**Structural Loading of Cross Deck Connections for Trimaran Vessels**

by

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B.S. Nuclear Engineering
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Submitted to the Department of Ocean Engineering and the Department of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degrees of

Naval Engineer

and

Master of Science in Civil and Environmental Engineering

at the
Massachusetts Institute of Technology

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## ABSTRACT

This work investigates the fundamental relationships of wave loading on cross deck structures for trimaran vessels. In contrast with a monohull ship, trimaran vessels experience several possible structural loading cases including: longitudinal bending, transverse bending, torsional bending, spreading and squeezing of hulls, inner and outer hull slam pressures, wet deck slam pressures, loading from ship's motions, and whipping of slender hulls. This work investigates wave loading cases that result in transverse and torsional bending of the cross deck structure.

The wave loading cases investigated include: side hull troughing and cresting in longitudinal waves, side hull torsion in longitudinal waves, and transverse hogging and sagging. For each of these load cases, a design load using a fully statistical sea state was derived using an analytical model of a trimaran represented by rigidly connected box barges. The design loadings with a reliability index of 5 for almost 500 trimaran configurations were calculated varying main hull length, side hull length, side hull transverse placement, and side hull longitudinal placement. The design loadings were curve fit to a fourth order polynomial in the three independent variables.

The load predictions of the analytical box model of a trimaran were applied to a trimaran vessel with a realistic hull form using the finite element ship structural analysis program MAESTRO. Given the number of approximations and assumptions in the analytical model, the forces predicted by analytical model agreed closely with the finite element model's results.

The fitted curve of design loadings allows an initial design stage loading estimate for cross deck structural loading, given general characteristics of length and spacing of a trimaran's hulls. This estimate of structural loading combined with other characteristics of good trimaran design including stability, roll, and resistance characteristics will aid in optimizing an overall trimaran ship design.


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# List of Terms

| | |
|---|---|
| $B_m$ | main hull's beam |
| $B_s$ | side hull's beam |
| $FB_{lg}$ | vertical force on cross-structure in longitudinal waves (troughing and cresting) |
| $FB_{tr}$ | vertical force in transverse waves (transverse hogging/sagging) |
| $F_m$ | main hull's freeboard (also side hull freeboard) |
| $g$ | gravitational constant |
| $H_s$ | observed significant wave height |
| $h_w$ | actual wave height |
| $H_{wave\_lg}$ | longitudinal wave amplitude |
| $H_{wave\_tr}$ | transverse wave amplitude |
| $L_m$ | main hull's length |
| $L_s$ | side hull's length |
| $MB_{lg}$ | moment on cross-structure in longitudinal waves (longitudinal twisting) |
| $\nabla_{still}$ | original still water displacement |
| $p$ | index of the wave height |
| $p_{ray}$ | Rayleigh probability distribution |
| $q$ | index of the wavelength |
| $t$ | index of the observed significant wave height |
| $T$ | wave period |
| $T_m$ | main hull's draft |
| $Trim_{still}$ | original still water trim (assumed to be zero) |
| $T_s$ | side hull's draft |
| $x$ | longitudinal position |
| $X_{cf}$ | longitudinal position of the entire ship's center of floatation |
| $X_s$ | longitudinal position of the side hull with respect to main hull amidships |
| $y$ | transverse position |
| $Y_s$ | transverse position of the side hull with respect to main hull centerline |
| $\Delta T$ | change in heave of the ship due to the wave |
| $\Theta_{pitch}$ | change in pitch of the ship due to the longitudinal wave |
| $\lambda$ | wavelength of the wave |
| $\varphi$ | phase of the wave applied for each loading condition |

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# Chapter 1 Introduction

Over recent decades a growing demand for higher speed ships has led to the development of several new hull form concepts. These hull forms include catamarans, surface effects (SES) ships, small waterplane twin-hull (SWATH) ships, pentamaran, and trimaran ships to name a few. Of these 'new' hull forms the multi-hull vessel's origins can be traced to back several centuries to many seagoing peoples with outrigger canoes. In more recent times the multi-hull ships have been used in several racing, pleasure, and commercial vessels.

The benefits of the trimaran hull form have been studied extensively over the past several years at the University College London (UCL) [1]. In 2000 the RV TRITON, Figure 1 below, a trimaran demonstrator project for the United Kingdom's Royal Navy, was launched to test the trimaran hull form [2].

**Figure 1 – RV Triton [2]**

While much work in the area of trimaran hull form design has been accomplished by the UCL studies, the structural loading experienced by the cross-deck structure of the trimaran hull form is still largely unknown. Classification societies such as the American Bureau of Shipping (ABS) [3] or Det Norske Veritas (DNV) [4] currently have design codes for a traditional monohull's design loadings in terms of the ship's relevant dimensions and a sea-state coefficient dependent on ships dimensions to provide sufficient design margin for the life of a ship.

However, currently no such design codes exists for trimarans in general or specifically their cross-deck structures. The goal of this work is to be able to state similar design loadings based on the relevant parameters of a trimaran ship.

The trimaran's structural loading will depend strongly on the longitudinal extent as well as the longitudinal and transverse location of the outer hulls. These parameters of the outer hulls, by necessity, depend on the operational requirements and uses of the ship. In contrast with a conventional mono-hull ship, the structural loading of the trimaran potentially involves several additional loading cases not experienced by mono-hull ships. These loading cases may include longitudinal bending, transverse bending, torsional bending, spreading and squeezing of hulls, inner and outer hull slam pressures, wet deck slam pressures, loading from ship's motions, and whipping of slender hulls.

## 1.1 Thesis and general approach

Of the above-mentioned loading cases this work will focus on the structural loading in the longitudinal, transverse, and torsional wave loading cases that affect the cross-structure between the main and outer hulls of a trimaran. As previously mentioned, the loading of the cross structure between the hulls of a trimaran will depend strongly on the longitudinal extent and location of the trimaran's side hulls. This work will quantify the effects of various outer hull placements and sizes on the trimaran's cross-deck structural loading. Once the structural loading as functions of placement and size are determined, this information could be used in conjunction with other trimaran design parameters such as stability, roll, and resistance characteristics to optimize an overall trimaran ship design.

The approach for this study will be to first determine analytical approximations to the trimaran cross-deck structural loading using simple and symmetric box-type hull shapes for each of the three hulls. These analytical solutions will account for worst-case statistical sea state for various outer hull placement and size. Next these analytical approximations will be compared with quasi-finite element solutions obtained using the ship structural design program Method for Analysis Evaluation and Structural Optimization (MAESTRO) on hull forms more closely resembling actual hulls of trimarans. Comparison of these two approaches will provide an estimate the validity of the analytical approximations for various combinations of sea state and different trimaran configurations of placement and size of the outer hulls.

## 1.2 Background

The openly available previous work in the area of trimaran structural design to date has been fairly limited in scope. In general, the previous studies have assumed a worst case deterministic loading level in a few loading cases for specific designs of trimarans. The foci of these studies have been to investigate the cross-structure contribution to primary hull bending and transverse cross-structure bending in rolling conditions. The results of these studies are included in references [5] through [10].

The first of these studies examined the contribution from the side hull and cross deck structure to overall ship structural performance in longitudinal bending for both hogging and sagging [5]. The next study involving trimaran structures focused on performing a detailed structural point design including scantling sizes to estimate the structural weight fraction of a specific frigate-sized trimaran as compared to a monohull [6]. The third study again investigated the contribution of side hull and cross deck structure to the resistance of primary hull bending in hogging and sagging [7]. The next study [8] involved a reevaluation of the contribution to primary bending resistance from the side hulls and cross structure contained in references [5] and [7] with a more refined model of the trimaran hull form.

While references [5] through [8] dealt primarily with longitudinal loading in primary bending, reference [9] investigated the trimaran's structural behavior under transverse loading due to rolling the trimaran's side hulls to complete submergence or broach. The last study in trimaran structural design [10] investigates low weight alternatives to cross structure in loading condition cause by a ship rolling its hulls to complete submergence or broach.

The previous work on trimaran structural design to this point has only scratched the surface of the possible relevant structural design issues of this new hull form. While the previous work has sought to characterize a few deterministic loading scenarios for a small range of ships, this work will characterize the structural wave loading of the trimaran's cross-deck structure subjected to a statistical sea state for a variety of trimaran configurations and sizes.

# Chapter 2 General Trimaran Characteristics

The trimaran hull form has been studied extensively over the past several years at the University College London. The results of these studies have produced several variants of the trimaran ship. Some of the relevant characteristics of those designs are shown below in Table 1.

**Table 1 – Principal characteristics of UCL trimaran studies [1]**

| | Small Support Vessel | Offshore Patrol Vessel | RV TRITON | Fast Ferry | Canadian Ferry | Corvette | ASW Frigate | ASW Frigate | AAW Destroyer | Cruise Liner | LPH | Small Carrier |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Displacement (tonne) | 234 | 514 | 1117.6 | 1130 | 1350 | 1777 | 4200 | 4300 | 4978 | 9050 | 11850 | 16657 |
| Extreme Length (m) | 61.04 | 78.8 | 98 | 105 | 120 | 112 | 154.7 | 156.8 | 168.6 | 192 | 191.5 | 231.6 |
| Extreme Beam (m) | 10.85 | 13.7 | 22.5 | 19.2 | 25 | 20 | 27.5 | 25.9 | 25 | 28 | 40 | 43 |
| Depth (m) | 4.3 | 8.5 | 9 | 8.5 | 8 | 8.85 | 10.23 | 12.1 | 11.1 | 13.2 | 23.35 | 23.5 |
| Main Hull LWL (m) | 59.8 | 76.8 | 91 | 99 | 115 | 106.7 | 148.7 | 149.8 | 151.3 | 178.3 | 177.2 | 220 |
| Main Hull Beam WL (m) | 4.2 | 4.2 | 6.848 | 6.8 | 6.5 | 8.5 | 10.4 | 10.8 | 10.8 | 13 | 13.5 | 14.5 |
| Main Hull Draft WL (m) | 2.1 | 3.4 | 3.2 | 3.4 | 3.2 | 4.25 | 5.2 | 5.3 | 4.8 | 6.4 | 8.74 | 8 |
| Side Hull Displacement | 4.20% | 3.10% | 3.70% | 4.00% | 3.80% | 4.30% | 5.50% | 3.70% | 4.70% | 3.00% | 5.00% | 6.80% |
| Side Hull LWL (m) | 19.9 | 28 | 34.2 | 35 | 30 | 50 | 36 | 56.9 | 65 | 71.3 | 65.2 | 82 |
| Side Hull Beam WL (m) | 1.06 | 0.74 | 1.45 | 1.5 | 2 | 2.7 | 3 | 2 | 2.5 | 2.8 | 3.65 | 4 |
| Side Hull Draft (m) | 0.9 | 2.1 | 2.31 | 2 | 1.5 | 1.35 | 3.6 | 2.8 | 2.7 | 2.6 | 4.37 | 6.5 |
| Max Speed (knots) | 25 | 25 | 20 | 38 | 36 | 30 | 28 | 28 | 28 | 26 | 18 | 27 |
| Ps (MW) | 2.14 | 4.3 | 4 | 20 | 20 | 20 | 24 | 26 | 29 | 31.5 | 16.8 | 70 |

The general form of the trimaran in these balanced trimaran ship designs is determined by several factors including stability, roll, and resistance characteristics of a trimaran ship. In general the length of the side hulls is determined by intact and damaged stability requirements [1]. The motion characteristics for trimarans have been examined [1]. Another study indicates that outer hull waterplane area strongly affects roll motion [11]. Favorable resistance characteristics of trimaran outer hull placement have also been studied [12].

From the trimaran characteristics of the UCL designs in Table 1, other important characteristics of balanced trimaran ship designs were calculated or derived with the results shown below in Table 2.

**Table 2 – Additional characteristics of UCL trimaran studies**

| | Small Support Vessel | Offshore Patrol Vessel | RV TRITON | Fast Ferry | Canadian Ferry | Corvette | ASW Frigate | ASW Frigate | AAW Destroyer | Cruise Liner | LPH | Small Carrier |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Main Hull Relations** | | | | | | | | | | | | |
| Main Hull L/B | 14.24 | 18.29 | 13.29 | 14.56 | 17.69 | 12.55 | 14.30 | 13.87 | 14.01 | 13.72 | 13.13 | 15.17 |
| Main Hull B/T | 2.00 | 1.24 | 2.14 | 2.00 | 2.03 | 2.00 | 2.00 | 2.04 | 2.25 | 2.03 | 1.54 | 1.81 |
| Main Hull D/T | 2.05 | 2.50 | 2.81 | 2.50 | 2.50 | 2.08 | 1.97 | 2.28 | 2.31 | 2.06 | 2.67 | 2.94 |
| **Main-Side Hull Relations** | | | | | | | | | | | | |
| Side/Main Hull L/L | 0.33 | 0.36 | 0.38 | 0.35 | 0.26 | 0.47 | 0.24 | 0.38 | 0.43 | 0.40 | 0.37 | 0.37 |
| Side/Main Hull T/T | 0.43 | 0.62 | 0.72 | 0.59 | 0.47 | 0.32 | 0.69 | 0.53 | 0.56 | 0.41 | 0.50 | 0.81 |
| Side/Main Hull B/B | 0.25 | 0.18 | 0.21 | 0.22 | 0.31 | 0.32 | 0.29 | 0.19 | 0.23 | 0.22 | 0.27 | 0.28 |
| Side /Main hull y/B | 1.17 | 1.54 | 1.54 | 1.30 | 1.77 | 1.02 | 1.18 | 1.11 | 1.04 | 0.97 | 1.35 | 1.34 |
| **Side Hull Relations** | | | | | | | | | | | | |
| Side Hull L/B | 18.77 | 37.84 | 23.59 | 23.33 | 15.00 | 18.52 | 12.00 | 28.45 | 26.00 | 25.46 | 17.86 | 20.50 |
| Side Hull B/T | 1.18 | 0.35 | 0.63 | 0.75 | 1.33 | 2.00 | 0.83 | 0.71 | 0.93 | 1.08 | 0.84 | 0.62 |

The trimaran characteristics shown in Table 2 will be used later in section 4.1 for development of the analytical trimaran model to set proper limits governing the range of characteristics for investigation of the applicable trimaran design space.

