COMPONENT BASED MODE ISOLATION IN BUCKLING ANALYSES

PREPARED BY

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1. INTRODUCTION

Static analysis for thin-walled structures under compression and/or shear loads may not be sufficient to obtain all possible failure modes. These kinds of loads can trigger different type of stability failures like buckling.

Figure 1 – Sample Structures Exhibited Buckling Failure in Tests

In large assembly models containing many components, standard buckling solution algorithm derives Stiffness (K) and Differential Stiffness (K_d) matrices by taking account of all elements. Then, constructed eigenvalue problem is solved and Buckling Load Factor (BLF) values are derived. However, obtained mode shapes may not be on the component of interest, rather on supporting components. At this point, detailed visual inspection is required and re-run operation is likely to be needed for increasing number of roots.

This writing aims to demonstrate an alternative method for isolating mode shapes for specific components of the built FE model and reduce post-processing effort.

2. MODEL DESCRIPTION

For the sake of simplicity, study model consists of only two components: Top plate and side walls. Both components are meshed with 2D shell elements (CQUAD4) and their connections are modeled with 1D spring-damper elements (CBUSH) representing fasteners. They are all shown in Figure 2 as green, blue and red, respectively.

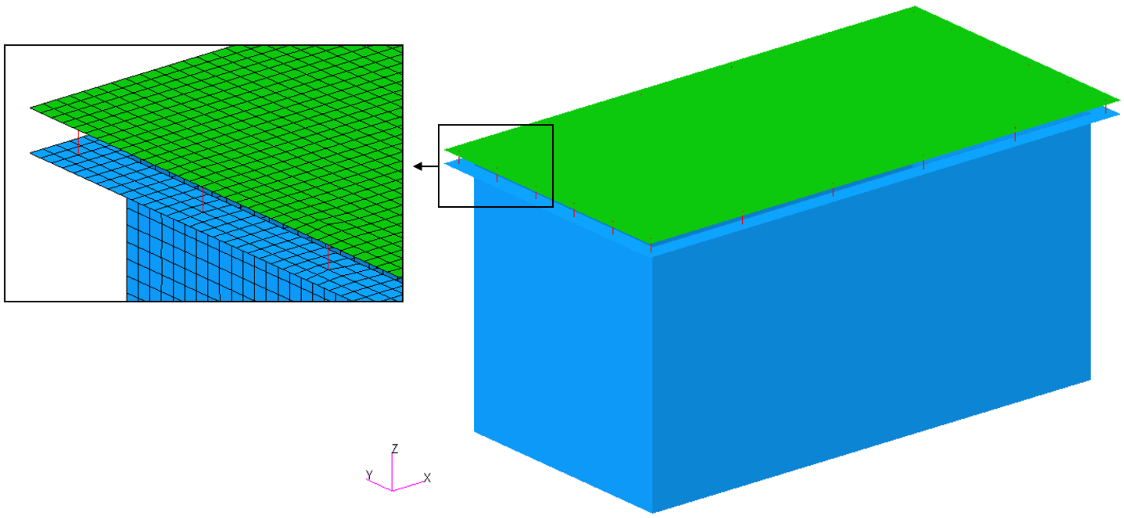

Figure 2 – Finite Element Model Overview

As boundary conditions, lower-most nodes of side walls are constrained in global 123 directions. As applied loads, longitudinal compressive forces for top plate and gravity acting on global -Z direction are introduced. Details are shown in Figure 3.

