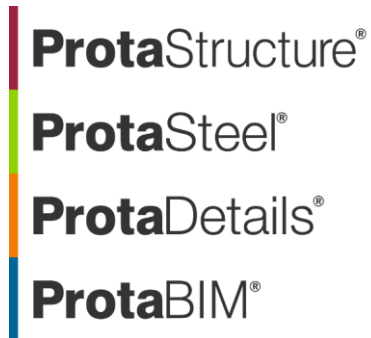




ProtaStructure Design Guide

Group Sum and Shearwall/Corewall Forces

Version 2.0

30 June 2022

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Introduction

This guide will provide clearance and verification on the shearwalls modeled with the finite element (FE) shell model. ProtaStructure utilizes the Group Sum methodology to calculate the total responses at the top and bottom of the shearwalls modeled with FE shell elements.

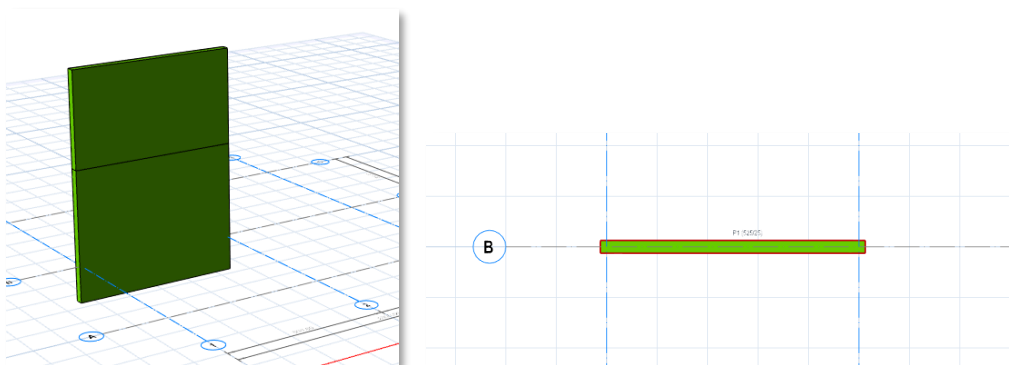
In the following models, various loading types are tested. ProtaStructure has an integrated option for exporting your model to general-purpose analysis packages, such as SAP2000. This guide will use this feature for results comparison.

The examples covered in this document use various static load cases to obtain shearwall responses. Seismic load cases are intentionally avoided to eliminate additional complexity and post-processing that general-purpose analysis packages do not usually perform, such as amplifying RSA results to EQS, accidental eccentricities, overstrength factors, and so on.

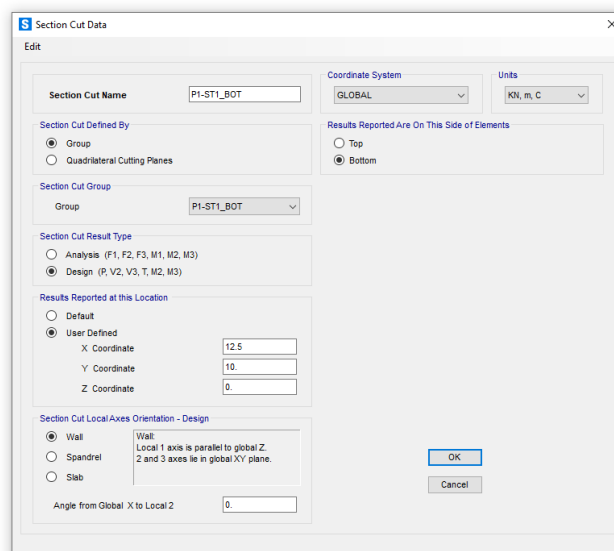
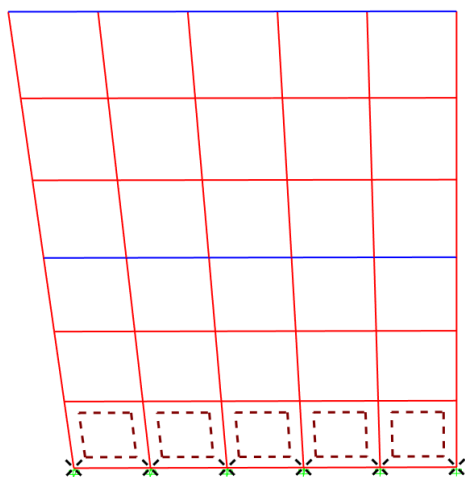
For simplicity, uncracked section properties are considered. ProtaStructure can consider cracked and uncracked load cases using different stiffness matrices in the same analysis run. Only cracked section properties are exported to SAP2000.

Case 1: Shearwall Under a Uniform Pressure Along Local Axis 3

A simple two-story shearwall was modeled in ProtaStructure. The wall has a cross-section of 5x0.25 m and a 3m storey height. FE Shell elements are used in analytical modeling.

