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ProtaStructure Design Guide

Base Isolation

Version 2.0 01 July 2022

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Introduction

This guide shows how to model a base isolation system in ProtaStructure for your seismically isolated buildings. Procedures for modeling, design requirements and reporting of the results are within the scope of this guide. Where necessary, tips and recommendations for selected seismic codes are given.

Please note that base isolation units in ProtaStructure can only be modeled by a link element using linear elastic properties for currently released versions.

Modeling of Base Isolator

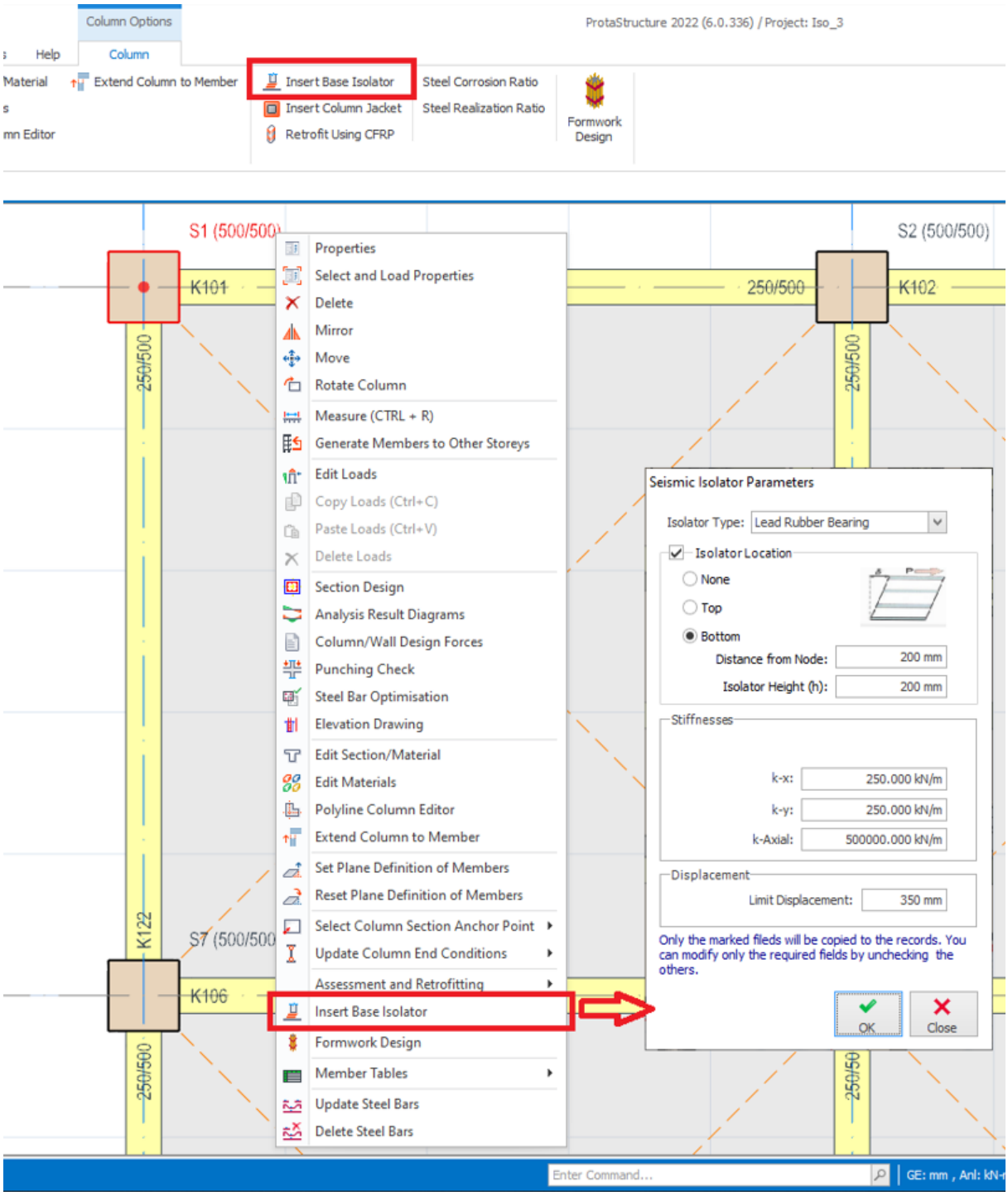
A preliminary isolation system design should be conducted before you start modeling the isolators on your structural model. In practice, the 'Equivalent Lateral Force Procedure' in the base isolation chapters of the seismic code is used to obtain stiffness and target displacement of the isolation system. Next, the isolation system performance is evaluated using linear or nonlinear analyses.