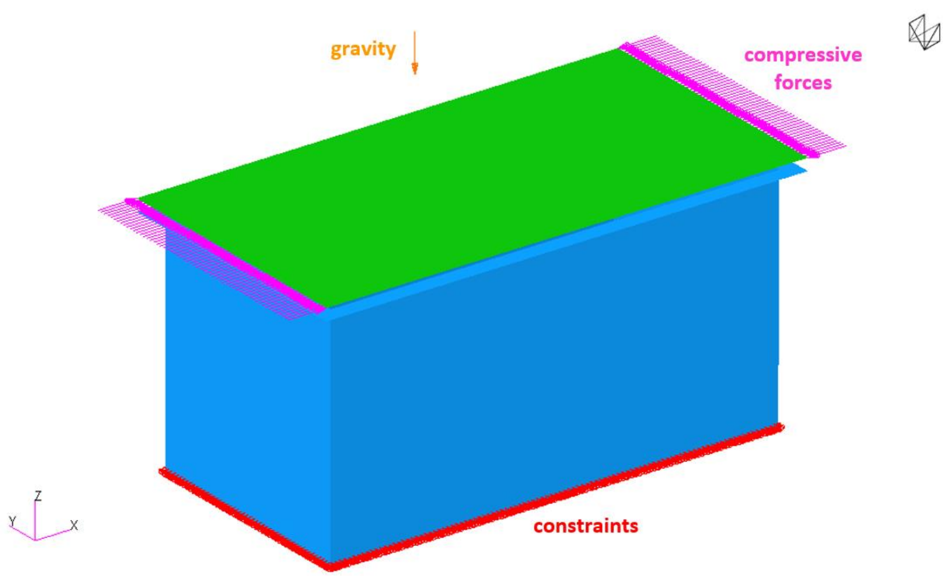

Figure 3 – Loads and Boundary Conditions Shown in FEM

3. ANALYSIS RESULTS

Goal of the performed analysis is **to only inspect buckling behavior of the top plate**.

For the described FE model, two separate SOL105 – Linear Buckling solutions are performed on MSC Nastran 2021.2 and results are inspected on MSC Patran 2021.1.

In the first run, standard buckling algorithm is used and results are used as reference. In the second run, exclude algorithm is utilized as defining a bulk data set for side walls and excluding these for model's Differential Stiffness calculation by '**PARAM,EXCLUDE**' statement. Details are highlighted in red boxes in Figure 4.

```
SOL 105
CEND
ECHO = NONE
SUBCASE 1
   SUBTITLE=Default
   SPC = 5
   LOAD = 6
   DISPLACEMENT(PLOT)=ALL
SUBCASE 2
   SUBTITLE=Default
   SPC = 5
   METHOD = 1
   VECTOR(PLOT)=ALL
   STATSUB = 1
   PARAM,EXCLUDE,99

BEGIN BULK

$ Nodes from Group: NON_INTERESTED_GRIDS
SET1, 99, 223242, THRU, 223249, 223446, THRU, 223453, 223850,
, THRU, 223857, 224054, THRU, 224057, 224157, THRU, 224160,
, 224458, THRU, 240057, 241338, THRU, 241353, 241370, THRU,
, 242601
```

Figure 4 – BDF Structure for Exclude Buckling Solution

Due to symmetry on the side walls, some conjugate modes are observed in buckling analysis. Although these modes show different mode shapes mathematically, they represent same condition physically. BLF values are approximately same, therefore conjugate modes are treated as a single mode throughout this writing.

Standard Run Results			Exclude Run Results			BLF Comparison
Mode #	Location	BLF Value	Mode #	Location	BLF Value	% Difference
01-02	Side Wall	0.3695				
03-04	Side Wall	0.6826				
05-06	Side Wall	0.8646				
07	Top Plate	1.1193	01	Top Plate	1.1344	+1.36%
08-09	Side Wall	1.1324				
10	Top Plate	1.2205	02	Top Plate	1.2391	+1.52%
11-12	Side Wall	1.3848				
13-14	Side Wall	1.5244				
15	Top Plate	1.6365	03	Top Plate	1.6452	+0.53%