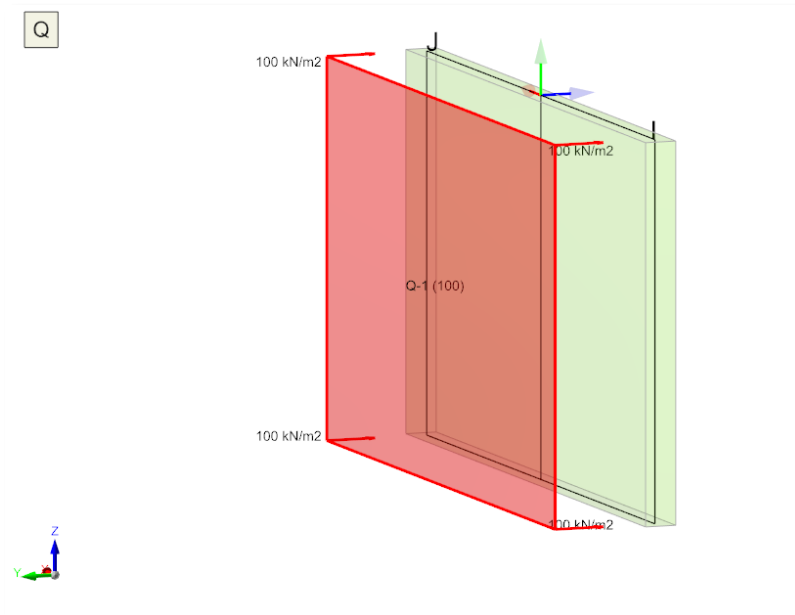


3D and Plan View of the shearwall in ProtaStructure



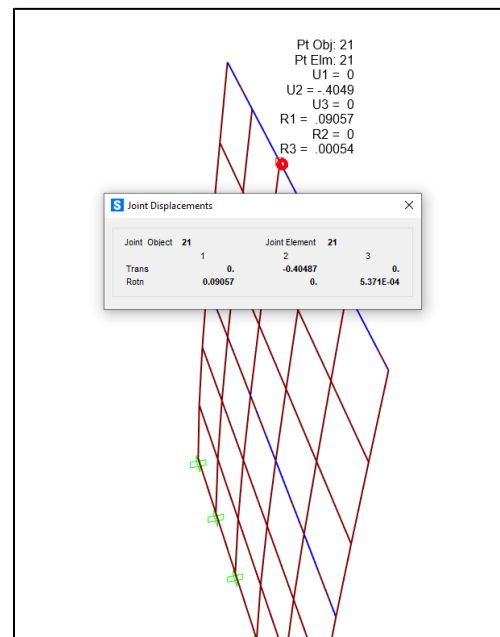
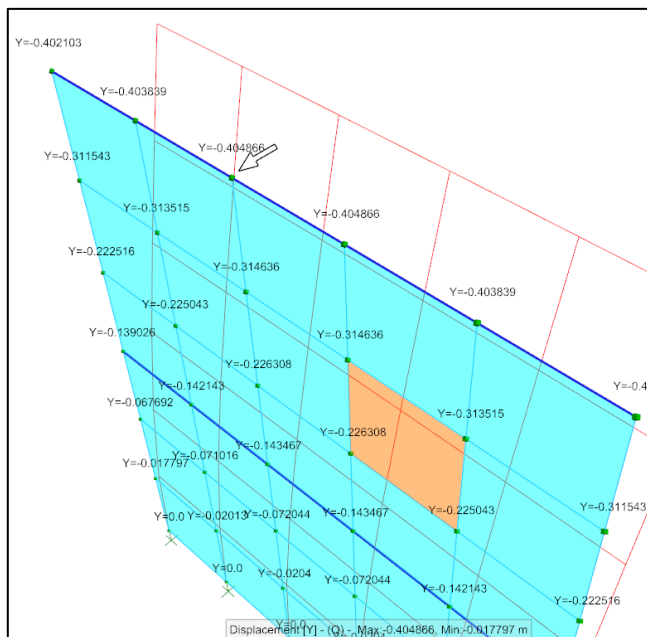
The same shearwall modeled in SAP2000 and section-cut definitions are assigned

Section-Cut definitions at the top and bottom of the wall panels are automatically transferred to SAP2000 when the analytical model is exported from ProtaStructure.

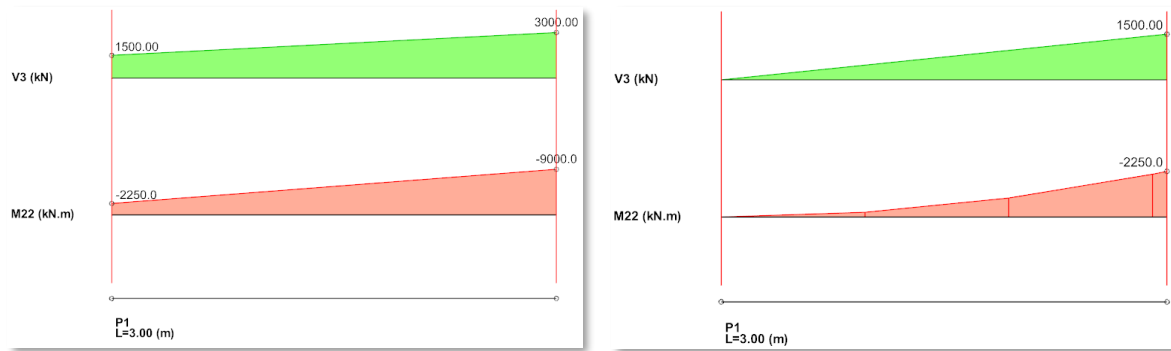


Uniform load assigned to shearwall along positive local axis 3

The shearwall is loaded with a 100kN/m^2 uniformly distributed area load along its positive local axis 3 (or global Y) in the Q load case. There are no other loads assigned in the Q load case for the sake of comparison.



Displacements in Y-Direction: ProtaStructure on the left and SAP2000 on the right.



Shear and moment diagrams of shearwall panels under Q load case in ProtaStructure.

Section Cut Forces - Design

Units: As Noted

Filter:

SectionCut Text	OutputCase	CaseType Text	P KN	V2 KN	V3 KN	T KN-m	M2 KN-m	M3 KN-m	GlobalX m	GlobalY m	GlobalZ m
P1-ST1_BOT	Q	LinStatic	0	0	-3000	9.659E-11	-9000	0	12.5	10	0
P1-ST1_TOP	Q	LinStatic	0	0	-1500	1.641E-10	-2250	0	12.5	10	0
P1-ST2_BOT	Q	LinStatic	0	0	-1500	1.145E-10	-2250	0	12.5	10	0
P1-ST2_TOP	Q	LinStatic	0	0	7.41E-11	-2.156E-11	-3.043E-11	0	12.5	10	0