# Chapter 3 Theory

The most accurate way to determine a ship's structural loading is to perform a fully dynamic analysis of the ship in a completely statistical sea state accounting for added mass and damping of the ocean in relation with the ship's motions with provisions to add the effects of the ship's forward speed and heading. However, even with today's advanced computational capabilities, this level of analysis is prohibitive for an investigation of the basic structural loading attributes of a new hull form such as the trimaran. Therefore, the emphasis of this work will study a static analysis of the wave loading of a trimaran, which often is sufficient as a first estimate of structural loading [13].

The cross-deck structural wave loading of the trimaran is affected by two major considerations: the longitudinal and transverse placement of the outer hulls, and the waterplane area (length and beam) of the outer hulls. How each of these outer hull characteristics affect each loading case is detailed below.

## 3.1 Wave Loading Cases

### 3.1.1 Longitudinal Bending

The longitudinal bending loading of a traditional monohull ship is generally characterized by two loading cases: hogging and sagging. Similarly, the longitudinal bending loads exerted on the trimaran's cross-deck structure might be expected to be described in terms of the hogging and sagging cases. However, in the case of a trimaran there can be two cases of hogging or sagging. These cases include hogging or sagging of the main hull as well as that of the outer hulls. Longitudinal bending loads in hogging and sagging of the side hulls was investigated in [8] and found to be virtually insignificant. While hogging and sagging of the main hull must be designed for in the overall structural design of a trimaran, the primary bending conditions of the main hull of a trimaran is not significantly different than that of a conventional monohull ship. Additionally, the contribution to resistance of primary bending of the ship due to the addition of the trimaran's cross-structure was investigated with the results in references [5] through [8], and hence the main hull longitudinal hogging and sagging problem is not further investigated in depth in this work.

3.1.2 Coincident Side Hull Troughing and Cresting in Longitudinal Waves

While the longitudinal bending forces incurred from the side hulls experiencing a wave of a wavelength that can produce hogging or sagging on the side hulls are not significant [8], the possibility of the wave crest or trough coinciding with the side hull length can create a significant vertical structural loading. This loading is due to the coincidence of location of the side hulls with a trough or a crest of a wave. While specific wavelengths can create a significant vertical force on the side hulls due to broaching or immersing the side hulls, the overall structural response of the entire ship is minimal compared with the wavelengths associated with primary bending in the trimaran's main hull hogging or sagging. These conditions are shown below in Figure 2 through Figure 5 with the hulls of the trimaran represented by box barges.

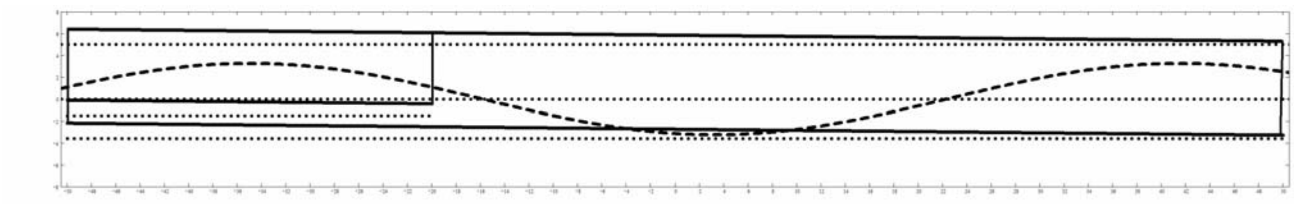

**Figure 2 – Longitudinal Cresting with Side Hulls Aft**

Figure 2 through Figure 5 show profile views of various possible configurations of coincident side hull troughing and cresting for a trimaran of typical proportions as determined from Table 2. The dotted lines show the still water position of the trimaran and waterline, the dashed line shows the wave, and the solid lines show the trimaran's response to the wave.

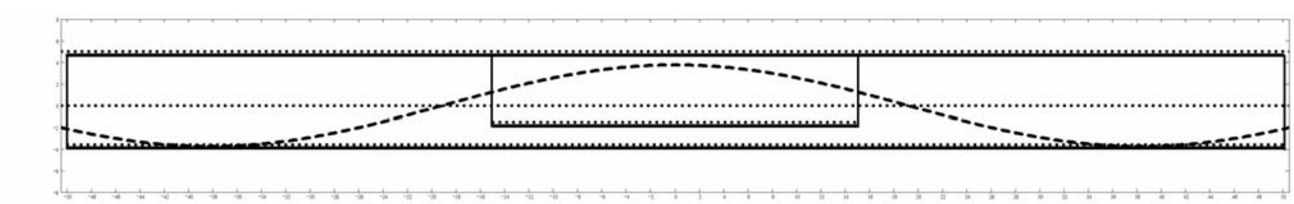

**Figure 3 – Longitudinal Cresting with Side Hulls Amidships**

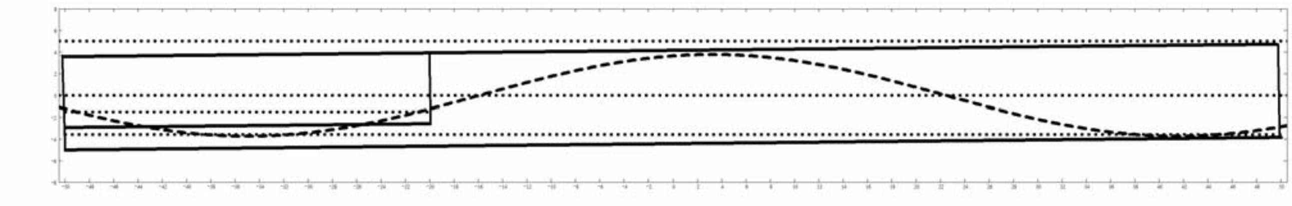

**Figure 4 – Longitudinal Troughing with Side Hulls Aft**

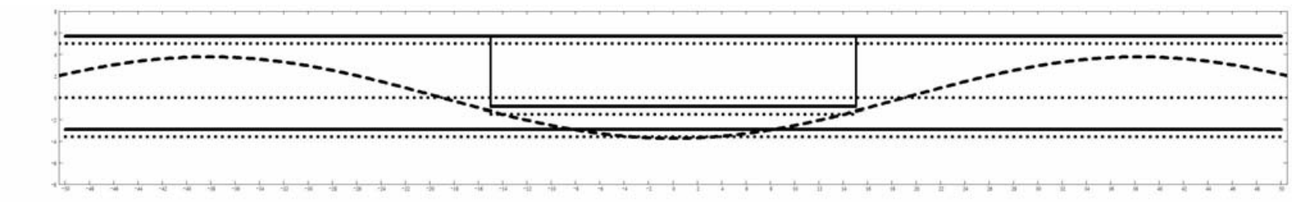

**Figure 5 – Longitudinal Troughing with Side Hulls Amidships**

In contrast with the traditional primary bending of hogging and sagging, coincident side hull troughing and cresting creates a vertical loading that increases and decreases the contribution of side hull buoyancy. For example, as can be seen in Figure 5 above, the main hull experiences a partial sagging condition, while the trough of the wave drops out from beneath the side hulls creating a vertical downward force on the cross-structure due to the loss of buoyancy of the side hulls. The troughing situation is especially relevant in the case where the outer hulls are relatively short compared to the main hull. The situation is similar for a cresting wave creating an upward vertical force on the outer hulls due to increased immersion and buoyancy.

The coincident side hull troughing and cresting conditions arise from the configuration of the trimaran's side hulls not being the same length as the main hull. Depending on the length of the main and side hulls, the side hulls could experience radical changes in their buoyant support and contribution while the main hull is relatively unaffected from the view point of a traditional primary bending conditions.

### 3.1.3 Side Hull Torsion in Longitudinal Waves

As with the case of side hull troughing and cresting, the unequal lengths of the hulls introduces a torsional structural loading on the side hull and cross-deck connection which is not experienced in traditional monohull ship designs. The side hull torsional loading can be seen below in Figure 6 through Figure 8.

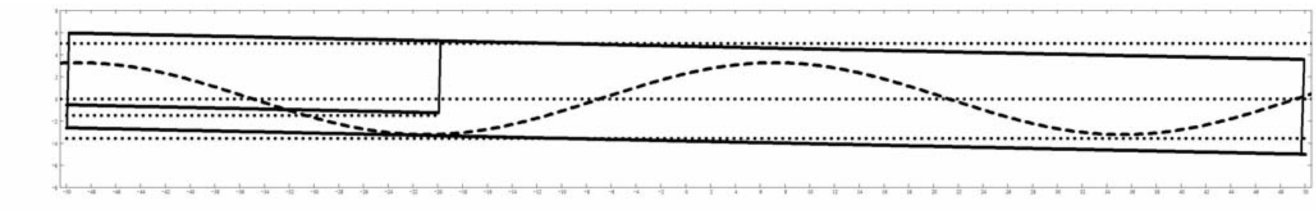

**Figure 6 – Negative Phase Twisting with Side Hulls Aft**

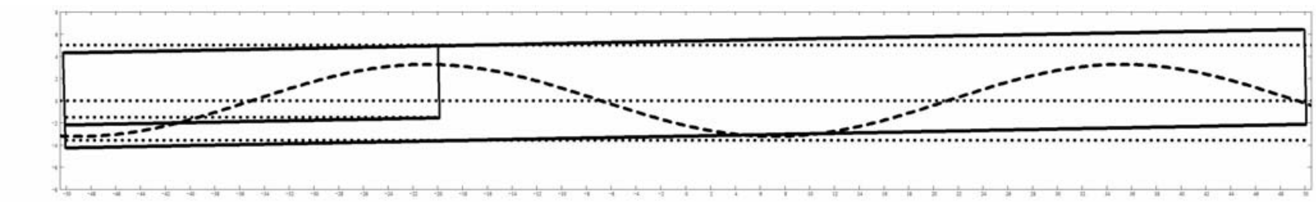

**Figure 7 – Positive Phase Twisting with Side Hulls Aft**

Figure 6 through Figure 8 show a profile view of various possible configurations of longitudinal torsional loading for a trimaran of typical proportions as determined from Table 2. The dotted lines show the still water position of the trimaran and waterline, the dashed line shows the wave, and the solid lines show the trimaran's response to the wave.

The longitudinal side hull torsion loading arises from similar conditions as that of side hull troughing and sagging. For certain side hull lengths and corresponding wavelengths produced by a particular sea-state, the side hull and cross-deck structure will experience large torsional forces while the main hull is relatively structurally unaffected when compared to its worst case loading conditions.

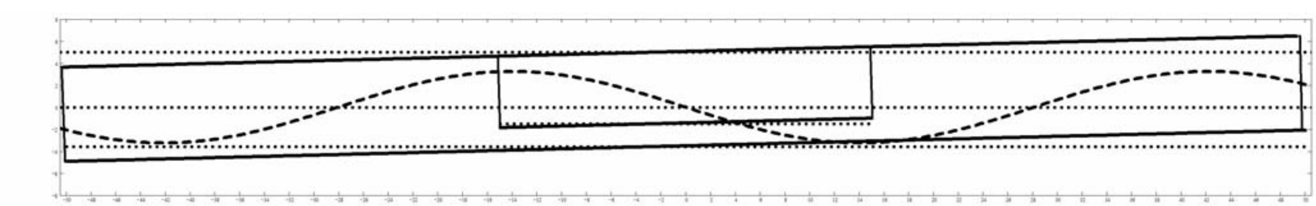

**Figure 8 – Twisting with Side Hulls Amidships**

### 3.1.4 Transverse Bending

A traditional monohull ship's structural loading is primarily characterized by the longitudinal bending cases of sagging and hogging. However, the form of the trimaran with its outer stabilizing hulls necessarily involves two new cases of structural loading in transverse bending that is not a concern with a traditional monohull design. These could probably be best described as "transverse hogging" and "transverse sagging." The transverse sagging load case is shown below in Figure 9, while transverse hogging is shown in Figure 10. Figure 9 and Figure 10 show an end view of a typical trimaran ship represented with box hulls.

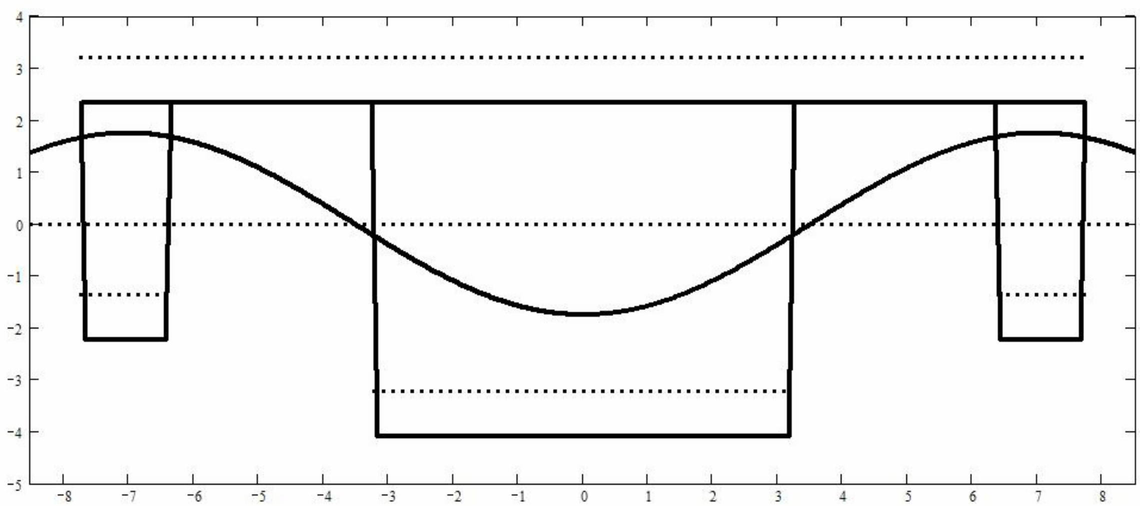


**Figure 9 – Transverse Sagging**

The dotted lines in the figures show the original still water position of the trimaran, and the heavy lines show the effect on the ship in a transverse beam wave condition. Like the loading conditions previously mentioned, the transverse beam wave condition gives rise to a situation where the side hulls are again gaining or losing buoyancy as compared to the still water case. This change in buoyancy leads to vertical forces applied to the trimaran's cross-deck structure. Depending on the trimaran's outer hull placement and the wavelengths of the beam waves encountered, the side hulls could be completely broached from or immersed in the water.