Table 1 – Summary of the Results and Comparison

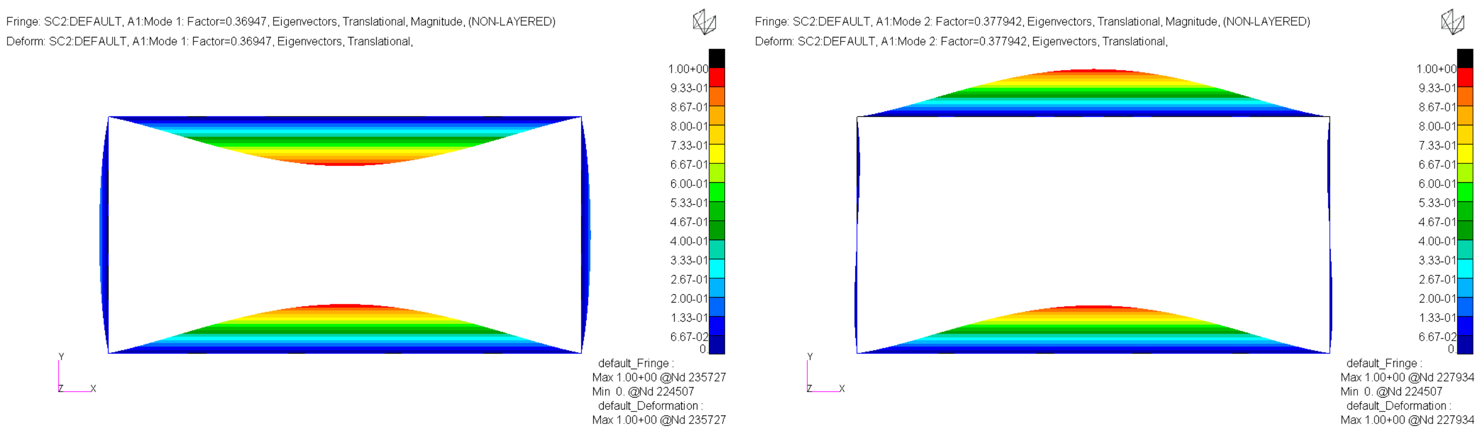

Figure 5 – Example of Obtained Conjugate Modes

Obtained results from two different solutions are presented in tabular form, noting that standard run BLF values are used as reference in percentage calculations.

Mode shapes from standard and exclude solutions are presented below **for top plate**:

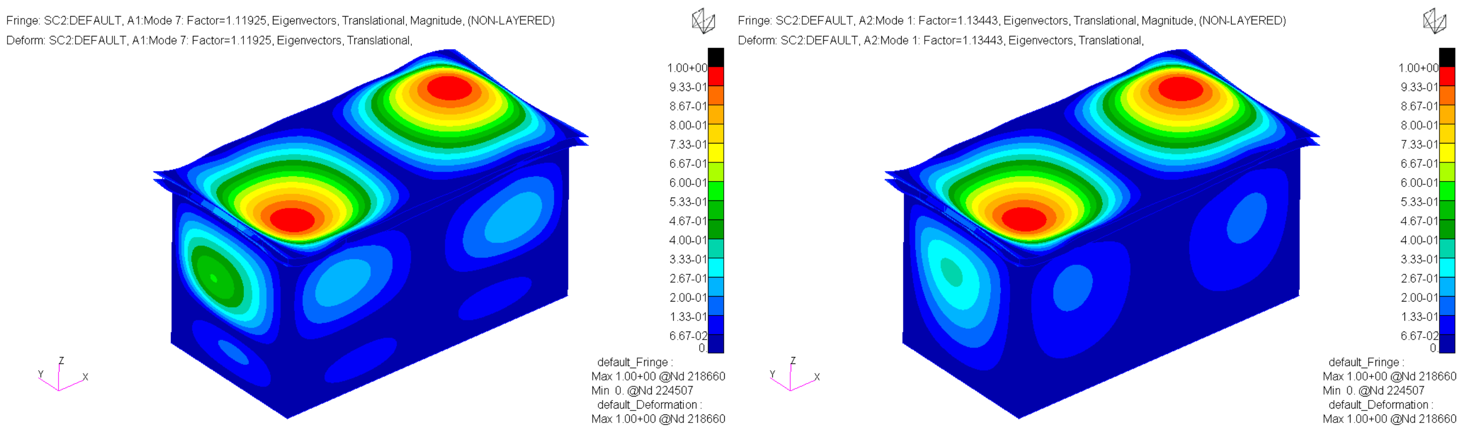

Figure 6 – Top Plate Mode 01 (standard run on left, exclude run on right)