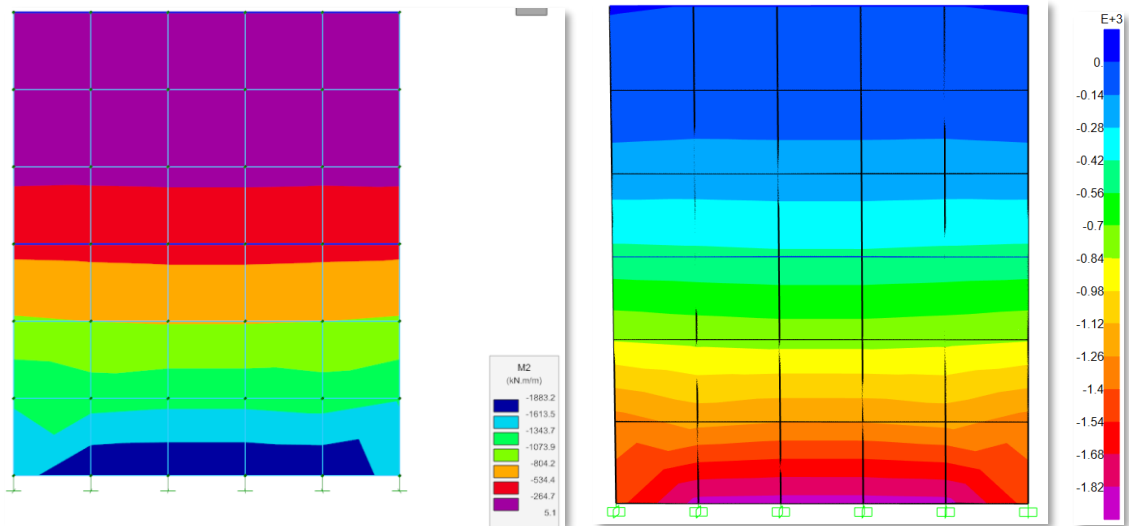
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Add Tables... Done

Section cut results representing shear and moment results under Q load case in SAP2000.

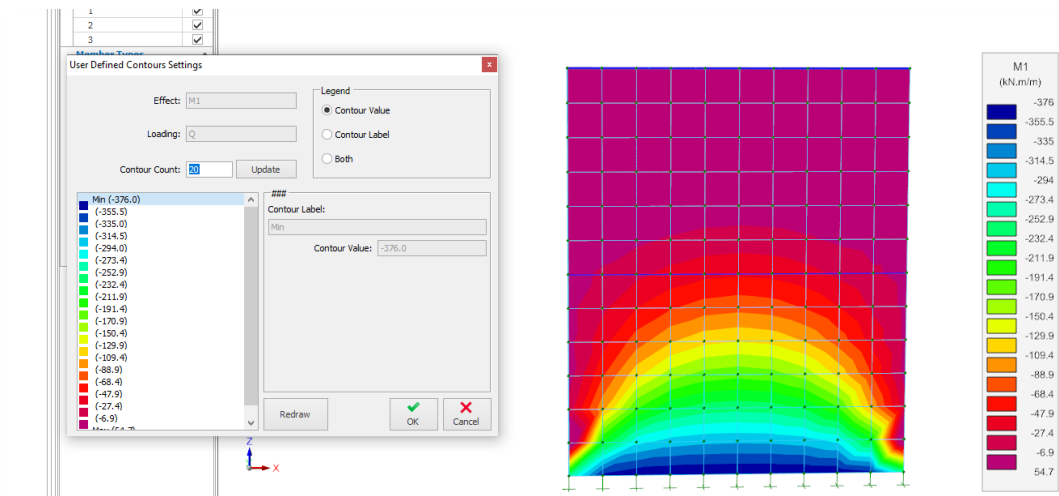
Results are summarized in the following table.

	ProtaStructure	SAP2000
Maximum Deformation at the Same Top Node	-0.404866 m	-0.40487 m
Shear Wall Base Moment, M22 (P1_ST1_BOT)	-9000 kN.m	-9000 kN.m
Base Shear Force, V3 (P1_ST1_BOT)	-3000 kN	-3000 kN

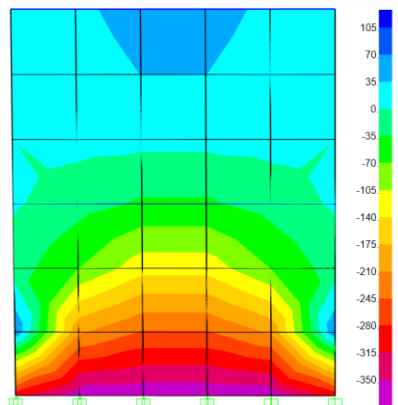


Contour comparison of M2 moments on shells ProtaStructure on the left, SAP2000 on the right

ProtaStructure interpolates contour lines from the results on joints at each corner of the shells. Hence, the mesh sensitivity should be considered when interpreting and comparing the results. Mesh size can be controlled via the “Building Analysis > Model Options > Shearwall Options”. Also, users can create user-defined contours to adjust contour boundaries and contour accuracy further. The results can be seen below for M1 moments.