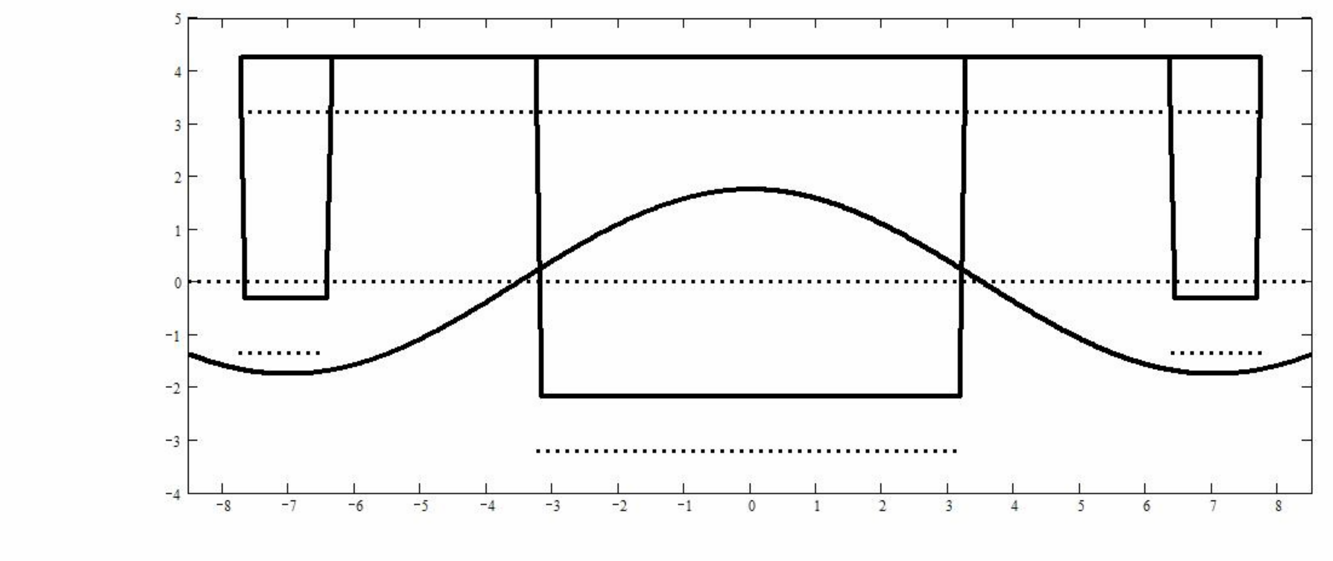


**Figure 10 – Transverse Hogging**

The "transverse hogging" case in Figure 10 is in reality an unstable condition, since the trimaran in this loading condition will most likely roll until one of its outer hulls rests in the water. However, the transverse hogging has been presented in its unstable condition because it is equivalent to the limiting load case where the outer hull is completely broached from the water.

### 3.1.5 Other Possible Loading Cases

The structural loading conditions outlined in sections 3.1.2, 3.1.3, and 3.1.4 above only take into account the limited scenarios where the wave front direction is either completely in a head seas or beam seas orientation. Obviously, the majority of the wave fronts experienced by any ship in its service life time will in general be at some oblique angle to the ship's heading. This oblique angle will contain some of the characteristics of the load cases outline above with additional hydrodynamic forces tending to squeeze and spread the hulls in the transverse direction.

In addition to the transverse hydrodynamic forces, other dynamic loading effects due to the ship's speed and heading will also need to be accounted for to perform a complete analysis. While these other structural loadings and effects are important to the final structural design and integrity of the completed trimaran ship, the complexity involved in accounting for each effect is staggering.  For the scope of this work, investigating the basic loading parameters, the structural loading conditions of coincident side hull troughing and cresting, side hull longitudinal torsion, and transverse hogging/sagging will be studied as to describe the loading conditions to which a trimaran's cross-deck structure is subjected.

# Chapter 4 Analysis Tools

## 4.1 Analytical Trimaran Model

Over the course of this research almost 40 versions of analytical trimaran models were developed with each version adding successively more functionality and detail. However, the core of the analytical thesis model is that it approximates a trimaran as three rigidly connected "box barges" of appropriate dimensions obtained from Table 2. The analytical model then statically balances the trimaran on a wave and calculates the load forces, as described in section 3.1, applied to the cross-deck structure between the hulls. In this section the details of the final analytical thesis model will be discussed. Specific equations from the model will be provided in 0Appendix A. While any programming language would have been perfectly acceptable computational tool, the MathCAD program was used to perform the calculations for the analytical model due to its visually attractive mathematical interface.

Classification societies such as the American Bureau of Shipping (ABS) [3] or Det Norske Veritas (DNV) [4] often state design codes for ships strength in terms of the ship's relevant dimensions and a sea-state coefficient dependent on ships dimensions to provide sufficient design margin for the life of a ship. The goal of the analytical thesis model is to be able to state similar design loadings based on the relevant parameters of a trimaran ship. The design loadings obtained for the load cases described sections 3.1.2, 3.1.3, and 3.1.4 are shown below in Table 3 while the relevant design parameters or the trimaran ship are shown in Table 4.

**Table 3 –Structural Loading from sections 3.1.2, 3.1.3, and 3.1.4**

| | |
|---|---|
| $FB_{lg}$ | the vertical force on cross-structure in longitudinal waves (troughing and cresting) |
| $MB_{lg}$ | the moment on cross-structure in longitudinal waves (longitudinal twisting) |
| $FB_{tr}$ | the vertical force in transverse waves (transverse hogging/sagging) |

**Table 4 – Relevant Trimaran Parameters Affecting Design Loading**

| | |
|---|---|
| $B_m$ | the main hull's beam |
| $L_m$ | the main hull's length |
| $T_m$ | the main hull's draft |
| $F_m$ | the main hull's freeboard (also side hull freeboard) |
| $B_s$ | the side hull's beam |
| $L_s$ | the side hull's length |
| $T_s$ | the side hull's draft |
| $X_s$ | the longitudinal position of the side hull wrt main hull amidships |
| $Y_s$ | the transverse position of the side hull wrt main hull centerline |

### 4.1.1 Analytical Model Parts

The analytical model used for this work consists of two major components. These are the calculation of the ships motions and forces and the calculation of the representative sea states. Each part is described below with its corresponding equation provided in Appendix A.

#### 4.1.1.1 Entry of Statistical Sea State

A joint frequency table in both wave period and significant wave height for the northern North Atlantic Ocean was obtained from [14]. This table was converted to a joint probably table whose results are shown below in Table 5 and Table 6. This joint probability table of wave height and period was used for a statistical representation of the most severe sea state in which the trimaran hull form would be subjected. The data represented in Table 5 and Table 6 is often approximated with well known distributions such as the Brentschneider or other spectra. However, these spectra often described in only a few parameters and do not always fully capture the true nature of the joint probability of the sea state in the wave height and wavelength parameters. Therefore, the observed tabular data was utilized.

**Table 5 – Joint Probability Mass Table of Significant Wave Height and Period**

| Significant Wave Height (m) | Spectral Peak Period (s) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
| 0.5 | 0.0006 | 0.004 | 0.0106 | 0.0157 | 0.0163 | 0.0136 | 0.0098 | 0.0064 | 0.0039 | |
| 1.5 | 9E-05 | 0.0021 | 0.0123 | 0.0322 | 0.0511 | 0.0581 | 0.0528 | 0.041 | 0.0285 | |
| 2.5 | 0 | 8E-05 | 0.0015 | 0.0083 | 0.0229 | 0.039 | 0.0471 | 0.0446 | 0.0353 | |
| 3.5 | 0 | 0 | 6E-05 | 0.0008 | 0.0048 | 0.0137 | 0.0241 | 0.0296 | 0.028 | |
| 4.5 | 0 | 0 | 0 | 4E-05 | 0.0006 | 0.0031 | 0.009 | 0.0156 | 0.0188 | |
| 5.5 | 0 | 0 | 0 | 0 | 3E-05 | 0.0004 | 0.0021 | 0.0057 | 0.0095 | |
| 6.5 | 0 | 0 | 0 | 0 | 0 | 2E-05 | 0.0003 | 0.0014 | 0.0035 | |
| 7.5 | 0 | 0 | 0 | 0 | 0 | 0 | 2E-05 | 0.0002 | 0.0009 | |
| 8.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2E-05 | 0.0001 | |
| 9.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2E-05 | |
| 10.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 11.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 12.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 14.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

Where each wave height indicated is the center of a 1 meter range of heights

**Table 6 – Joint Probability Mass Table of Significant Wave Height and Period**

| Significant Wave Height (m) | Spectral Peak Period (s) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 21 | 22 |
| 0.5 | 0.0023 | 0.0013 | 0.0007 | 0.0004 | 0.0002 | 0.0001 | 7E-05 | 4E-05 | 2E-05 | 2E-05 |
| 1.5 | 0.0182 | 0.011 | 0.0063 | 0.0035 | 0.0019 | 0.001 | 0.0006 | 0.0003 | 0.0002 | 0.0002 |
| 2.5 | 0.0245 | 0.0154 | 0.009 | 0.005 | 0.0026 | 0.0013 | 0.0007 | 0.0003 | 0.0002 | 0.0001 |
| 3.5 | 0.0216 | 0.0144 | 0.0085 | 0.0046 | 0.0023 | 0.0011 | 0.0005 | 0.0002 | 1E-04 | 7E-05 |
| 4.5 | 0.017 | 0.0123 | 0.0075 | 0.004 | 0.0019 | 0.0008 | 0.0003 | 0.0001 | 5E-05 | 3E-05 |
| 5.5 | 0.0107 | 0.0088 | 0.0057 | 0.0031 | 0.0014 | 0.0006 | 0.0002 | 7E-05 | 2E-05 | 1E-05 |
| 6.5 | 0.0053 | 0.0053 | 0.0039 | 0.0022 | 0.001 | 0.0004 | 0.0001 | 4E-05 | 1E-05 | 0 |
| 7.5 | 0.002 | 0.0026 | 0.0023 | 0.0014 | 0.0006 | 0.0002 | 7E-05 | 2E-05 | 0 | 0 |
| 8.5 | 0.0005 | 0.001 | 0.0011 | 0.0008 | 0.0004 | 0.0001 | 4E-05 | 1E-05 | 0 | 0 |
| 9.5 | 0.0001 | 0.0003 | 0.0004 | 0.0004 | 0.0002 | 8E-05 | 2E-05 | 1E-05 | 0 | 0 |
| 10.5 | 2E-05 | 7E-05 | 0.0001 | 0.0002 | 0.0001 | 5E-05 | 1E-05 | 0 | 0 | 0 |
| 11.5 | 0 | 1E-05 | 4E-05 | 6E-05 | 5E-05 | 2E-05 | 1E-05 | 0 | 0 | 0 |
| 12.5 | 0 | 0 | 1E-05 | 2E-05 | 2E-05 | 1E-05 | 0 | 0 | 0 | 0 |
| 13.5 | 0 | 0 | 0 | 0 | 1E-05 | 0 | 0 | 0 | 0 | 0 |
| 14.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Where each wave height indicated is the center of a 1 meter range of heights

#### 4.1.1.2 Conversion of Statistical Sea State

The data represented in Table 5 and Table 6 give the joint probability of a sea state having a given significant wave height and period. However, the data given is for short term observations of a narrow-banded, fully developed sea state reported in terms of significant wave height. However, significant wave height is a one parameter descriptor of the probability distribution for a fully developed sea state. The probability of the peak values of the actual wave amplitudes for a fully developed sea state are described by a Rayleigh distribution with significant wave height as the distribution function parameter. Correspondingly, each entry of Table 5 and Table 6 actually describes the joint probability of a certain Rayleigh distribution occurring. Since the limiting design of the trimaran is concerned with an overall probability of the wave loading conditions encountered, the data in Table 5 and Table 6 was converted to represent an absolute joint probability of actual wave height verses wave period in lieu of significant wave height.

Using [15], equation (1) was derived. Equation (1) is the Rayleigh probability distribution of actual wave height in terms of significant wave height.

$$p_{ray}\left(h_w, t\right) = 4 \cdot \frac{h_w}{\left(H_{s_t}\right)^2} \cdot e^{-2 \cdot \left[\frac{h_w^2}{\left(H_{s_t}\right)^2}\right]} \qquad (1)$$

Where:
$p_{ray}$ – the Rayleigh distribution probability as functions of wave height and the index t
$h_w$ – the actual wave height
$H_s$ – the observed significant wave height
t – the index of the observed significant wave height in Table 5 and Table 6

Using the Rayleigh probability distribution in equation (1), for each significant observed wave height, the probability of being in each wave height range of Table 5 and Table 6 was calculated by integrating the Rayleigh distribution in one meter segments. The result of the integral was multiplied by the joint probability shown in Table 5 and Table 6 and then added to the other associated probabilities affecting that wave height region. The result is shown in below in Table 7 and Table 8.