Please do not forget that the isolation system design and evaluation are iterative. Engineers might need to reanalyze the structure to obtain economic and performance targets repeatedly. As a result, isolators may have the same or different mechanical or geometric properties depending on the axial load for different loading combinations. ProtaStructure will allow you to model the same or different types of isolators under each column or shear wall.

General Modeling Tips

We recommend the following best practice approach for modeling a base isolation system into the ProtaStructure to help establish valid models.

- An isolation unit can be inserted either from the 'Column Options' tab or by right-clicking on the selected column(s).
- When clicked on 'Insert Base Isolator', a window will appear asking for isolator type, location, and mechanical properties.
    - One can select Lead Rubber Bearing, Friction Pendulum, and Triple Friction Pendulum types from the 'Isolator Type' dropdown menu. For the time being, all three types have the same linear elastic mechanical input properties.
    - ProtaStructure will modify the structural system and add a link element to the specified location when isolator location and total height are introduced. If 'None' is selected, the assigned isolator(s) will be deleted from the structure.
    - The two orthogonal lateral stiffnesses and axial stiffness of the isolator are manually entered in the 'Stiffnesses' section; thus, the structural stiffness matrix is modified accordingly.
    - As an additional parameter, the estimated target displacement is included. Target displacement is solely used to see if the displacement response of isolators beneath each column or shearwall, as determined by 'Equivalent Static Load' or 'Response Spectrum' analysis, exceeds the limit.
- When the 'OK' button is clicked, ProtaStructure will ask the user if the input parameters will be applied to all columns/walls or only to the selected elements.
- The seismic isolation elements will be shown in black color when it is placed on a column/wall.



Inserting a Seismic Isolator

Note: *If the desired axial stiffness input of the isolator has a higher-order magnitude than the allowable order by the ProtaStructure, the user can increase the order from Settings Center > Unit Format > Line Load > Field Width. (The line load field width is set as '10' by default).*