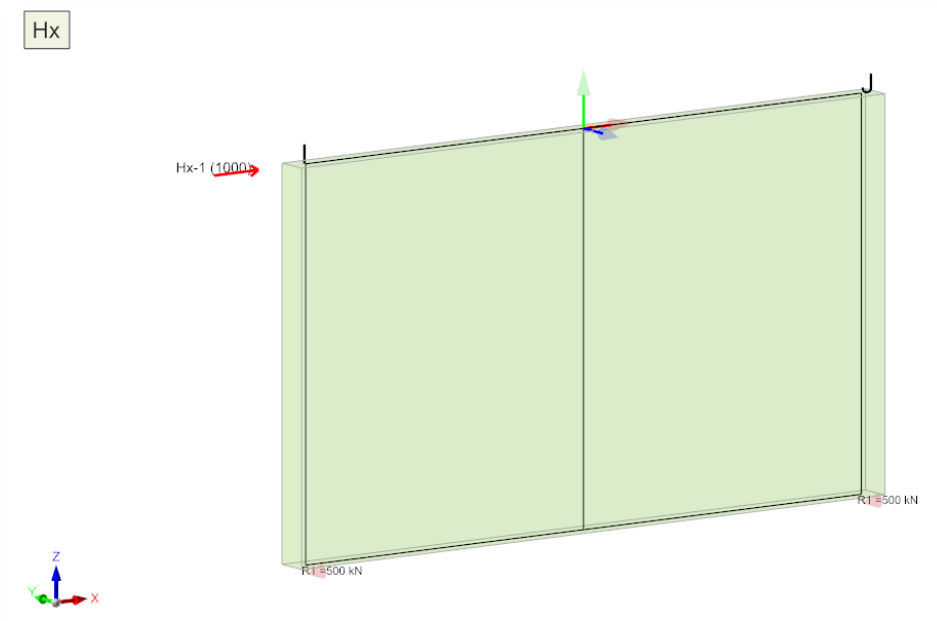


User-defined contour options in ProtaStructure, representing M1 moments

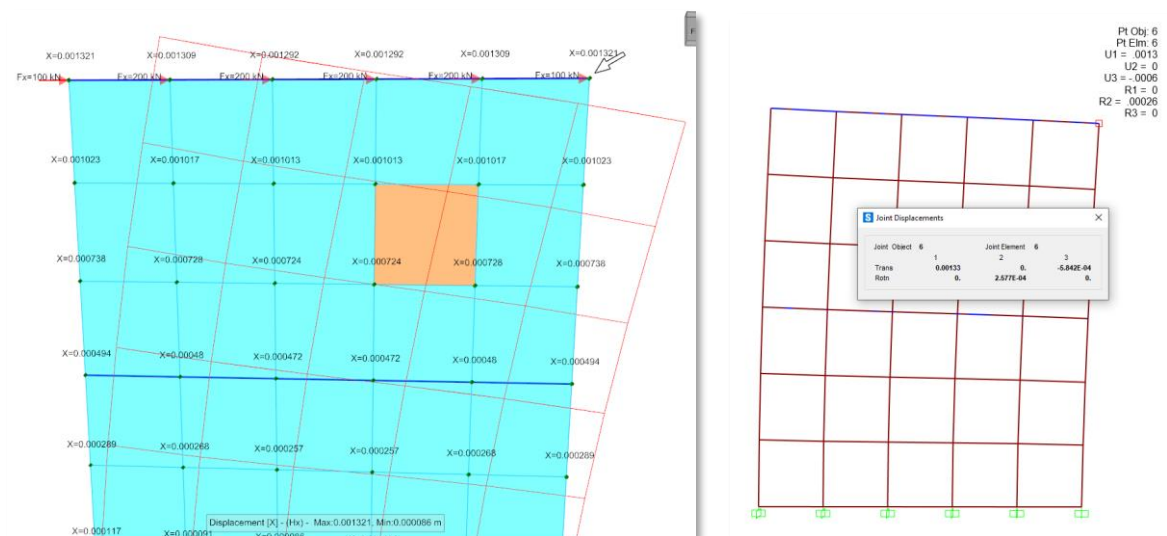


M1 moments in SAP2000 under the same loading conditions

Case 2: Shearwall Under a Point Load Along Local Axis 1



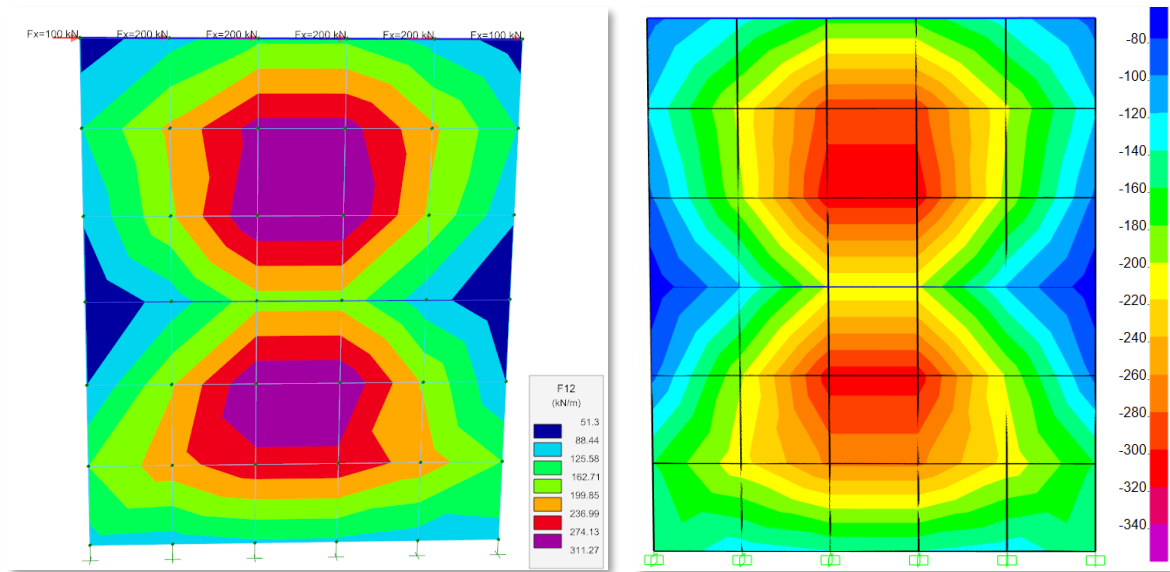
In the second case, the shearwall is loaded with a 1000 kN point load at its top along local axis 1 (X Direction in the model).