**Table 7 – Joint Probability of True Wave Height and Period (3-11 second periods)**

| Significant Wave Height (m) | Spectral Peak Period (s) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
| 0.5 | 0.0006 | 0.0053 | 0.0183 | 0.0371 | 0.0535 | 0.0609 | 0.0584 | 0.0492 | 0.0372 | |
| 1.5 | 3E-05 | 0.0008 | 0.0054 | 0.0163 | 0.0315 | 0.045 | 0.0517 | 0.0502 | 0.0424 | |
| 2.5 | 3E-06 | 8E-05 | 0.0007 | 0.003 | 0.0081 | 0.0152 | 0.0218 | 0.0252 | 0.0245 | |
| 3.5 | 3E-08 | 5E-06 | 9E-05 | 0.0006 | 0.002 | 0.0049 | 0.0085 | 0.0115 | 0.0128 | |
| 4.5 | 0 | 5E-07 | 1E-05 | 1E-04 | 0.0005 | 0.0014 | 0.0031 | 0.005 | 0.0063 | |
| 5.5 | 0 | 3E-08 | 1E-06 | 2E-05 | 0.0001 | 0.0004 | 0.0011 | 0.0021 | 0.003 | |
| 6.5 | 0 | 0 | 1E-07 | 3E-06 | 3E-05 | 0.0001 | 0.0004 | 0.0008 | 0.0014 | |
| 7.5 | 0 | 0 | 2E-08 | 5E-07 | 6E-06 | 3E-05 | 0.0001 | 0.0003 | 0.0006 | |
| 8.5 | 0 | 0 | 0 | 6E-08 | 1E-06 | 9E-06 | 4E-05 | 0.0001 | 0.0003 | |
| 9.5 | 0 | 0 | 0 | 1E-08 | 3E-07 | 2E-06 | 1E-05 | 5E-05 | 0.0001 | |
| 10.5 | 0 | 0 | 0 | 0 | 3E-08 | 5E-07 | 4E-06 | 2E-05 | 5E-05 | |
| 11.5 | 0 | 0 | 0 | 0 | 8E-09 | 1E-07 | 1E-06 | 6E-06 | 2E-05 | |
| 12.5 | 0 | 0 | 0 | 0 | 0 | 2E-08 | 3E-07 | 2E-06 | 7E-06 | |
| 13.5 | 0 | 0 | 0 | 0 | 0 | 5E-09 | 1E-07 | 7E-07 | 3E-06 | |
| 14.5 | 0 | 0 | 0 | 0 | 0 | 0 | 1E-08 | 2E-07 | 1E-06 | |
| 15.5 | 0 | 0 | 0 | 0 | 0 | 0 | 4E-09 | 7E-08 | 4E-07 | |
| 16.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1E-08 | 1E-07 | |
| 17.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4E-09 | 5E-08 | |
| 18.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9E-09 | |
| 19.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4E-09 | |
| 20.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 21.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 22.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 23.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 24.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 25.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 26.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 27.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 28.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 29.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

**Table 8 – Joint Probability of True Wave Height and Period (12-22 second periods)**

Spectral Peak Period (s)

| Significant Wave Height (m) | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 0.0256 | 0.0163 | 0.0096 | 0.0053 | 0.0028 | 0.0014 | 0.0007 | 0.0004 | 0.0002 | 0.0002 |
| 1.5 | 0.0317 | 0.0212 | 0.0128 | 0.007 | 0.0036 | 0.0018 | 0.0008 | 0.0004 | 0.0002 | 0.0002 |
| 2.5 | 0.0203 | 0.0145 | 0.009 | 0.005 | 0.0025 | 0.0011 | 0.0005 | 0.0002 | 9E-05 | 7E-05 |
| 3.5 | 0.0117 | 0.0089 | 0.0058 | 0.0032 | 0.0016 | 0.0007 | 0.0003 | 0.0001 | 4E-05 | 3E-05 |
| 4.5 | 0.0063 | 0.0052 | 0.0035 | 0.002 | 0.001 | 0.0004 | 0.0001 | 5E-05 | 2E-05 | 1E-05 |
| 5.5 | 0.0033 | 0.003 | 0.0021 | 0.0012 | 0.0006 | 0.0002 | 8E-05 | 3E-05 | 7E-06 | 4E-06 |
| 6.5 | 0.0017 | 0.0016 | 0.0012 | 0.0007 | 0.0004 | 0.0001 | 5E-05 | 1E-05 | 3E-06 | 1E-06 |
| 7.5 | 0.0008 | 0.0009 | 0.0007 | 0.0004 | 0.0002 | 8E-05 | 3E-05 | 8E-06 | 1E-06 | 5E-07 |
| 8.5 | 0.0004 | 0.0005 | 0.0004 | 0.0003 | 0.0001 | 5E-05 | 1E-05 | 4E-06 | 5E-07 | 1E-07 |
| 9.5 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 8E-05 | 3E-05 | 9E-06 | 2E-06 | 2E-07 | 4E-08 |
| 10.5 | 9E-05 | 0.0001 | 0.0001 | 9E-05 | 5E-05 | 2E-05 | 5E-06 | 1E-06 | 8E-08 | 1E-08 |
| 11.5 | 4E-05 | 6E-05 | 7E-05 | 5E-05 | 3E-05 | 1E-05 | 3E-06 | 7E-07 | 3E-08 | 3E-09 |
| 12.5 | 2E-05 | 3E-05 | 3E-05 | 3E-05 | 2E-05 | 6E-06 | 2E-06 | 4E-07 | 8E-09 | 0 |
| 13.5 | 8E-06 | 1E-05 | 2E-05 | 2E-05 | 1E-05 | 4E-06 | 1E-06 | 2E-07 | 2E-09 | 0 |
| 14.5 | 3E-06 | 7E-06 | 1E-05 | 9E-06 | 6E-06 | 2E-06 | 6E-07 | 1E-07 | 0 | 0 |
| 15.5 | 2E-06 | 3E-06 | 5E-06 | 5E-06 | 3E-06 | 1E-06 | 3E-07 | 5E-08 | 0 | 0 |
| 16.5 | 6E-07 | 1E-06 | 2E-06 | 3E-06 | 2E-06 | 7E-07 | 2E-07 | 2E-08 | 0 | 0 |
| 17.5 | 3E-07 | 7E-07 | 1E-06 | 1E-06 | 1E-06 | 4E-07 | 1E-07 | 1E-08 | 0 | 0 |
| 18.5 | 7E-08 | 3E-07 | 6E-07 | 7E-07 | 6E-07 | 2E-07 | 5E-08 | 4E-09 | 0 | 0 |
| 19.5 | 4E-08 | 1E-07 | 3E-07 | 4E-07 | 4E-07 | 1E-07 | 3E-08 | 2E-09 | 0 | 0 |
| 20.5 | 7E-09 | 4E-08 | 1E-07 | 2E-07 | 2E-07 | 6E-08 | 1E-08 | 0 | 0 | 0 |
| 21.5 | 4E-09 | 2E-08 | 7E-08 | 1E-07 | 1E-07 | 4E-08 | 8E-09 | 0 | 0 | 0 |
| 22.5 | 0 | 3E-09 | 2E-08 | 4E-08 | 5E-08 | 2E-08 | 3E-09 | 0 | 0 | 0 |
| 23.5 | 0 | 2E-09 | 1E-08 | 2E-08 | 3E-08 | 9E-09 | 2E-09 | 0 | 0 | 0 |
| 24.5 | 0 | 0 | 3E-09 | 6E-09 | 1E-08 | 3E-09 | 0 | 0 | 0 | 0 |
| 25.5 | 0 | 0 | 2E-09 | 3E-09 | 8E-09 | 2E-09 | 0 | 0 | 0 | 0 |
| 26.5 | 0 | 0 | 0 | 0 | 3E-09 | 0 | 0 | 0 | 0 | 0 |
| 27.5 | 0 | 0 | 0 | 0 | 2E-09 | 0 | 0 | 0 | 0 | 0 |
| 28.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

#### 4.1.1.3 Equations of Applied Waves

To create the loading conditions discussed above in sections 3.1.2, 3.1.3, and 3.1.4 from the wave height and period data in Table 7 and Table 8, the waves were applied as described below.

First the deep-water wavelength approximation was made by equation (2) for each period in Table 7 and Table 8.

$$\lambda = \frac{g}{2\cdot\pi}\cdot(T)^2 \tag{2}$$

Where:
λ – the wavelength of the wave
g – the gravitational constant
T – the wave period from Table 7 and Table 8

Equation (2) applied to each indicated wave period yielded the wavelengths indicated in below Table 9.

**Table 9 – Deep Water Wavelengths**

| Period (s) | Wavelength (m) |
|---|---|
| 3 | 14.05 |
| 4 | 24.97 |
| 5 | 39.02 |
| 6 | 56.19 |
| 7 | 76.48 |
| 8 | 99.89 |
| 9 | 126.42 |
| 10 | 156.08 |
| 11 | 188.85 |
| 12 | 224.75 |
| 13 | 263.77 |
| 14 | 305.91 |
| 15 | 351.17 |
| 16 | 399.56 |
| 17 | 451.06 |
| 18 | 505.69 |
| 19 | 563.44 |
| 21 | 688.30 |
| 22 | 755.42 |

Next the following wave equations for the longitudinal and transverse directions were applied with the proper phasing to apply the loading conditions described in sections 3.1.2, 3.1.3, and 3.1.4. The coordinate system used for the analytical model was those of traditional ship coordinate systems of x-longitudinal, y-transverse, and z-vertical. The coordinate system of the analytical model is shown below in Figure 11.

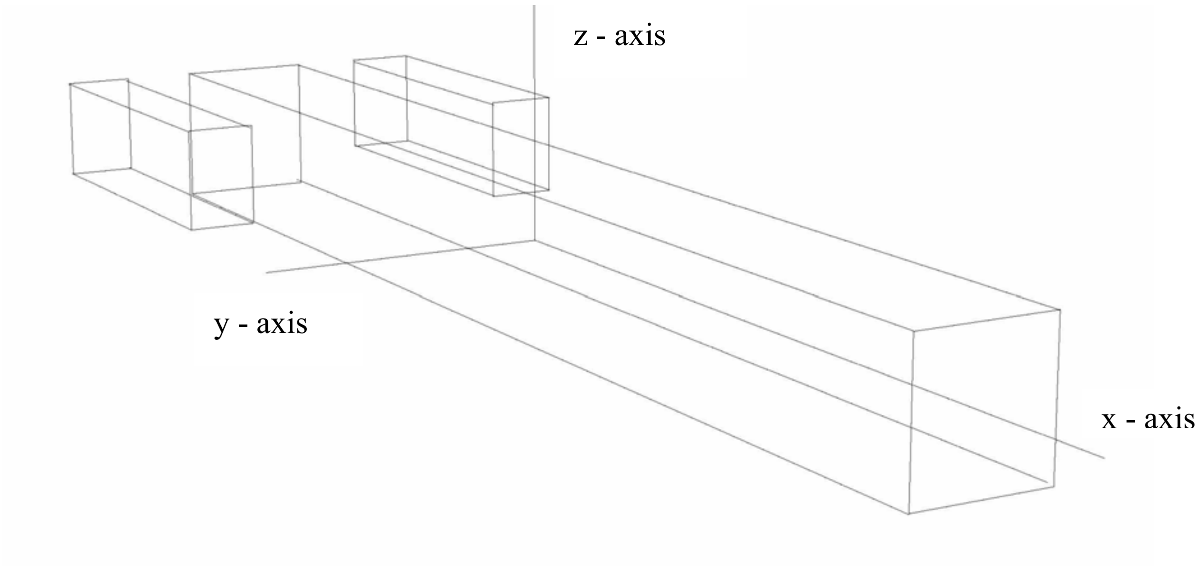


**Figure 11 – Analytical Model Coordinate System**

The wave equations used to create the specific loading conditions are show below in equations (3) and (4).

$$H_{wave\_lg}(x,p,q,\phi,X_s) = \frac{h_{w_p}}{2}\cdot\sin\left[\frac{2\cdot\pi}{\lambda_q}\cdot(x - X_s) - \phi\right] \qquad \phi_{lg} = \begin{pmatrix} 0 \\ 90 \\ 180 \\ 270 \end{pmatrix}\cdot deg \qquad \phi_{lg} = \begin{pmatrix} pos\_twist \\ trough \\ neg\_twist \\ crest \end{pmatrix} \tag{3}$$

$$H_{wave\_tr}(y,p,q,\phi) := \frac{h_{w_p}}{2}\cdot\cos\left[\frac{2\cdot\pi}{\lambda_q}\cdot(y) - \phi\right] \qquad \phi_{tr} = \begin{pmatrix} 0 \\ 180 \end{pmatrix}\cdot deg \qquad \phi_{tr} = \begin{pmatrix} hog \\ sag \end{pmatrix} \tag{4}$$

Where:
$H_{wave\_lg}$ – is the longitudinal wave amplitude as functions of the shown variables
$H_{wave\_tr}$ – is the transverse wave amplitude as functions of the shown variables
$h_w$ – the actual wave height from Table 7 and Table 8
x – the longitudinal position
$X_s$ – the longitudinal position of the side hull wrt main hull amidships
y – the transverse position
λ – the wavelength of the wave
φ – the phase of the wave applied for each loading condition
p – the index of the wave height Table 7 and Table 8
q – the index of the wavelength from Table 9

Equations (3) and (4) define the wave amplitude in the longitudinal and transverse directions respectively. Both equations are functions of the index p which references the wave heights in Table 7 and Table 8. The wave definition equations are also functions of the index q referencing the wavelengths in Table 9. Additionally equation (3) is defined so that the origin of the wave is longitudinally offset to coincide with the longitudinal center of the side hull, $X_s$. Equations (3) and (4) are also defined as a function of applied phase angle so that each phase angle can be easily applied to generate the load cases defined in sections 3.1.2, 3.1.3, and 3.1.4. Finally, sinusoidal waves were used to approximate the wave functions rather than trochoidal waves, which more truly represent water waves, since the difference between sinusoidal and trochoidal waves for the wavelengths of concern is relatively small.

4.1.1.4 Calculation of Motion due to Applied Waves

After the waves applied to the trimaran hull form were defined as in equations (3) and (4) above, the next step in finding the load forces on the trimarans cross-structure was to perform a static balance of the ship for a particular wave. For the longitudinal wave cases, the static balance required simultaneously solving for the pitch and heave of the ship. While solving simultaneously equations for heave and pitch of a ship is conceptually simple, the practice of executing this concept is somewhat cumbersome. To perform the static balance, the underwater volume and the first moment of that volume subjected to the wave must balance with the displacement and moment of the ship in the pitched and heaved condition. This process involved iteratively solving equations (5) and (6) below using a modified Newton's method. Equation (5) is the heave equation.

$$\nabla_{still} = B_m \cdot \int_{\frac{-L_m}{2}}^{\frac{L_m}{2}} \left[ H_{wave\_lg}(x,\phi) - \Delta T - (x - X_{cf}) \cdot \sin(\Theta_{pitch}) \right] dx \ldots$$

$$+ 2 \cdot B_s \cdot \int_{X_s - \frac{L_s}{2}}^{X_s + \frac{L_s}{2}} \left[ H_{wave\_lg}(x,\phi) - \Delta T - (x - X_{cf}) \cdot \sin(\Theta_{pitch}) \right] dx \qquad (5)$$

Where:

$\Delta T$ – the change in heave of the ship due to the longitudinal wave
$\Theta_{pitch}$ – the change in pitch of the ship due to the longitudinal wave
$H_{wave\_lg}$ – is the longitudinal wave height as functions of position and phase from (3)*
x – the longitudinal position
φ – the phase of the wave applied for each loading condition
$B_m$ – the main hull's beam
$L_m$ – the main hull's length
$B_s$ – the side hull's beam
$L_s$ – the side hull's length
$X_s$ – the longitudinal position of the side hull wrt main hull amidships
$X_{cf}$ – the longitudinal position of the entire ship's center of floatation
$\nabla_{still}$ – the original still water displacement
$Trim_{still}$ – the original still water trim (assumed to be zero)
* For simplicity the wave height here is only shown as functions of position and phase with wave height and wavelength indices omitted.