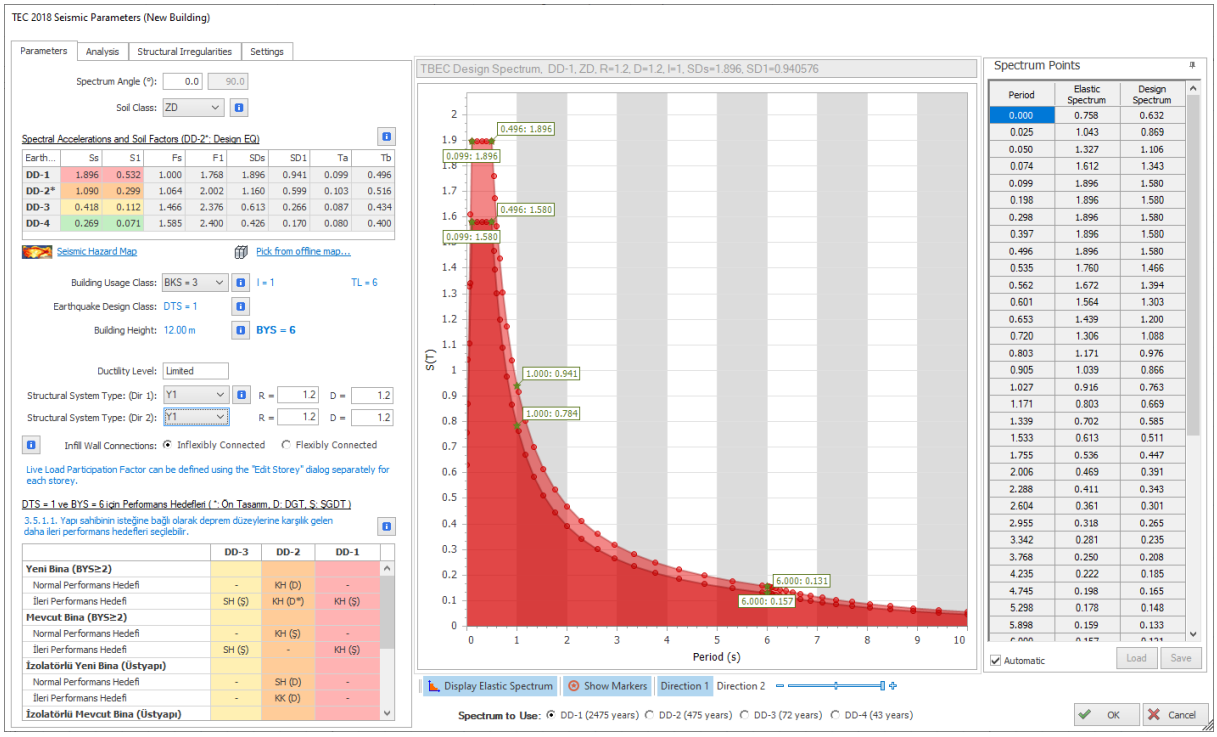
Specific Modeling Requirements for Base Isolated Structures

Response Modification, Overstrength, and Building Importance Factors

- In seismic isolation applications, the superstructure is desired to remain linear elastic. In other words, the input energy from the earthquake is carried by the flexible isolation layer. Little or no damage is allowed to superstructural or substructural members. Therefore, in the design process, the response modification factor (i.e., behavior factor 'q' in Eurocode) or overstrength factor is taken as equal or close to unity (R = 1). Please refer to the seismic isolation chapter of your specified seismic code for selecting the ductility demand, overstrength, and building importance factors for isolated buildings.

- ProtaStructure will not automatically modify the response parameters mentioned above for some seismic codes. Thus, the user might need to change 'Seismic Parameters' according to the seismic code requirements. An example of seismic parameters is shown below for the Turkish Seismic Code 2018 (R=1.2 and D= 1.2). As can be seen, the elastic response spectrum and the design response spectrum are very close or equal to each other.

Note: *This procedure can be applied for structures having elastomeric or sliding bearings with little or no damping capabilities. The guidelines in the next section can be followed if the bearings have significant damping properties.*