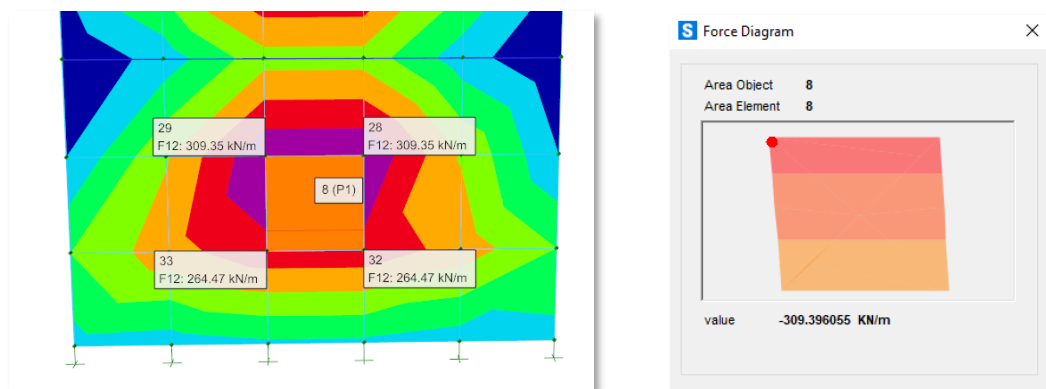
Displacements in X-Direction: ProtaStructure on the left and SAP2000 on the right.

Results are summarized in the following table.

	ProtaStructure	SAP2000
Maximum Deformation at the Same Top Node	0.001445 m	0.0013m
Shear Wall Base Moment, M33 (P1_ST1_BOT)	6000 kNm	6000 kNm
Base Shear Force, V2 (P1_ST1_BOT)	-1000 kN	-1000 kN



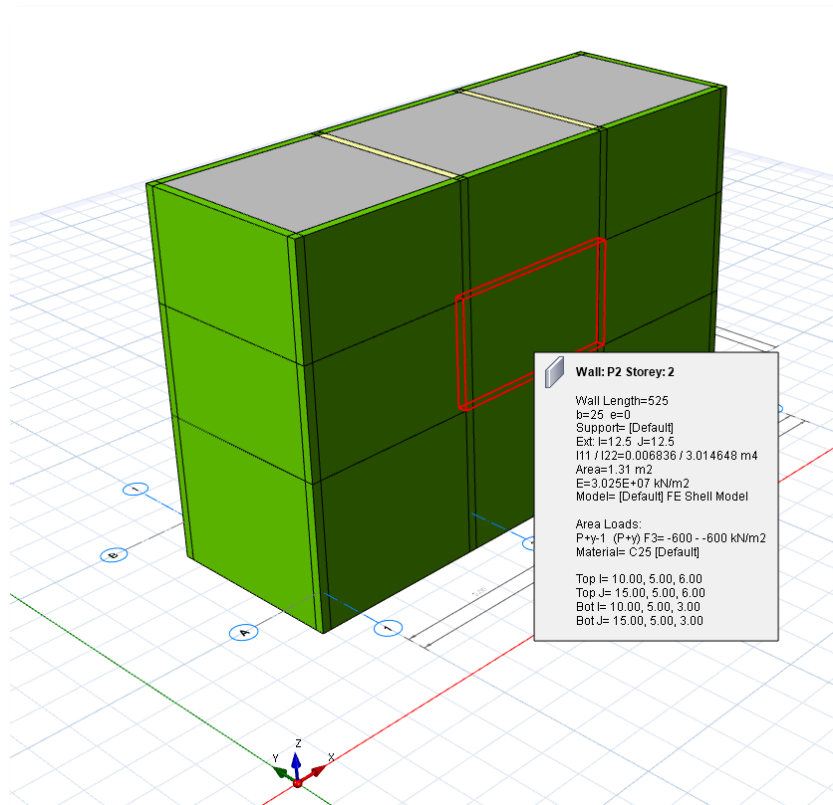
F12 Shearing Membrane Force Comparison ProtaStructure on the left, SAP2000 on the right



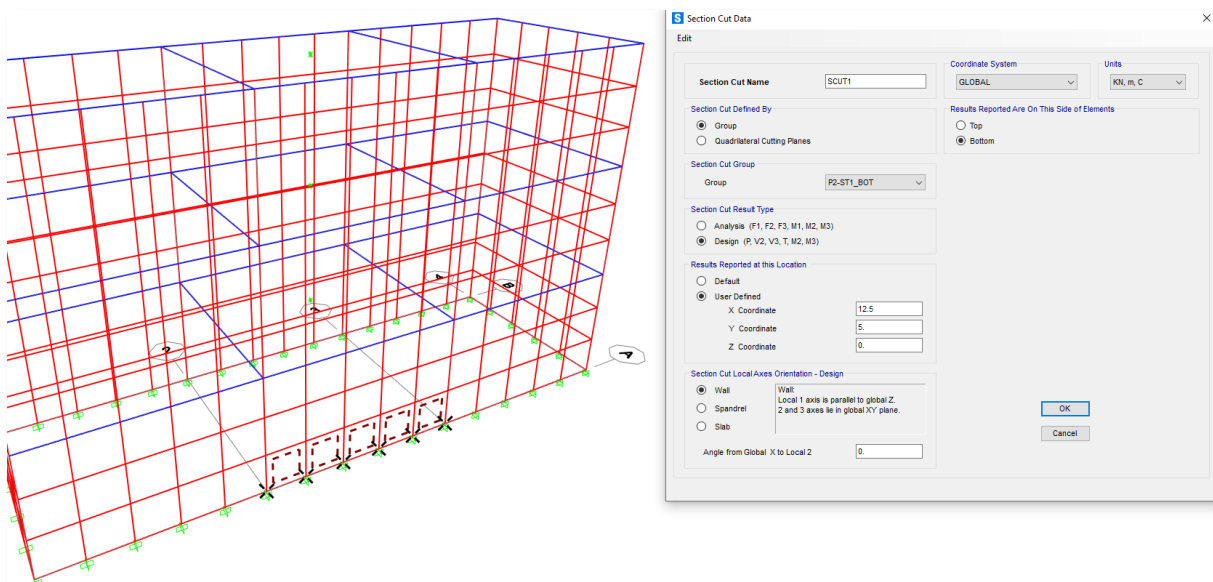
Comparison of the F12 value at node 29 for Hx-1 load case ProtaStructure on the left, SAP2000 on right