Equation (6) is the heave equation.

$$Trim_{still} = B_m \cdot \int_{\frac{-L_m}{2}}^{\frac{L_m}{2}} \left[H_{wave\_lg}(x,\phi) - \Delta T - (x - X_{cf}) \cdot \sin(\Theta_{pitch})\right] \cdot (x - X_{cf})\, dx \ldots$$

$$+ 2 \cdot B_s \cdot \int_{X_s - \frac{L_s}{2}}^{X_s + \frac{L_s}{2}} \left[H_{wave\_lg}(x,\phi) - \Delta T - (x - X_{cf}) \cdot \sin(\Theta_{pitch})\right] \cdot (x - X_{cf})\, dx$$

(6)

Where:
The definitions of terms from equation (5) apply.

As with the longitudinal case above, the heave of the trimaran due to transverse waves was calculated in a similar manner. However, since this work does not deal with the affects of roll on the ship and takes as a worst case the "transverse hogging and sagging" described in section 3.1.4, only one integral equation was needed to solve for the ship's heave in transverse waves.

$$\nabla_{still} = L_m \cdot \int_{\frac{-B_m}{2}}^{\frac{B_m}{2}} \left(H_{wave\_tr}(y,\phi) - \Delta T\right) dy + 2 \cdot L_s \cdot \int_{Y_s - \frac{B_s}{2}}^{Y_s + \frac{B_s}{2}} \left(H_{wave\_tr}(y,\phi) - \Delta T\right) dy$$

(7)

Where:
$\Delta T$ – the change in heave of the ship due to the transverse wave
$H_{wave\_tr}$ – is the transverse wave height as functions of position and phase from (4)*
y – the transverse position
$\varphi$ – the phase of the wave applied for each loading condition
$B_m$ – the main hull's beam
$L_m$ – the main hull's length
$B_s$ – the side hull's beam
$L_s$ – the side hull's length
$Y_s$ – the transverse position of the side hull wrt main hull centerline
$\nabla_{still}$ – the original still water displacement
* For simplicity the wave height here is only shown as functions of position and phase with wave height and wavelength indices omitted.

While equations (5), (6), and (7) display the conditions for a static balance on waves, the motion parameters of heave and pitch ($\Delta T$ and $\Theta_{pitch}$) were solved for in terms of a change from the initial still water conditions that were assumed to be zero. The motion parameters of heave and pitch in the analytical model were left as functions of several variables that defined the general characteristics of the trimarans dimensions, so that the motion of several different variations of trimarans could be computed.

4.1.1.5 Calculation of Forces due to Motion in Waves

Once the motions of the trimaran due to the static balance were found as explained section 4.1.1.4, the forces due to those motions were calculated. The motion parameters of the ship in waves in section 4.1.1.4 were determined in reference to the still water condition. Consequently, the force calculation was performed as a change from the still water waterline position of the trimaran's side hulls. For example, if the side hull is more immersed than the still water position as in the "transverse sagging" case shown in Figure 12, then the buoyancy of the water provides an upward force on the cross-structure.

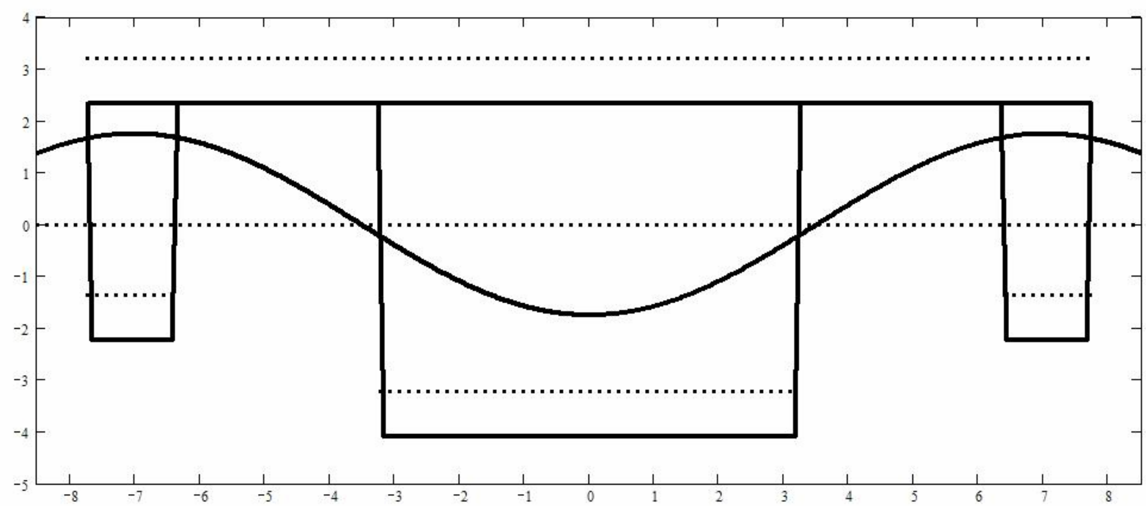


**Figure 12 – Transverse Sagging Applying Upward Buoyant Force on Cross Structure**

The force calculations for transverse hogging and longitudinal cresting or troughing are similar. In these cases the particular wave height and phase that the trimaran encounters either provides more or less buoyancy to the side hulls and consequently cantilevered type vertical forces are applied to the cross structure.

The twisting force applied to the cross structure of the trimaran was calculated in a similar manner as the vertical forces. The ship was statically balanced on the wave at phases of maximum twisting forces on the cross structure, and then the twisting moment due to the wave was calculated as a change from the still water condition. A case of this twisting situation is shown in Figure 13 which causes a positive twisting moment to be applied to the cross structure.

The position of the calculation of the twisting moment coincided with the longitudinal center of the side hull. The vertical position of the twisting moment was assumed to be at the original vertical position of side hull draft, which is an approximate position due the ships heaving and pitching motions.

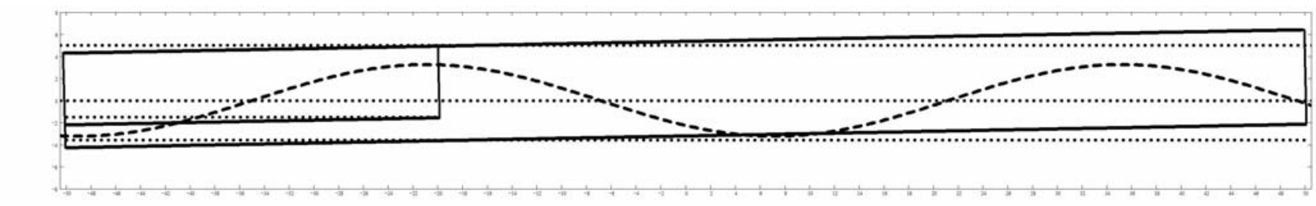

**Figure 13 – Positive Phase Twisting with Side Hulls Aft**

The analytical model calculated the vertical forces and twisting forces applied to the side hull due to the motion in waves. The model was generalized such that these forces were calculated as functions of many variables so that the model could be used to repetitively calculated forces for different wave states and trimaran configurations. These parameters included those of wave height, wavelength, and wave phase from the wave equations of (3) and (4). The pertinent parameters of the trimaran such as length, beam, draft, hull spacing and freeboard were also included in the force calculations.

The dependent forces variables and there independent variables are shown below in equations (8), (9), and (10) with position of application shown in Figure 14 their full definition of calculation shown in Appendix A.

$$FB_{lg}\left(p, q, \phi, X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) \tag{8}$$

$$MB_{lg}\left(p, q, \phi, X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) \tag{9}$$

$$FB_{tr}\left(p, q, \phi, Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) \tag{10}$$

Where:

$FB_{lg}$ – the vertical force on cross-structure in longitudinal waves (troughing and cresting)
$MB_{lg}$ – the moment on cross-structure in longitudinal waves (longitudinal twisting)
$FB_{tr}$ – the vertical force in transverse waves (transverse hogging/sagging)
p – the index of the wave height Table 7 and Table 8
q – the index of the wavelength from Table 9
φ – the phase of the wave applied for each loading condition
$X_{cf}$ – the longitudinal position of the entire ship's center of floatation
$X_s$ – the longitudinal position of the side hull wrt main hull amidships
$T_m$ – the main hull's draft
$B_m$ – the main hull's beam
$L_m$ – the main hull's length
$F_m$ – the main hull's freeboard (also side hull freeboard)
$T_s$ – the side hull's draft
$B_s$ – the side hull's beam
$L_s$ – the side hull's length
$Y_s$ – the transverse position of the side hull wrt main hull centerline

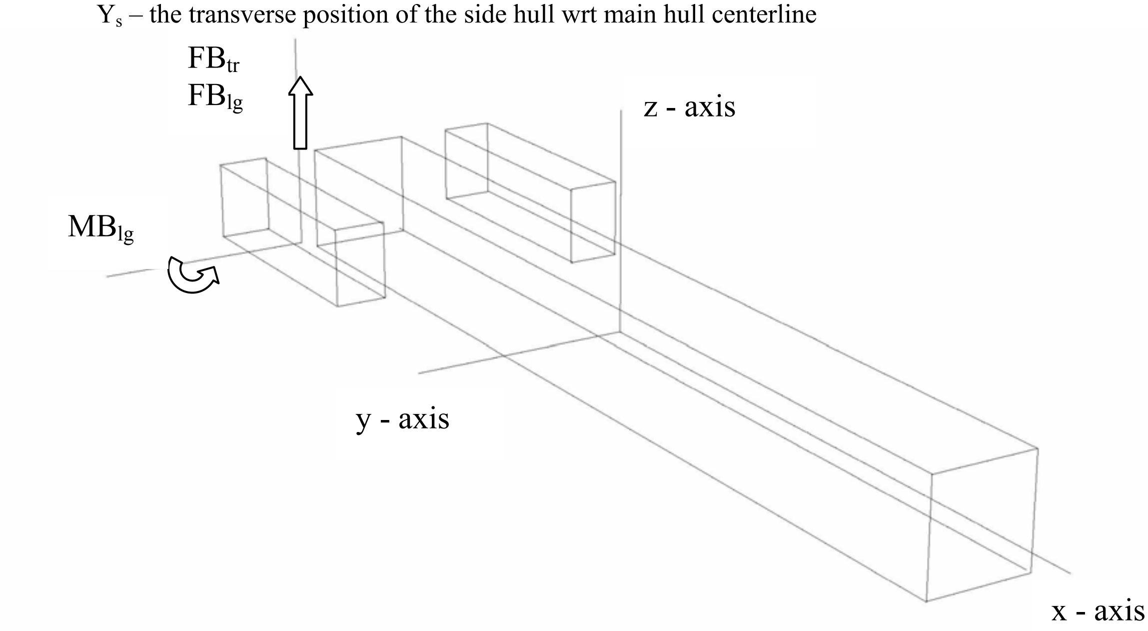


**Figure 14 – Analytical Model Position of Calculated Forces**

One main assumption for the calculation of forces and moments in the analytical model was that the initial still water position of the side hulls provided a neutrally buoyant displacement. This neutrally buoyant condition enforces a condition that there are no applied forces to the cross structure due to still water buoyancy conditions. While this would seem to be a reasonable design condition, it would not be a necessary condition and any imbalance in the still water forces would require accounted for. For the purpose of this work, however, the still water loading was assumed to be zero so that the nature of the structural loading in waves could be determined by equations (8), (9), and (10).

Another simplification in the analytical model was that wet deck slamming of waves with large wave heights into the trimaran cross-deck structure was not taken into account. While this assumption will eventually need to be restored to fully calculate the structural effects of sea state on trimarans, the effects were not found to be extremely relevant given the scope of this investigation. For example, for a 100m long trimaran of representative dimensions from Table 1, to obtain impact of waves with the trimarans cross deck structure would require significant wave heights on the order of 6 meters. This wave height corresponds to sea states of 6 or 7 [14]. Not only are these sea states very high for a ship of 100 meters, but also these sea states are relatively unlikely probabilistically as can be seen in Table 5 and Table 6. Therefore, discounting the cross-deck slamming for this analysis can be justified for this work.

#### 4.1.1.6 Calculation of Design Forces due to a Full Sea Spectrum

Once the functions used to calculate the forces on the cross deck structure were defined in equations (8), (9), and (10), it was then possible to define a design load that the cross deck structure of a trimaran must withstand. Design loads are often stated in terms of safety factors or design margins. But at the root of a statistical design process design loads can also be stated in terms of the reliability index, which is what was used in this work. The reliability index used for this investigation was 5, which is suggested for naval war ships in [16]. In the strictest sense, the reliability index must take into account the probability distributions of both the load and the strength factors of a design. However, for the purpose of this work only the probability distribution of the sea-state and thus wave loading was used in the calculation of the reliability index. Omitting the probabilistic nature of the strength curves equates to knowing the failure strength deterministically, which is a reasonable simplification when considering steel manufacturing quality assurance techniques. Once the design loading for a trimaran of general dimensions is determined, the partial safety factors for each possible failure mode could then be calculated if desired [16].

In addition to the reliability index, the other information need to determine the design loading for each load case of defined in sections 3.1.2, 3.1.3, and 3.1.4, was the susceptible wavelength for trimaran of particular dimensions. For example, the United States Naval design standard [17] and [18] for primary hull bending of a monohull ship has been to design for a trochoidal wave as shown in (11).

$$h_w = 1.1 \cdot \sqrt{L_m} \qquad \lambda = L_m \tag{11}$$

While equation (11) approximates the loadings of a fully statistical sea-state relatively well for traditional naval ships, the formulation does not work well for a trimaran due to the varying lengths and spacing of the trimaran hulls. Therefore, the susceptible wave length for each load case described in sections 3.1.2, 3.1.3, and 3.1.4 was determined by finding the wavelength in which the maximum forces were produced from equations (8), (9), and (10) when considering the fully statistical sea state as described in Table 7 and Table 8.