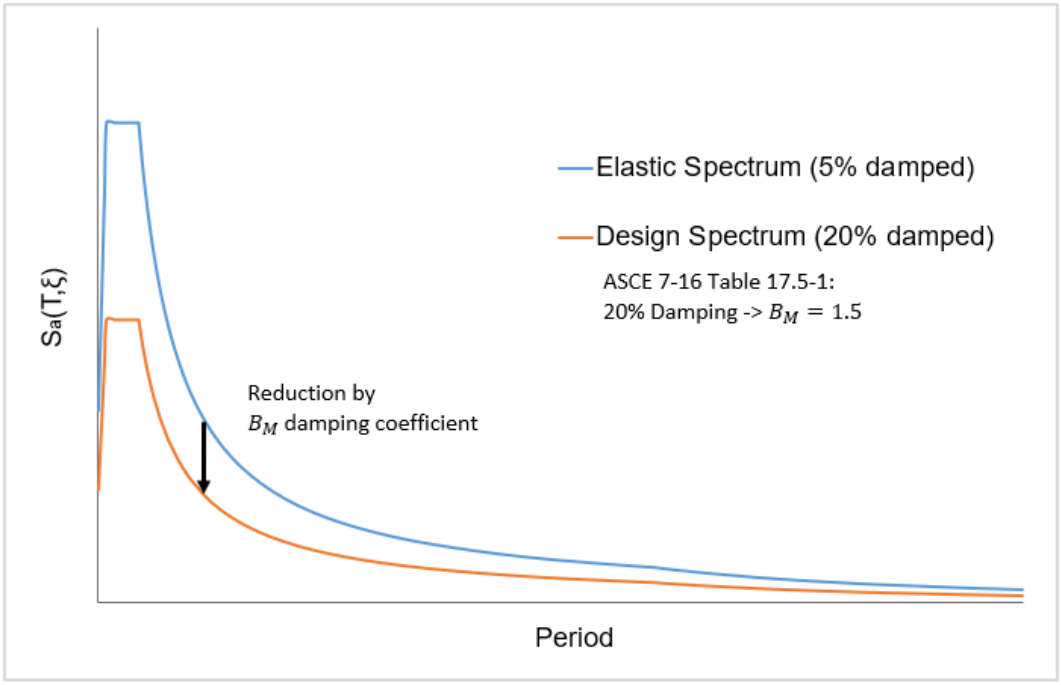


Elastic and Design Response Spectra

Damping the Seismic Input

Due to the significant damping capability of the seismic isolation layer, the seismic excitation transferred to the superstructure is significantly decreased. ProtaStructure does not allow the user to define effective linear damping for the base isolators. Therefore damping of the isolation layer should be introduced to the program with different methods.

- The user can modify spectral demands used for isolated structures by using damping coefficients. The damping coefficient is a function of the damping ratio of the isolation system. It can be found in the base isolation chapter of the corresponding seismic code (i.e., ASCE7-10 and ASCE7-16 Table 17.5-1, EC8-1 Eq 3.6, TEC2018 Eq 14.32). In this case, ProtaStructure does not automatically modify the spectral accelerations; thus, the modified response spectrum should be introduced manually. An example of the elastic spectrum modification is given below for the ASCE7-16 specification for an equivalent isolation damping ratio of 20%.



Modification of Elastic Spectrum

Note: *For structures with significant behavior contribution of higher modes, the damping coefficients shall be applied to the regions of the elastic response spectrum that corresponds to the modes dominated by the isolation layer. Otherwise, the superstructural demands induced by the higher modes might be underestimated.*

