top/Bottom**, **Selected Steel Bars Top/Bottom**, and **Design Status**.
7. **Design Moments** and **Required Steel Areas** are automatically calculated from the Strip Diagram, and you cannot change these values. However, you can change the **Selected Bars**. If selected bars are not sufficient, the **Design Status** will change to a **Red Cross Sign**.



File Name	Label	B1 B2 (mm)	h d (mm)	M - Top M - Bottom (kN.m)	As-Required Top/Bottom (mm2)	As-Provided Top/Bottom (mm2)	Steel Bars Top Bottom	Design Status
FE Strip	X1	-	250.0 225.0	57.2 102.9	559.87 1006.96	523.60 1130.97	H10/150 H12/100	✗
Patch	3C6	350.0 300.0	250.0 225.0	163.9 -	1233.35 -	1608.50 -	H16-125(T ₁) -	✓
Patch	3C7	350.0 300.0	250.0 225.0	164.2 -	1236.55 -	1608.50 -	H16-125(T ₁) -	✓

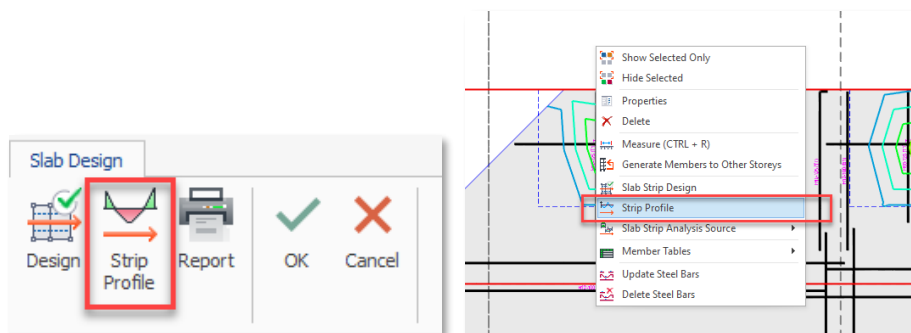
Interactive design window for a slab strip. All enclosed patch panels are listed underneath it. The top and bottom bending moments with 57.2 and 102.9 kNm values are fetched from the strip diagram. The rebars can be modified on this window.

Strip Profile (Diagrams)

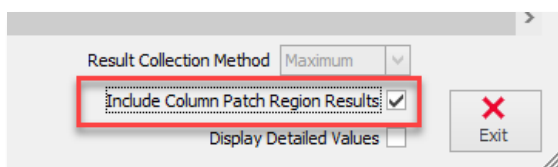
As explained above, an FE Fixed Band Strip collects results from longitudinal and transverse station points and generates **Deflection (δ)**, **Bending Moment (M)**, and **Bending Moment with Wood-Armer (Md)** diagrams.

The inclusion of Wood-Armer Effects in the design can be turned on and off using the **Settings > Slabs > Design > Wood-Armer Effects in Design** option.

The strip profiles are accessible through the interactive design window or strip right-click menu.