However, computing the forces produced for each entry in Table 7 and Table 8 requires statically rebalancing the trimaran for each wavelength and wave height in Table 7 and Table 8. The amount of computational effort to solve the static motion balance for all the entries in the statistical sea state is extremely large and essentially unnecessary since the low wave height waves will not produce high forces regardless of wave length. Therefore, to determine the wavelengths to which a trimaran of particular dimensions were susceptible, the forces encountered for each entry of a statistical sea state described in Table 7 and Table 8 were effectively searched for the highest forces. To alleviate the need for calculating every force produced at every possible sea state described in Table 7 and Table 8, two simplifications were made. First, only wavelengths that would have the ability to produce a maximum force were considered. For example, the structural response of a trimaran with a main hull length of 100 meters is minimal on a wave of with a wavelength of 755 meters from Table 9. This situation can be seen in Figure 15. In the case where the wavelength encountered is much longer than the length of the ship the ship gently rides the wave without experiencing large structural loadings. This concept is also the basis for the Naval design rules in (11).

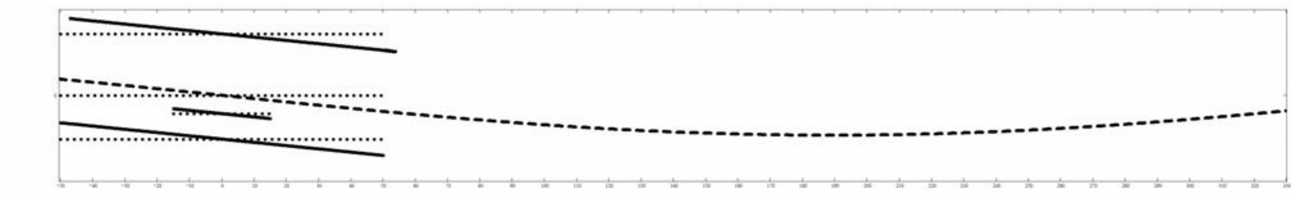

**Figure 15 – Profile View of 100m Trimaran Balanced on a Wave of Long Wavelength**

The second method utilized to reduce the computational effort of finding the susceptible wavelengths of a trimaran was to only calculate the forces produced from the maximum wave height for each respective wavelength which had a non-zero statistical probability in Table 7 and Table 8. Once the forces for the maximum wave height for each wavelength were calculated, the forces were compared and the susceptible wavelength was determined from the corresponding maximum force. For example, for the wave periods of 4 and 5 seconds the forces produced for 5.5 and 7.5 meter wave heights were calculated and compared.

Using these methods, the forces for each loading case in sections 3.1.2, 3.1.3, and 3.1.4 were calculated when subjected to applicable portions of the statistical sea state in Table 7 and Table 8. From those calculations, the susceptible wavelength index was set to the wavelength for the corresponding maximum force obtained. Once the susceptible wavelength for a given loading condition was determined, the design loading for that mode of loading could be calculated.

To determine the design loading for the susceptible wavelength, the joint probabilities in Table 7 and Table 8 were converted to a marginal probability distribution at the susceptible wavelength. Next, the force developed at each wave height in Table 7 and Table 8 at the susceptible wavelength was found. Finally, using the marginal probability and the developed forces at one meter wave height increments, the mean and standard deviation of the force distribution at the susceptible wavelength was determined. From there the design loading for each load case was determined using the reliability index of 5 so that the design loading would be 5 standard deviations from the mean loading.

This methodology of determining design loading was based on the joint probability mass function of Table 7 and Table 8. While this method certainly lends insight into the structural loading of trimarans due to wave motions, the tabular nature of the probability distributions in Table 7 and Table 8 leaves the evaluation of the forces experienced in waves somewhat granular. A more in depth investigation of this subject could be performed using a continuous functions to describe the sea-state probability distribution as in [13], but for the purposes of this work's investigation into the basic structural loading attributes of a trimaran hull for would be unnecessary.

#### 4.1.1.7 Calculation of Design Forces for Varying Sizes of Trimarans

Once the design forces as functions of the relevant parameters of the trimaran could be determined using the methods in section 4.1.1.6, the final component of the analytical thesis model computed the design forces for 468 different variations of trimaran sizes and placement configurations to investigate the possible design space of trimaran hull forms. The inputs that were allowed to vary were main hull length, side hull length, side hull x-location, side hull y-location these are shown in Table 10.

**Table 10 – Parameters varied for Trimaran Design Space**

| | |
|---|---|
| $L_m$ (main hull's length) | 60 - 300 meters in 20meter increments |
| $L_s$ (side hull's length) | 0.25 - 0.50 in increments of 0.05 of $L_m$ (main hull's length) |
| $X_s$ (longitudinal position of the side hull with respect to main hull amidships) | Five equally spaced position from aligned amidships to where aft perpendiculars of side and main hulls are aligned |
| $Y_s$ (transverse position of the side hull with respect to main hull centerline) | 1 – 1.5 of $B_m$ (main hull's beam) in increments of 0.1 |

The other relevant parameters needed for the computations, for example side hull beam, were calculated from fixed relations from Table 2 and reference [1] these are shown below in Table 11.

**Table 11 – Parameters Held in Fixed Relations for Trimaran Design Space**

| | |
|---|---|
| $B_m$ (main hull's beam) | Maintain $L_m$ / $B_m$ = 14 |
| $T_m$ (main hull's draft) | Maintain $B_m$ / $T_m$ = 2 |
| $D_m$ (main hull's depth)<br>Required to find ($F_m$ , main hull's freeboard) | Maintain $D_m$ / $T_m$ = 2.4 |
| $V_s$ (side hull volume) | Maintain at 4% $V_m$ (main hull volume) |
| $B_s$ (side hull's beam) | Maintain $B_s$ = $T_s$ (side hull's draft) |
| $T_s$ (side hull's draft) | Fixed by above constraints on $V_s$ $L_s$ $B_s$ |

The results of the required design force calculations for the design space are shown in 0Appendix B with an explanation of the analysis of the data provided in section 5.1.

## 4.2 Finite Element/ MAESTRO Analysis

Once the results from the analytical thesis model were obtained, a more refined model of a trimaran was made. The program used to create a more realistic model of a trimaran was the ship structural design program called Method for Analysis Evaluation and Structural Optimization (MAESTRO). The MAESTRO program, distributed by Proteus Engineering, was developed to analyze ship structures in a quasi-finite element analysis, with large stiffened panels as the elements between the finite element nodes. The utility of using a ship structural program such as MAESTRO is that it allows the ability to automatically balance a floating ship's structure in water utilizing linear wave theory. Naturally, the ability to include all the relevant hydrodynamic forces in the structural design of a ship is critical to accurate and safe ship design. In this case, MAESTRO only performs a static balance of a ship in waves, rather than a full dynamic analysis of the structure interacting with the ocean. However, allowing a static analysis that includes corrections for linear wave theory makes MAESTRO's results that much closer to reality.

### 4.2.1 Refined Finite Element MAESTRO Model

The complexity of building the MAESTRO model to the individual scantling of each component of the trimaran would be prohibitive for an initial investigation of the previous design space performed in 4.1.1.7. Therefore, one MAESTRO model was made to test the validity of the prediction of the analytical model presented in section 4.1. The particulars of the model in MAESTRO were obtained from [19] and are shown below in Table 12.

**Table 12 – Particular Dimensions of Real Ship Model Used**

| parameter | meters |
|---|---|
| $L_m$ | 106 |
| $B_m$ | 9 |
| $T_m$ | 5.2 |
| $D_m$ | 11.9 |
| $L_s$ | 35 |
| $B_s$ | 1.8 |
| $T_s$ | 1 |
| $X_s$ | -35.5 from amidships |
| $Y_s$ | 9 |

Using the relations in the analytical thesis model developed in section 4.1, the design loadings for longitudinal cresting/troughing, longitudinal twisting, and transverse hogging/sagging from sections 3.1.2, 3.1.3, and 3.1.4, were found. The results of these design values are shown below in Table 13.

**Table 13 – Analytical Model Predictions for Comparison to MAESTRO**

| Load Case | Force / Moment | Susceptible Wavelength (m) |
|---|---|---|
| Longitudinal Troughing | $-5.49 \times 10^5$ N | 76.5 |
| Longitudinal Cresting | $5.72 \times 10^5$ N | 76.5 |
| Positive Longitudinal Twist | $9.12 \times 10^6$ Nm | 56.2 |
| Negative Longitudinal Twist | $-1.16 \times 10^7$ Nm | 99.9 |
| Transverse Sagging | $1.09 \times 10^6$ N | 25.0 |
| Transverse Hogging | $-5.22 \times 10^5$ N | 14.0 |

A representative MAESTRO model from [19] using the parameters of Table 12 was simulated using the MAESTRO program. This model is shown below in Figure 16 through Figure 18. The input file of the MAESTRO model is approximately 60 pages of text files, and hence has not been included as an appendix to this work.