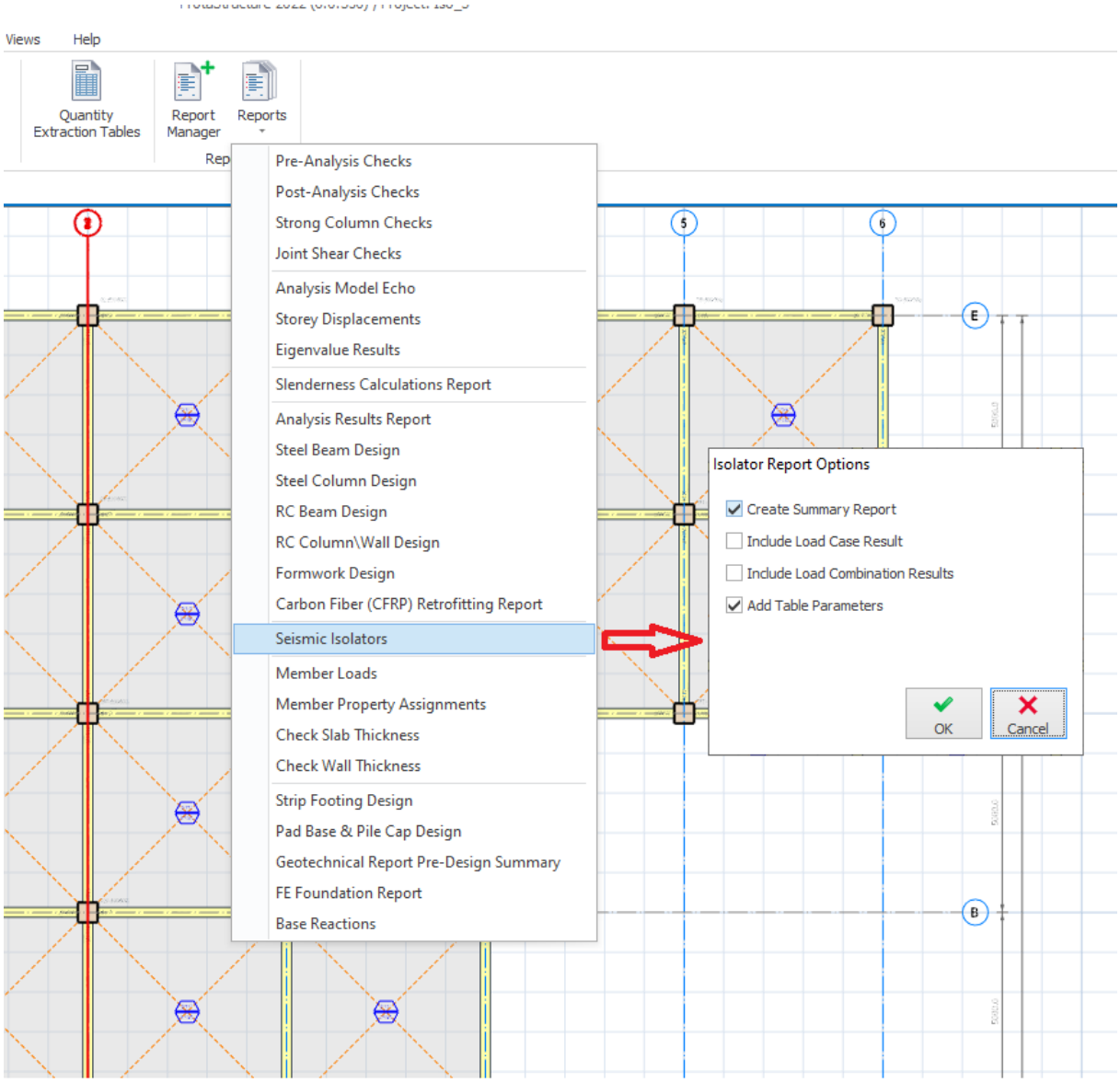
- To estimate the maximum displacement of the isolation system, the user can also analyze the structure with a 5% damped spectrum. Then, maximum displacements can be modified by the damping coefficients in the specifications mentioned above. This approach will only give the user an idea of how much displacement can the isolation system undergo. However, it will not apply the effect of damping on the seismic forces transferred to the superstructure.

Effective Section Rigidities of Structural Members

For some seismic codes, the cracked section rigidities of structural members used for seismic analyses of isolated buildings might be different than those of fixed base conventional structures. Therefore, please refer to your seismic code before making any changes to the section rigidities of structural members.

Reporting the Results

After the analysis, the base isolator results can be reported from '**Drawings&Reports > Reports > Seismic Isolators**'. 'Isolator Report Options' window will allow the user to create a summary or detailed report for all loading cases and combinations.



Seismic Isolator Reporting

- The default summary report includes isolators' lateral and axial stiffnesses, the axial loads from and maximum displacements obtained in the most critical loading combinations, and the displacement limit check for the isolators under each column.
- If all load cases and combinations are included in the options, the report will show detailed results for each loading status for each column.

Seismic Isolator Results

Common Parameters

K_x : Equivalent Stiffness of the Isolator in X Direction
K_y : Equivalent Stiffness of the Isolator in Y Direction
K_z : Axial Stiffness of the Isolator
N : Effective Axial Load on the Isolator
N_{max} : Maximum Axial Load on the Isolator
$dX\text{-}t_{max}$: Absolute Displacement of the Isolator Top Node in X Direction
$dX\text{-}b_{max}$: Absolute Displacement of the Isolator Bottom Node in X Direction
$dY\text{-}t_{max}$: Absolute Displacement of the Isolator Top Node in Y Direction
$dY\text{-}b_{max}$: Absolute Displacement of the Isolator Bottom Node in Y Direction
ΔX_{max} : Relative Displacement of the Isolator in X Direction
ΔY_{max} : Relative Displacement of the Isolator in Y Direction
Δ-Limit : Maximum Allowable Relative Displacement for Isolators