Case 3: Box-Shaped Structure Under a Uniform Pressure Along Local Axis 3

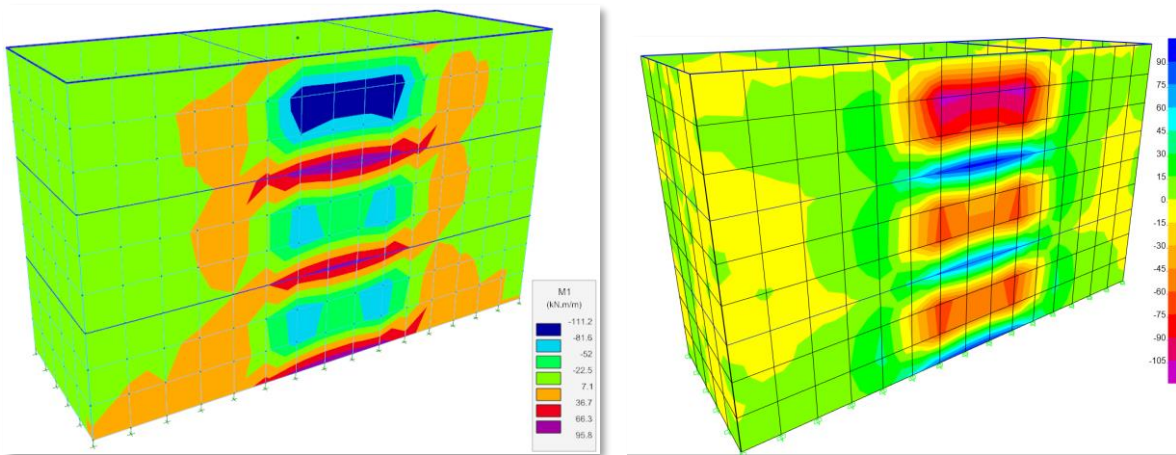
A box-shaped structure was modeled in ProtaStructure, which consists of shearwalls, slabs, and beams. The structure has three storeys, with 3 m in height. Shearwalls have dimensions of 5x0.25m. The structure is loaded with uniformly distributed pressure of 600 kN/m² along local axis 3 (Weak wall direction).



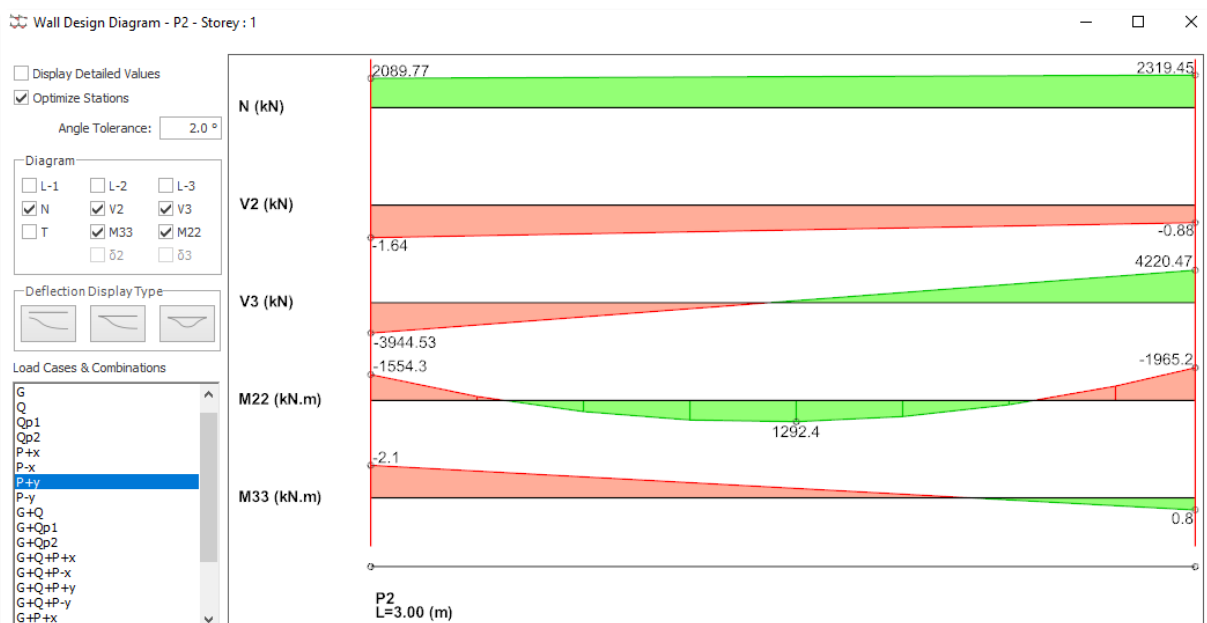
3D View of the shearwall in ProtaStructure



The same shearwall modeled in SAP2000 and section-cut definitions are assigned



Contour comparison of M1 moments on shells ProtaStructure on the left, SAP2000 on the right