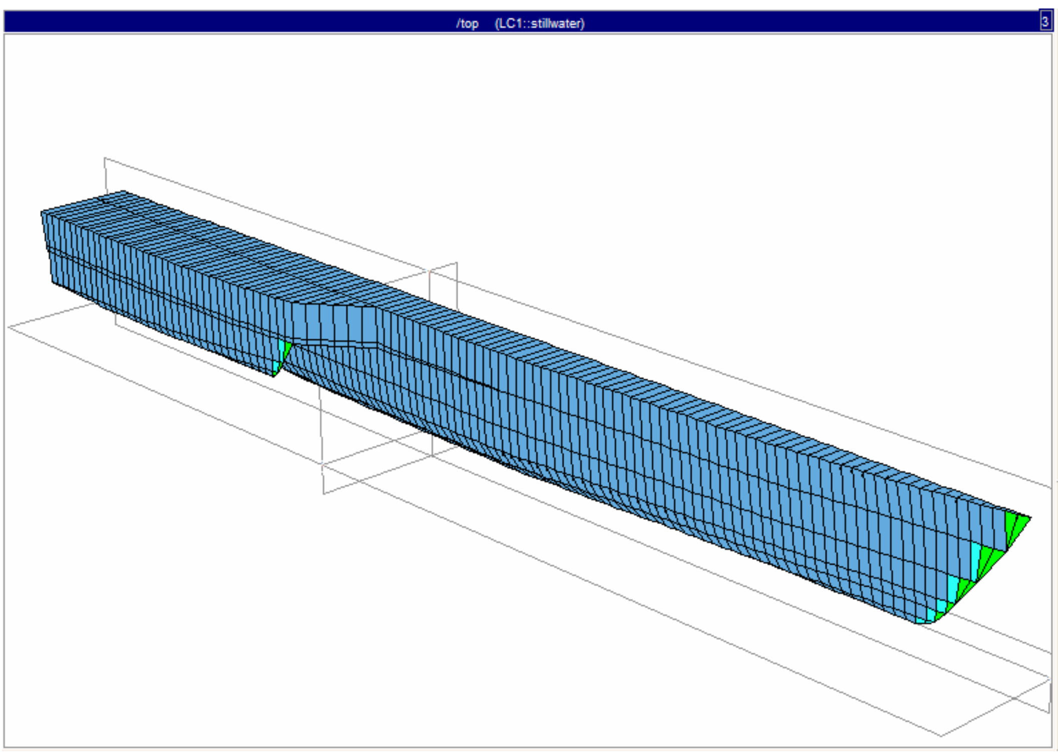


**Figure 16 – Starboard Bow Perspective of a MAESTRO Trimaran Half Model**

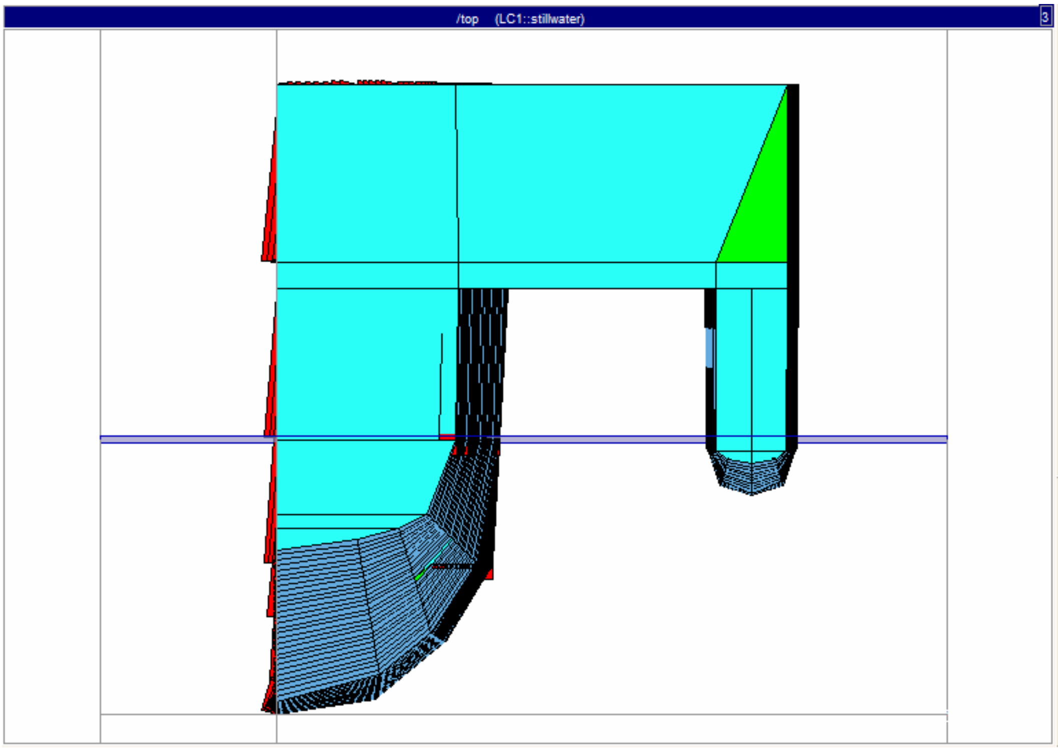


**Figure 17 – Aft Body Plan View of a MAESTRO Trimaran Half Model with Water Line**

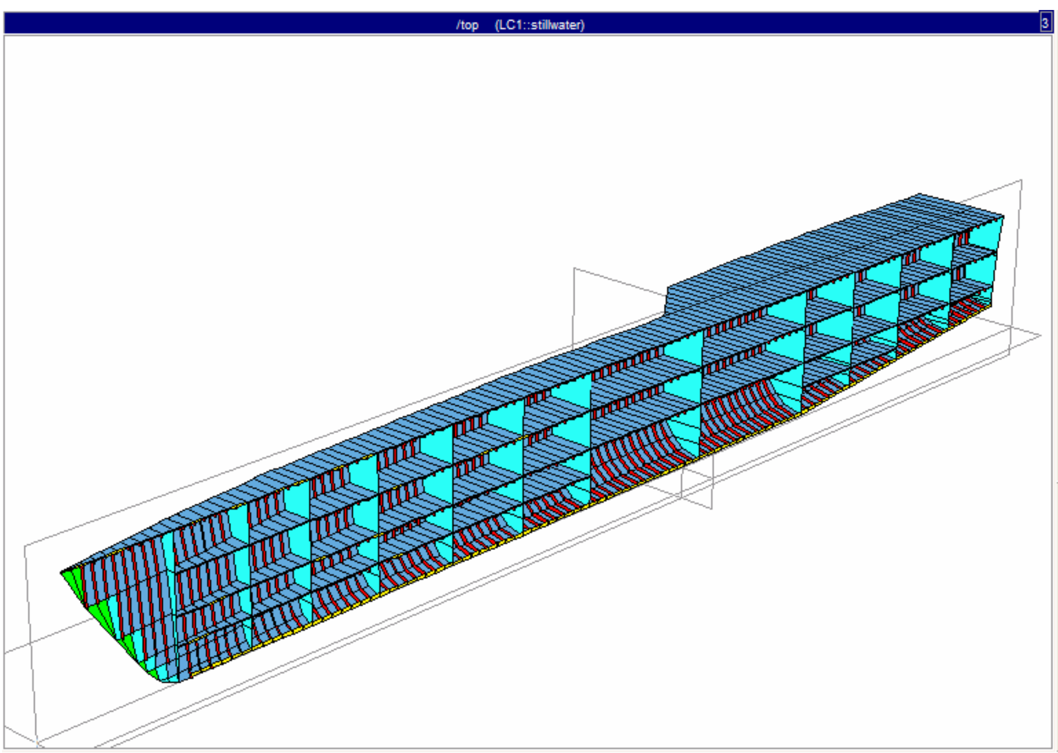


**Figure 18 – Port Bow Perspective of a MAESTRO Trimaran Half Model**

### 4.2.2 Statistically Significant Waves for the MAESTRO Model

As mentioned previously in section 4.1.1.6 a reliability index of 5 was used in the calculation of the design forces that a trimaran's cross structure should be able to withstand under the various loading cases defined in sections 3.1.2, 3.1.3, and 3.1.4. The use of the reliability index implies that the ship's Response Amplitude Operator (RAO) to a given sea state is known so that the forces produced by a particular sea state on the trimaran structure in particular failure modes can be calculated. Alternatively, as in the case of the analytical model in section 4.1, the forces produced could be calculated directly to response of the fully statistical sea state input without specifically knowing the RAO. However, to adequately compare the design forces predicted by the analytical model to the finite element model in MAESTRO the RAO of the MAESTRO model would have to be known or approximated. However, calculating the RAO of a new ship such as the trimaran would require a fully dynamic analysis including hydrodynamic effects, which is the difficult and largely unknown task in the first place.

This unknown RAO for the trimaran leads to the question of which wave height corresponds to producing a force that has a reliability index of 5, giving a design force of 5 standard deviations over the mean force for the fully statistical sea states described in Table 7 and Table 8. When dealing with ship response to waves, often motion RAO's are unity in the low frequency limit [15], which is exactly the static balance performed by MAESTRO. Therefore, the assumption was made that using wave heights that were five standard deviations above the mean wave height for each wave length would produce a force response in the various load cases described in sections 3.1.2, 3.1.3, and 3.1.4 that are five standard deviations over the mean.

Using the data from Table 7 and Table 8, the wave height to produce a response equivalent to the reliability index of 5 was calculated using the algorithm shown in Appendix C with the results shown below in Table 14.

**Table 14 – Equivalent Wave Height for Reliability Index of 5**

| Wave Period (sec) | Wave Length (m) | Mean + 5SD Wave Height (m) |
|---|---|---|
| 3 | 14.05 | 1.81 |
| 4 | 24.97 | 2.71 |
| 5 | 39.02 | 3.48 |
| 6 | 56.19 | 4.24 |
| 7 | 76.48 | 5.07 |
| 8 | 99.89 | 5.98 |
| 9 | 126.42 | 7.00 |
| 10 | 156.08 | 8.10 |
| 11 | 188.85 | 9.26 |
| 12 | 224.75 | 10.40 |
| 13 | 263.77 | 11.45 |
| 14 | 305.91 | 12.32 |
| 15 | 351.17 | 12.85 |
| 16 | 399.56 | 12.97 |
| 17 | 451.06 | 12.30 |
| 18 | 505.69 | 11.10 |
| 19 | 563.44 | 9.91 |
| 21 | 688.30 | 8.13 |
| 22 | 755.42 | 7.08 |

The values in Table 14 are also plotted in Figure 19. The shape and magnitude in Figure 19 roughly correspond to the wave coefficient values in the rule based formulas for longitudinal bending in references [3] and [4]. The fact that Figure 19 is so similar to current rule based classification societies wave coefficients implies that the simplification of applying a wave with a wave height that is 5 standard deviations over the mean for a given wavelength is most likely a valid simplification and concurs with current classification society practices.

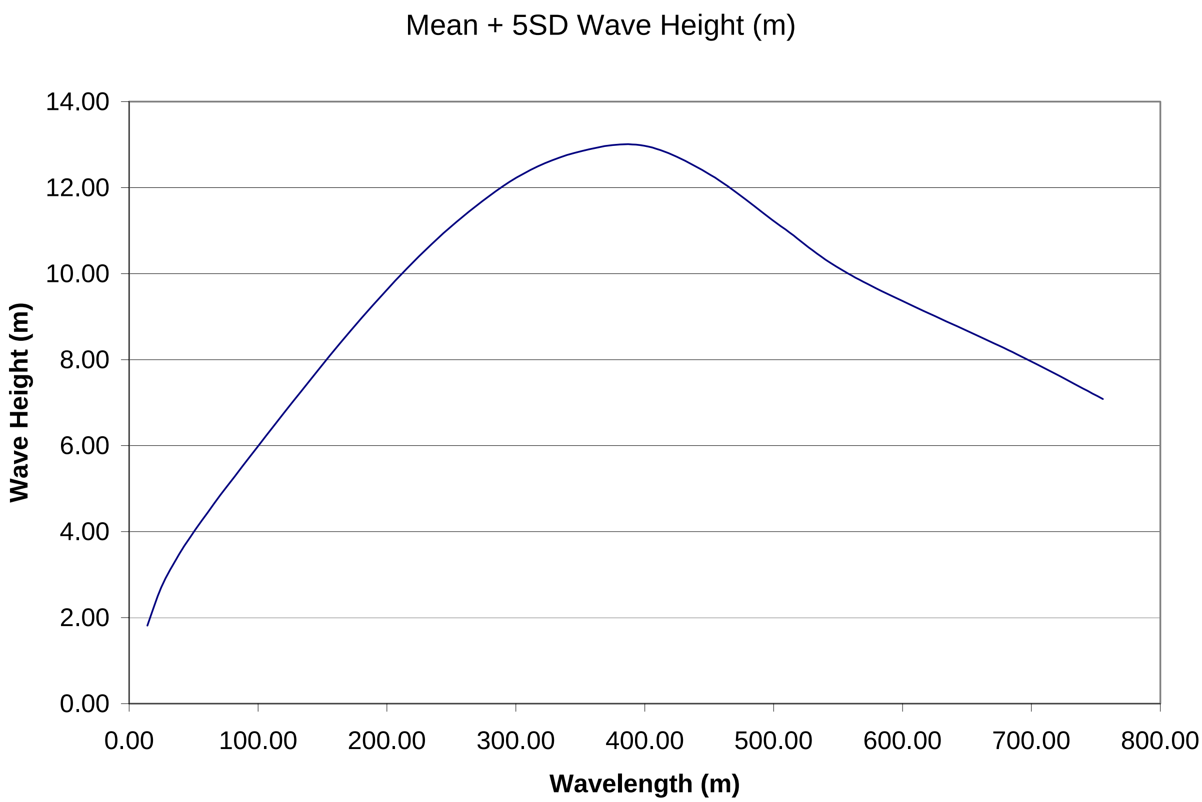


**Figure 19 – Reliability Index Wave Heights of 5 verses Wavelength**

Using the wave height and length data from Table 14 in conjunction with the load cases defined above in sections 3.1.2, 3.1.3, and 3.1.4, the MAESTRO program was used to compare how well the predicted values of forces from the analytical model match the wave balanced forces of the MAESTRO model.

### 4.2.3 MAESTRO Structural Failure Modes

The specific failure modes analyzed by MAESTRO from reference [20] are shown below in Table 15 through Table 17. These failure modes are specific to frame stiffened structures such as ships. The theoretical background behind these failure modes is detailed in [13].

**Table 15 – Panel Failure Modes**

| | |
|---|---|
| PCSF | Panel Collapse, Stiffener Failure |
| PCCB | Panel Collapse, Combined Buckling |
| PCMY | Panel Collapse, Membrane Yield |
| PCSB | Panel Collapse, Stiffener Flexural/Torsional Buckling |
| PYTF | Panel Yield, Tension in Flange |
| PYTP | Panel Yield, Tension in Plate |
| PYCF | Panel Yield, Compression in Flange |
| PYCP | Panel Yield, Compression in Plate |
| PSPB (2 modes) | Panel Serviceability, Plate Bending |
| PFLB | Panel Failure Local Buckling |

**Table 16 – Frame Failure Modes**

| | |
|---|---|
| FCPH (3 modes) | Frame Collapse, Plastic Hinge |
| FYCF (3 modes) | Frame Yield, Compression in Flange |
| FYTF (3 modes) | Frame Yield, Tension in Flange |
| FYCP (3 modes) | Frame Yield, Compression in Plate |
| FYTP (3 modes) | Frame Yield, Tension in Plate |

**Table 17 – Girder Failure Modes**

| | |
|---|---|
| GCT | Girder Collapse, Tripping |
| GCCF | Girder Collapse, Compression in Flange |
| GCCP | Girder Collapse, Compression in Plate |
| GYCF | Girder Yield, Compression in Flange |
| GYCP | Girder Yield, Compression in Plate |
| GYTF | Girder Yield, Tension in Flange |
| GYTP | Girder Yield, Tension in Plate |

MAESTRO measures the structural adequacy of each limiting failure mode using an adequacy parameter g(R) shown in (12).

$$g(R) = \frac{1 - \gamma \cdot R}{1 + \gamma \cdot R} \qquad (12)$$

Instead of using partial safety factors (γ) of 1.25 and 1.5 for the serviceability and collapse failure modes respectively, which are consistent with ship structural design practice, partial safety factors of 1 were used. Using safety factors of one is known as MAESTRO's Forensic Mode. Using MAESTRO in its Forensic Mode allowed the analytical and MAESTRO results to be compared on an equal basis. Where R is the strength ratio defined as the fraction of loading compared to the loading limit as shown in (13).

$$R = \frac{Q}{Q_L} \tag{13}$$

For each failure mode to be satisfied in each loading condition, the adequacy parameter must be above 0 to be above the failure criteria for that given failure mode.

4.2.4 MAESTRO Model Organization

The organizational tree structure of a general MAESTRO Model is shown below in Figure 20.

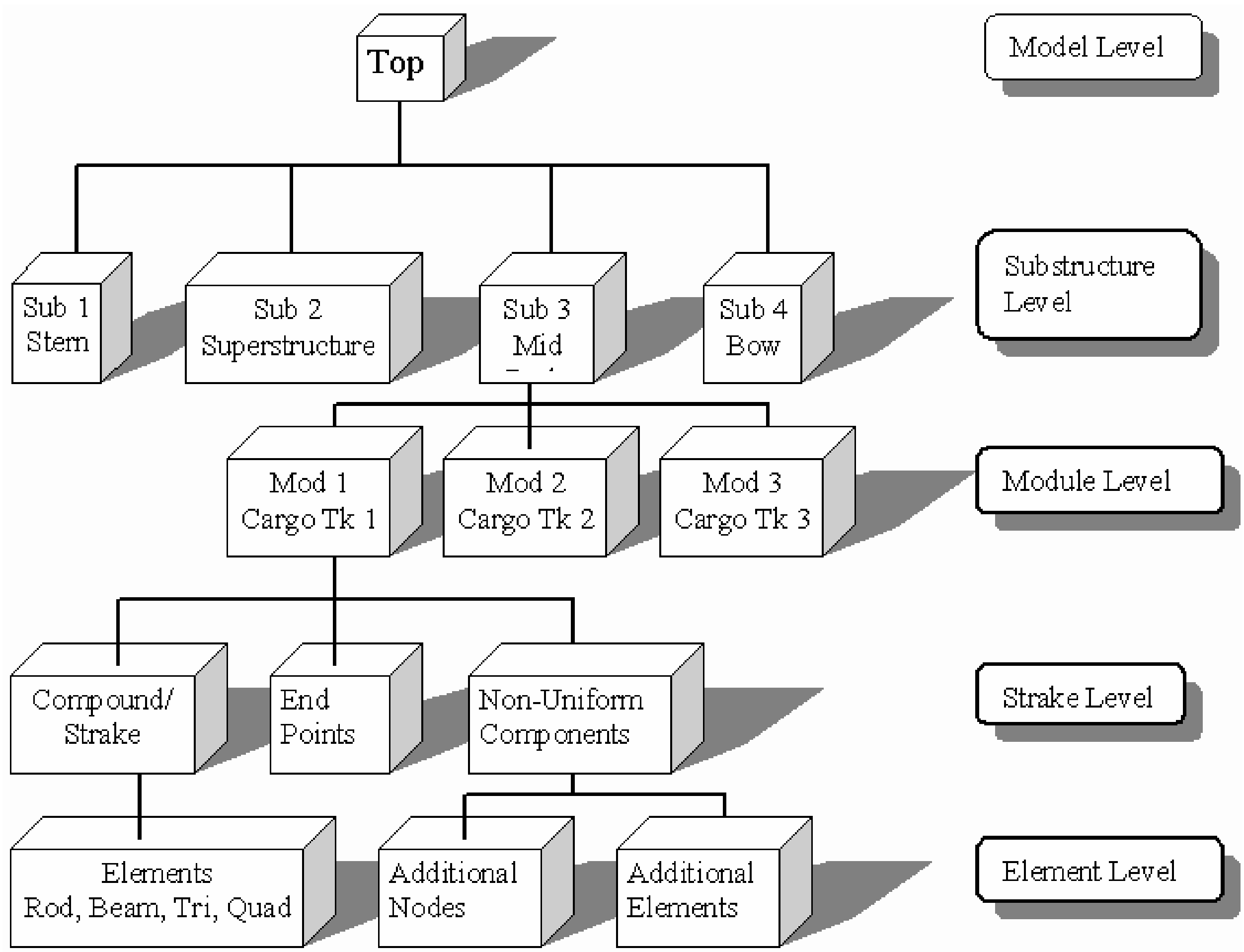


**Figure 20 – Organizational Structure of a General MAESTRO Model [20]**

The overall MAESTRO model is broken up in to substructures, modules, strakes, and elements. The specific failure modes mentioned above in Table 15 through Table 17 are analyzed at the strake level. A strake consists of plates, stiffeners, frames, and possibly girders, in which the stiffeners, frames, and girders are often T-shapes for ship structures. This strake evaluation of the failure modes is what makes MAESTRO a macro-finite element program.