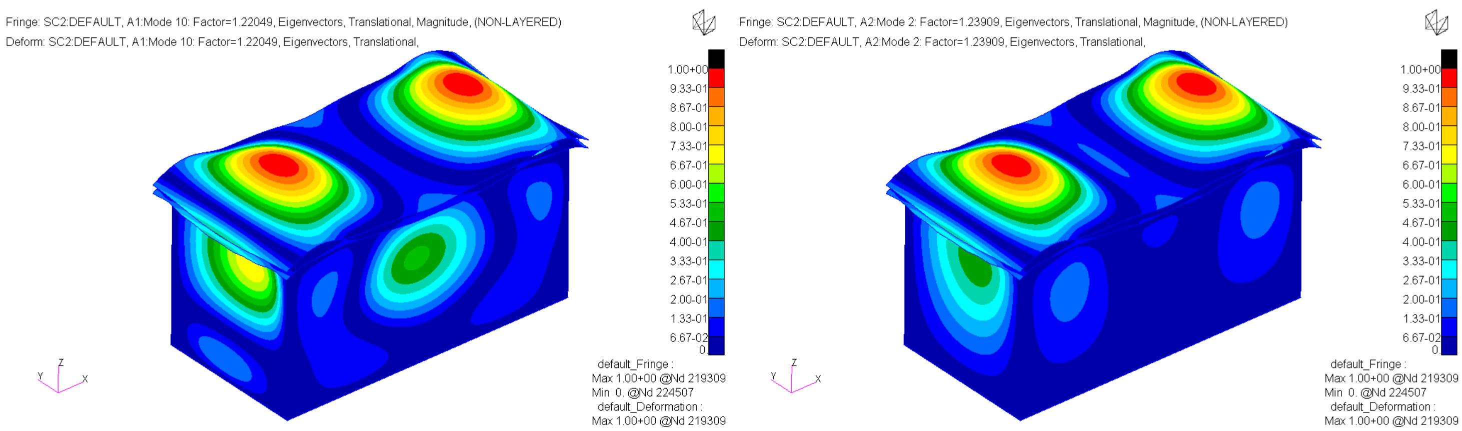

Figure 7 – Top Plate Mode 02 (standard run on left, exclude run on right)

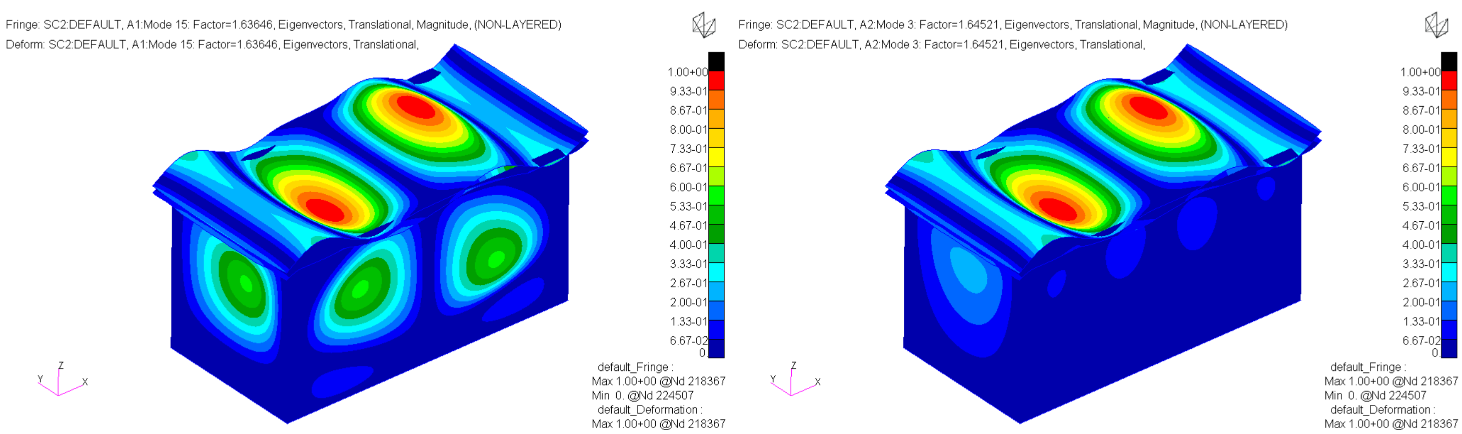

Figure 8 – Top Plate Mode 03 (standard run on left, exclude run on right)