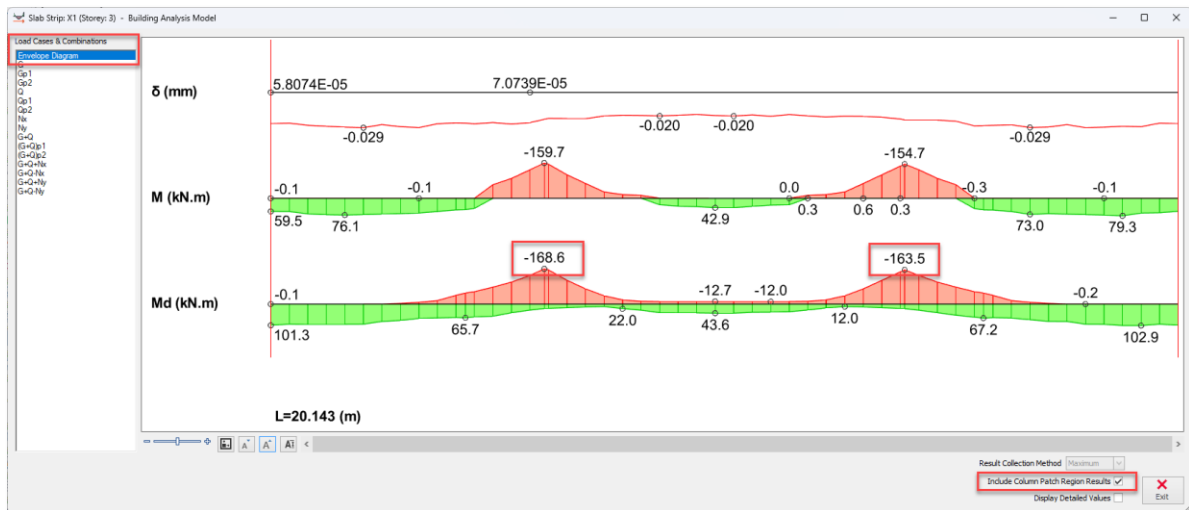


If there are enclosed patch panels within the tributary area of a fixed band strip, you will notice that “**Include Column Patch Region Results**” will be available on the strip diagram window. This option is included just for display purposes, so that you can review the results in detail.



Include Slab Patch Panel Results

When this option is checked on the diagram window, the results inside the patch panels will be included in the FE Fixed Band Strip diagram. You can notice the peak support moment.

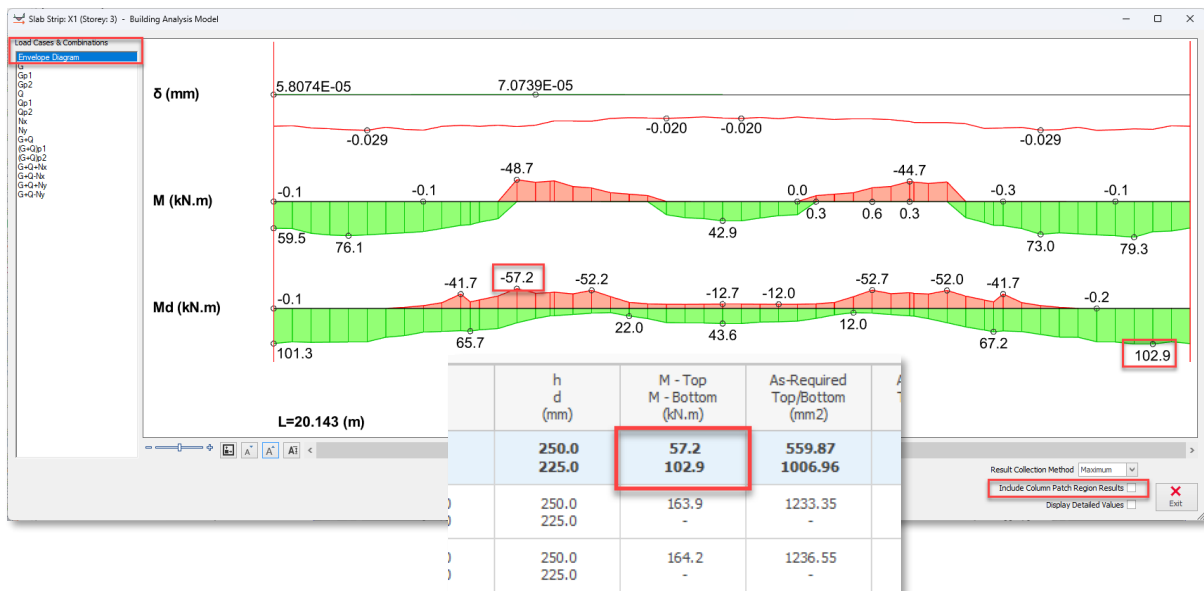


Do Not Include Column Patch Region Results

By default, the patch panel regions are excluded in FE Fixed Band strip results, and design is carried out accordingly. If this option is unchecked on the diagram window, the top bending moment results inside the patch regions will be excluded from the FE Fixed Band Strip diagram. This is the diagram used to calculate the **Top** and **Bottom Base Reinforcement**.

Important Remark

This is the default behavior in reinforcement design and cannot be changed.



In the diagrams above pay attention that the maximum negative moment is calculated as **168.6 kNm** in the absence of slab patch panels. This moment drops down to **57.2 kNm** when patch panels are present. The difference is compensated by the additional top reinforcement calculated in the associated slab patch panel. The same **102.9 kNm** positive moment is used for bottom reinforcement for both cases.

Thank You...

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