Summary Report

Column / Storey	K_x (kN/m)	K_y (kN/m)	K_z (kN/m)	N_{max} (kN)	Load	$\Delta\text{-}X_{max}$ (m)	Load	$\Delta\text{-}Y_{max}$ (m)	Load	Δ-Limit (m)	Status
S6 / 1	250.000	250.000	5.000E+05	330.01	Gc+Qc+Ez-Ex-	0.222161	Gc+Qc+Ez+Ex+	0.243819	Gc+Qc+Ez+Ey+	0.230000	Limit Exceeded!
S7 / 1	250.000	250.000	5.000E+05	330.01	Gc+Qc+Ez-Ex+	0.222161	Gc+Qc+Ez-Ex-	0.243819	Gc+Qc+Ez-Ey-	0.230000	Limit Exceeded!
S12 / 1	250.000	250.000	5.000E+05	329.11	Gc+Qc+Ez-Ey-	0.244106	Gc+Qc+Ez+Ex-	0.222425	Gc+Qc+Ez-Ey+	0.230000	Limit Exceeded!
S10 / 1	250.000	250.000	5.000E+05	329.11	Gc+Qc+Ez-Ex+	0.222425	Gc+Qc+Ez+Ex-	0.244106	Gc+Qc+Ez-Ey+	0.230000	Limit Exceeded!
S2 / 1	250.000	250.000	5.000E+05	330.01	Gc+Qc+Ez-Ey-	0.243819	Gc+Qc+Ez+Ex+	0.222161	Gc+Qc+Ez+Ey+	0.230000	Limit Exceeded!
S11 / 1	250.000	250.000	5.000E+05	330.01	Gc+Qc+Ez-Ey+	0.243819	Gc+Qc+Ez-Ex-	0.222161	Gc+Qc+Ez-Ey-	0.230000	Limit Exceeded!
S8 / 1	250.000	250.000	5.000E+05	498.28	G+Qp2	0.222359	Gc+Qc+Ez-Ex-	0.222359	Gc+Qc+Ez-Ey-	0.230000	Adequate
S1 / 1	250.000	250.000	5.000E+05	329.11	Gc+Qc+Ez-Ey+	0.244106	Gc+Qc+Ez-Ex+	0.222425	Gc+Qc+Ez+Ey-	0.230000	Limit Exceeded!
S3 / 1	250.000	250.000	5.000E+05	329.11	Gc+Qc+Ez-Ex-	0.222425	Gc+Qc+Ez-Ex+	0.244106	Gc+Qc+Ez+Ey-	0.230000	Limit Exceeded!
S5 / 1	250.000	250.000	5.000E+05	498.28	G+Qp2	0.222359	Gc+Qc+Ez+Ex+	0.222359	Gc+Qc+Ez+Ey+	0.230000	Adequate
S4 / 1	250.000	250.000	5.000E+05	498.28	G+Qp2	0.222340	Gc+Qc+Ez-Ex+	0.222340	Gc+Qc+Ez+Ey-	0.230000	Adequate
S9 / 1	250.000	250.000	5.000E+05	498.28	G+Qp2	0.222340	Gc+Qc+Ez+Ex-	0.222340	Gc+Qc+Ez-Ey+	0.230000	Adequate

Summary Report

Thank You

Thank you for choosing the **ProtaStructure** Suite product family.

It is our top priority to make your experience excellent with our software technology solutions.

Should you have any technical support requests or questions, please do not hesitate to contact us at all times through globalsupport@protasoftware.com and asiasupport@protasoftware.com

Our dedicated online support center together with our responsive technical support team is available to help you get the most out of Prota's technology solutions.

The Prota Team

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