Section Cut Forces - Design

File View Edit Format-Filter-Sort Select Options

Units: As Noted Section Cut Forces - Design

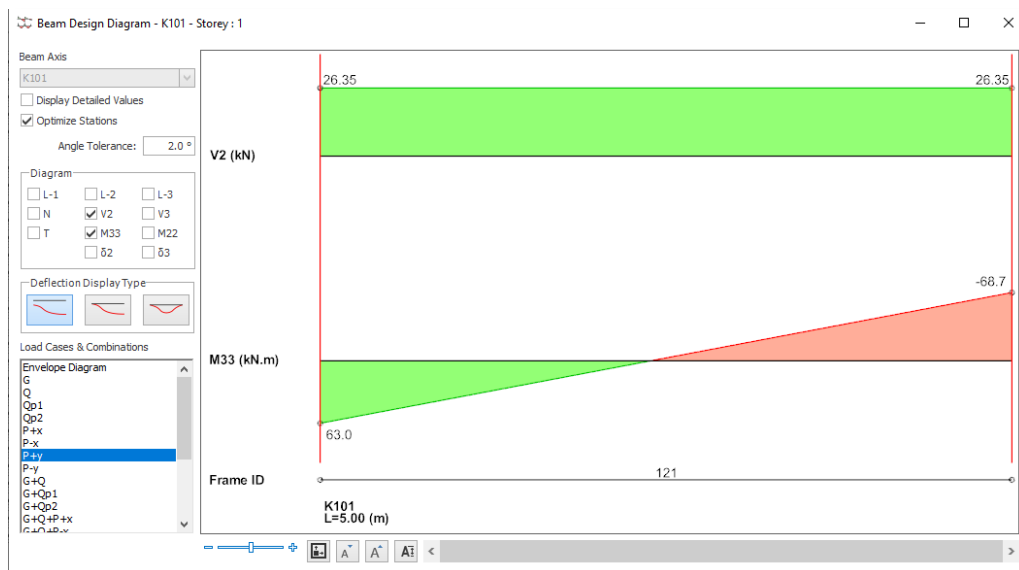
Filter:

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▶	SCUT1	P+y	LinStatic	2276.904	1.078	4223.524	0.6761	1971.3666	0.8496	12.5	5	
	SCUT2	P+y	LinStatic	2276.904	1.078	4223.524	0.6761	1971.3666	0.8496	12.5	5	

Shear and moment diagrams of P2 shear wall in Storey-1 under P+y load case in ProtaStructure on top, section cut results of the same wall in SAP2000 at the bottom.

Results are summarized in the following table.

P2 Wall Deformation & Base Reactions	ProtaStructure	SAP2000
Maximum Deformation at the Node #346	0.011615 m	0.01174m
Base Moment at P2 Wall, M22	1965.2 kNm	1971.4 kNm
Base Shear at P2 Wall, V3	4220.47 kN	4223.52 kN
Normal Force at Base, N or P	2319.45 kN	2276.9 kN



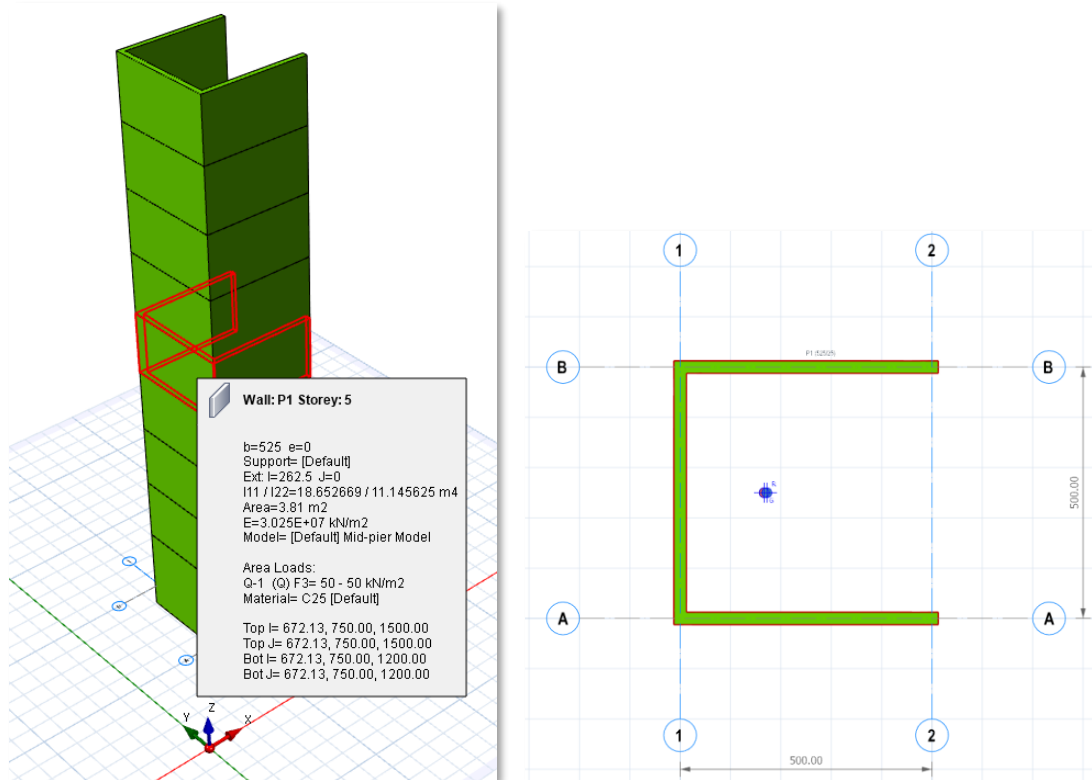
Moment and shear diagrams of the beam K-101 in ProtaStructure



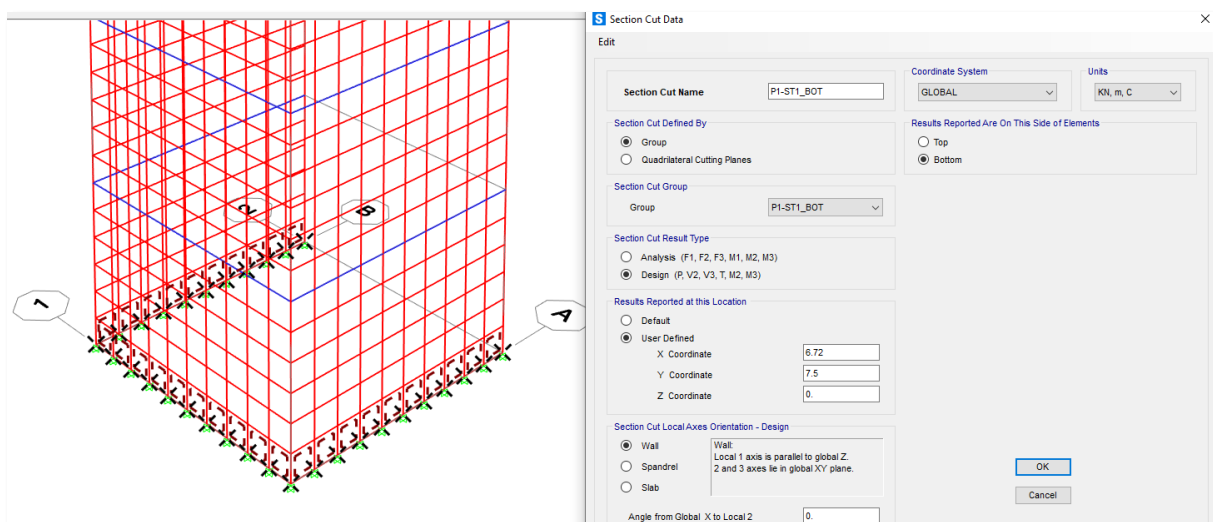
Moment and shear diagrams of the beam K-101 in SAP2000