Mode shapes from standard solution are presented below **for side walls**:

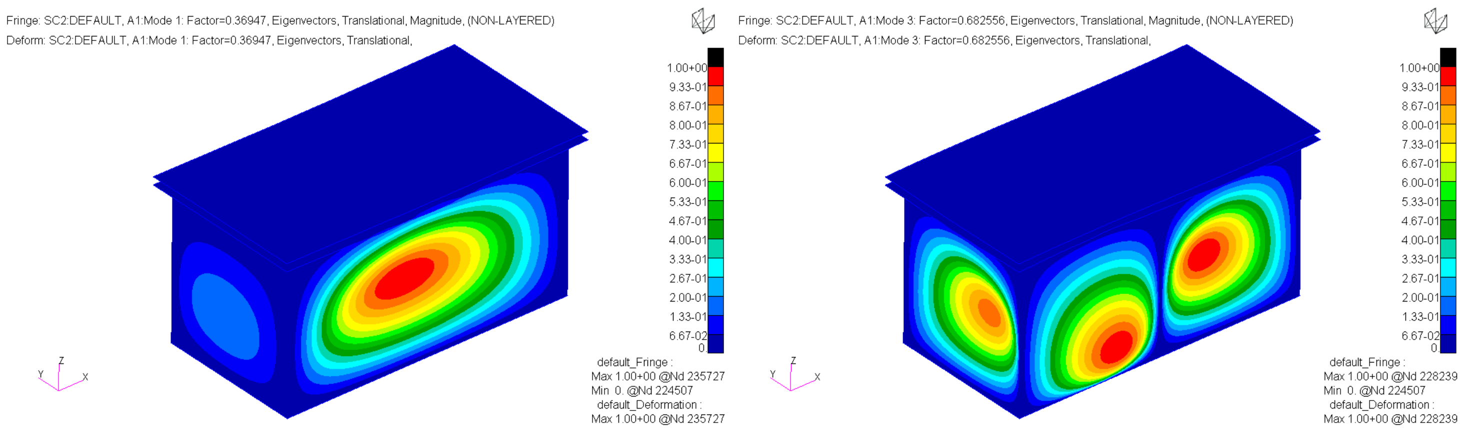

Figure 9 – Side Walls Standard Run Mode 01 on left - Mode 03 on right

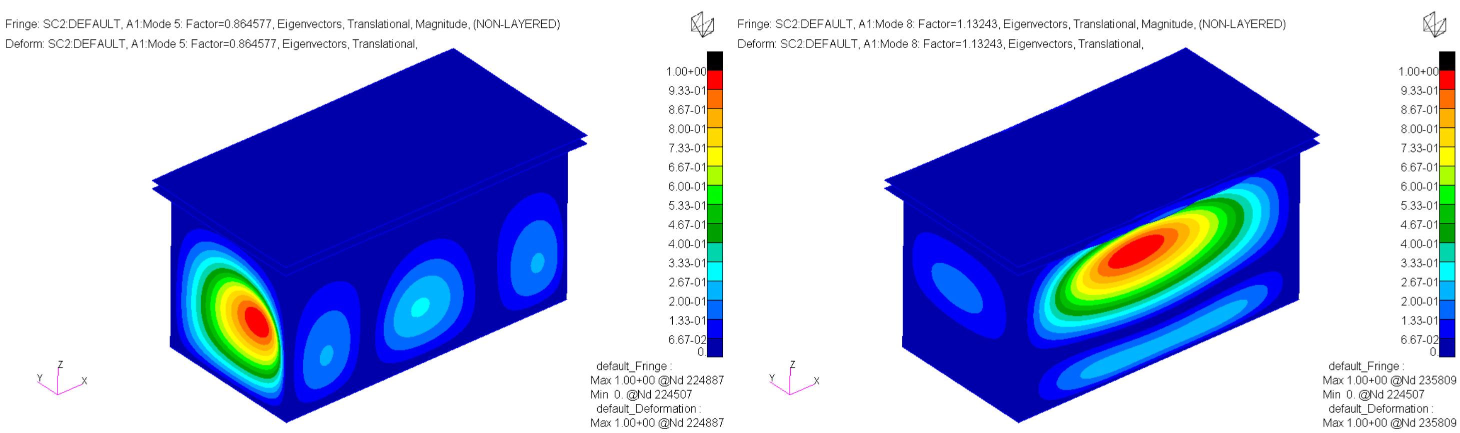

Figure 10 – Side Walls Standard Run Mode 05 on left - Mod 08 on right

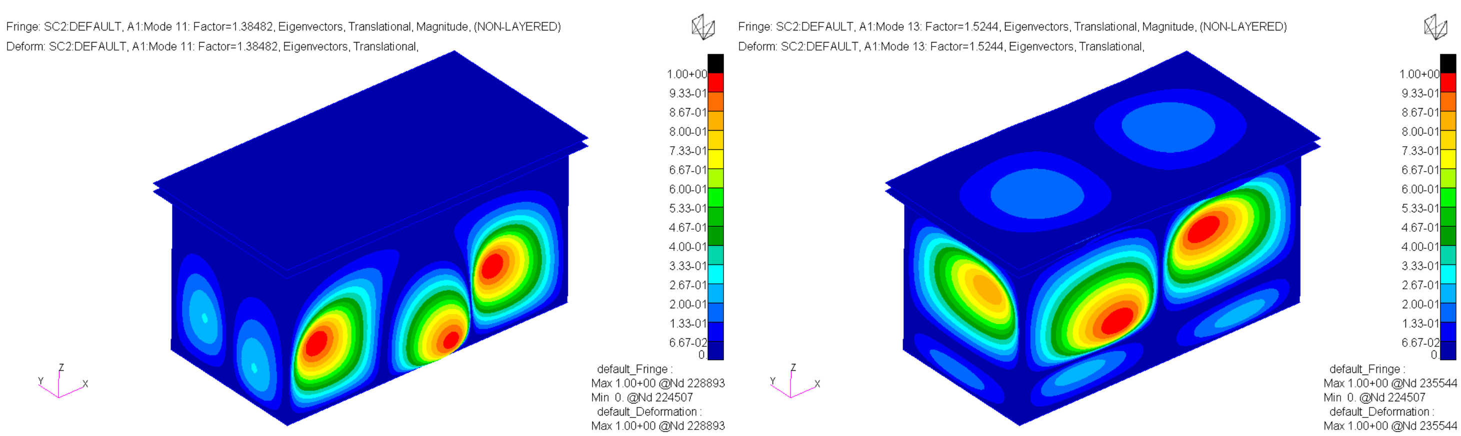

Figure 11 – Side Walls Standard Run Mode 11 on the left - Mode 13 on right

4. CONCLUSION

In the standard run, 15 roots are required to inspect first 3 modes of the top plate due to non-interested modes belong to side walls. On the other hand, exclude run only requires calculation of 3 roots since background algorithm has already excluded the side walls. Necessity for computing larger number of roots in standard run would cause significantly more run-time, especially in models with high DOF.

Apart from run-time, significantly more effort is required in the post-process of standard run. Non-interested modes should be disregarded manually by visual inspection. For instance, first 3 mode shapes of standard run are observed on sidewalls and 1^{st} mode for top plate is 4^{th} mode of overall solution. However, exclude run procedure disregards Differential Stiffness matrix contribution from excluded component and shows directly interested mode shapes. Therefore, it requires less post-process time since 1^{st} mode for top plate is 1^{st} mode of exclude solution.

Displayed mode shapes of top plate from both solutions are same and numeric results are summarized in Table 1. Obtained BLF values are not exactly same, but differences are within the acceptable range (i.e., 1.36%, %1.52 and 0.53%). Typically, exclude run yields to larger BLF values than standard run for this analysis model. These numerical deviations should be taken into account when using exclude algorithm in buckling analyses.

5. REFERENCES

I. MSC Nastran 2021.2 Quick Reference Guide
II. MSC Nastran 2021.2 Reference Guide
III. https://www.researchgate.net/figure/Typical-shear-dominant-failure-mode-showing-shear-buckling-of-the-web-for-plate-girder_fig22_256968684
IV. https://classes.mst.edu/civeng120/extra/examples/column_buckling/index.html