Case 4: Corewall with a Uniform Lateral Pressure

A U-Shaped corewall was modeled in ProtaStructure. The flanges of the corewall have a dimension of 5x0.25m. The height of the 9-story shearwall is 27m. The corewalls are always modeled with the Finite Element Shell model in ProtaStructure.



3D and Plan View of the corewall in ProtaStructure



The same corewall modeled in SAP2000 and section-cut definitions are assigned

Base Reaction and Group-Sum Results



Base shear and moment diagrams of P1 corewall under Q load case in ProtaStructure

S Section Cut Forces - Design

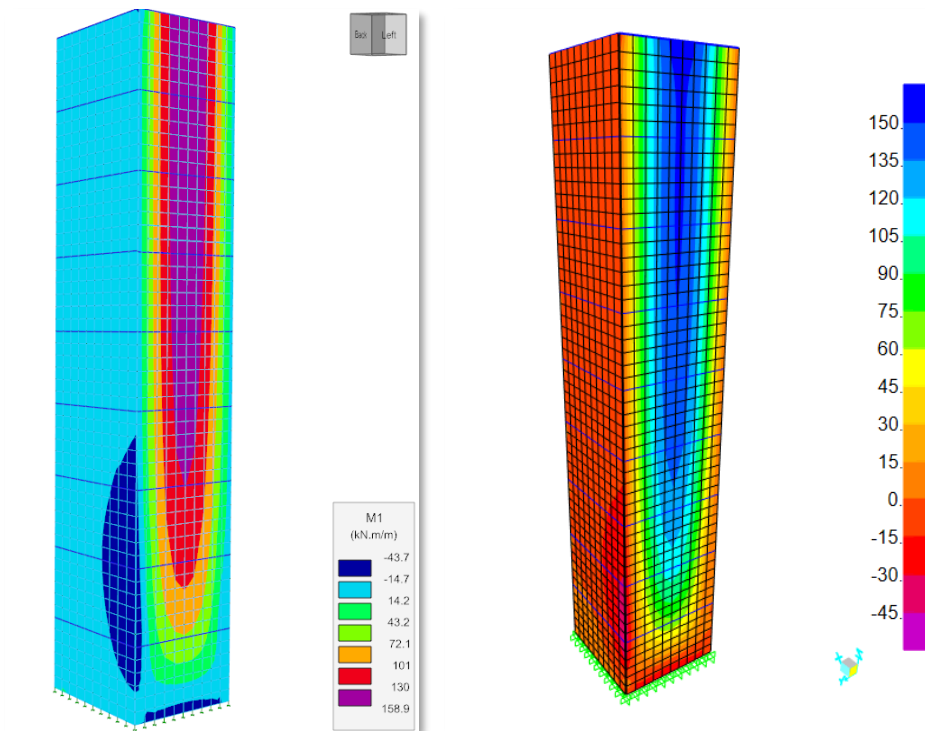
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Units: As Noted Section Cut Forces - Design

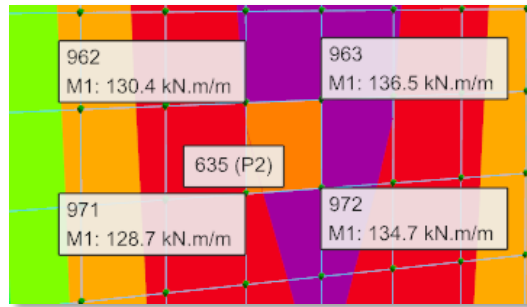
Filter:

	SectionCut Text	OutputCase	CaseType Text	P KN	V2 KN	V3 KN	T KN-m	M2 KN-m	M3 KN-m	GlobalX m	GlobalY m	GlobalZ m	Dir Uni
▶	P1-ST1_BOT	Q	LinStatic	1.294E-08	6750	5.145E-10	1.221E-09	8.352E-09	91125	6.72	7.5		0

Section cut results representing the base shear and moment diagrams of P1 corewall under Q load case in SAP2000



Contour comparison of M1 moments on shells ProtaStructure on the left, SAP2000 on the right



M1 moment values on joints at the shell 635 in ProtaStructure

Results are summarized in the following table.

Shell 635 M1 values	ProtaStructure	SAP2000
i (node 962)	130.4 kNm/m	130.5 kNm/m
j (node 963)	136.5 kNm/m	136.1 kNm/m
k (node 972)	134.7 kNm/m	134.6 kNm/m
l (node 971)	127.7 kNm/m	128.74 kNm/m

Information:

While analyzing the shell elements, ProtaStructure uses the Group-Sum method. This method calculates the resultant of the joint forces at the shell elements and represents them on the geometrical center of the shearwall or corewall. In SAP2000, the Group-Sum approach can be replicated with “Grouping” and defining “Section-Cuts”. While defining Section-Cuts, the represented shell elements and joints should be selected correctly, and the geometric center of the shape also be correctly entered. If the analytical model in ProtaStructure is exported to SAP2000, all the Groups and Section Cuts are assigned automatically.

Warning:

While comparing the results with third-party analysis packages, ensure that you use the same section modifiers in ProtaStructure and other software. For simplicity, you can set all section modifiers to 1.

Thank You

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