For the specific model shown in Figure 16 through Figure 18, the cross-deck structure between the main and side hulls has two substructures and five modules. While the entire trimaran ship was modeled in eight substructures and several modules, only the substructure and module organization for the cross deck structure is shown below in Figure 21 and Figure 22.

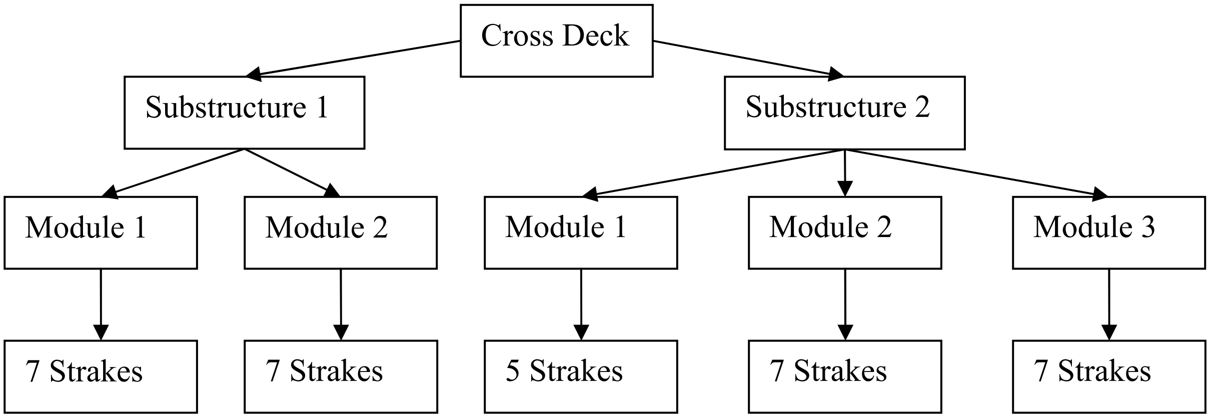


**Figure 21 – Organization for the Specific MAESTRO Model Analyzed**

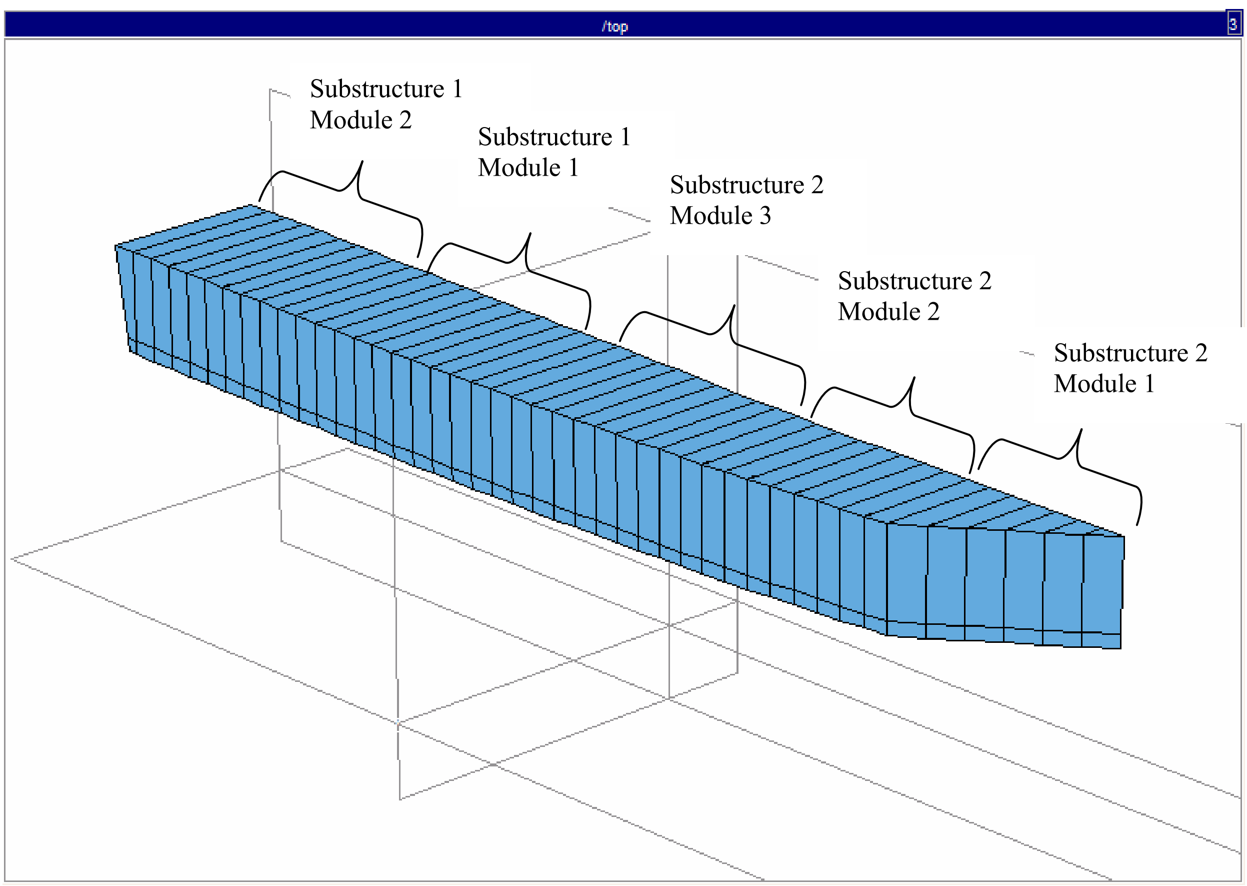


**Figure 22 – MAESTRO Model Organization of Trimaran Cross-Deck Structure**

### 4.2.5 MAESTRO Verification of Analytical Trimaran Model Predicted Forces

Once the analytical force predictions from Table 13 and the wave heights corresponding to 5 standard deviations above the mean from Table 14 at the applicable susceptible wavelengths were obtained, a basis for comparing and testing the analytical model's results to that obtained by MAESTRO in a full quasi-static linear theory wave balance was established. This comparison was accomplished by applying the analytical model's predicted forces from Table 13 as point forces in the finite element model to the stillwater MAESTRO model of the trimaran shown in Figure 16 through Figure 18, and then measuring as an output the failure modes shown in Table 15 through Table 17. Next, the MAESTRO output using the full quasi-static linear theory wave balance function provided by the MAESTRO program was analyzed. While the full output files from MAESTRO are over 1800 pages, excerpts from these output files are provided in Appendix E through Appendix J. Appendix E through Appendix J show the adequacy parameters calculated for both the analytical force predictions and the full MAESTRO quasi-static linear theory wave balance of the specific strakes from Figure 21 for each possible failure mode from Table 15 through Table 17 of the cross deck structure for the trimaran model . The discussion of the comparison of the analytical model to the MAESTRO Model results is included in section 5.2.

# Chapter 5 Results

## 5.1 Statistical Analysis of Analytical Trimaran Model Using JMP

The tabular results of the analytical box shaped trimaran model for various main hull lengths, side hull lengths, side hull transverse spacing, and side hull longitudinal placement from section 4.1.1.7 are shown in Appendix B. To determine the relations between the various characteristics of trimarans and the forces and moments generated on a trimaran's cross structure, the statistical discovery program JMP, developed by the SAS institute, was used. JMP can be used for virtually any type of statistical analysis. However, in the case of the analytical trimaran model, JMP was used to fit the force and moment data produced to three independent variables in lengths and spacing to a forth order polynomial including all the applicable cross terms between the independent variables.

For each load case the order of polynomial used to fit the predicted data was increased until the R-squared fit parameter and the predicted versus actual parameters were adequate to accurately predict the data in 0Appendix B. The entire fourth order fit equations and the curve fitting statistics are shown in 0Appendix D. The interaction profiles between the independent variables for each case of longitudinal cresting/troughing, longitudinal side hull twisting, and transverse sagging/hogging are shown in the following sections. The interaction plots show the interaction of the independent variables between each other and their contribution to the overall forces. For each polynomial fit obtained an accompanying equation is stated to help predict what forces an early stage structural designer can allot to the cross-structure.

### 5.1.1 Analytical Model Results for Longitudinal Side Hull Troughing

Figure 23 shows the side hull troughing forces as functions of the three independent variables of main hull length, side hull length as a fraction of main hull length, and side hull longitudinal placement for amidships as a fraction of main hull length.

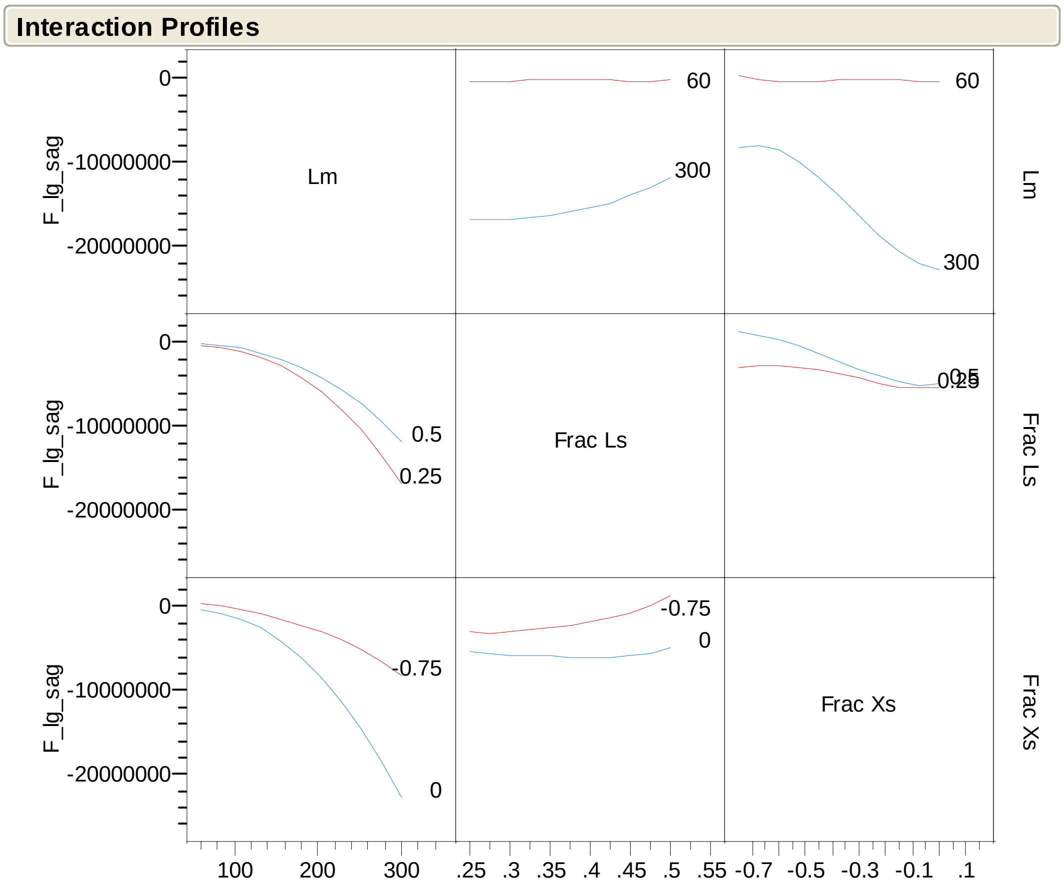


**Figure 23 – Longitudinal Wave Side Hull Troughing Independant Variable Interaction**

The interaction plot shows that as main hull length increases the vertical forces produced due to side hull troughing increase. This result is not surprising in view of the rising wave height versus wavelength characteristic of the statistical sea states described in Table 7 and Table 8, since as wave length of the encountered waves increases the statistically possible wave heights increase.

An interesting result from the bottom row of the interaction plot is that as the longitudinal location of the side hulls is moved aft, the trimaran's cross structure is not as susceptible to side hull troughing as when the side hull is placed in the longitudinally symmetric amidships position.

Another result from the middle row of Figure 23 is that vertical forces due to longitudinal troughing are only mildly sensitive to changes in the length of the side hull, but lessen as the length of the side hull increases. Finally, the interaction between variables can be studied as well. For example, having a smaller side hull length produces higher vertical forces when the side hulls are placed further aft than when the same side hull is placed amidships.

One final result from the side hull troughing data is the fit equation provided in (14). This equation gives the downward force as a function of three independent variables. For clarity the equation (14) is only shown to second order with the full fourth order equation included in Appendix D.

$$\begin{aligned} F_{trough} = {} & 3211000 + -61810 L_m + 2225000 \frac{L_s}{L_m} - 10020000 \frac{X_s}{L_m} - 273.9 \left(L_m - 180\right)^2 \ldots \\ & + 76210 \left(\frac{L_s}{L_m} - 0.375\right) \cdot \left(L_m - 180\right) - 136600 \left(\frac{X_s}{L_m} + 0.3125\right) \cdot \left(L_m - 180\right) \ldots \\ & + -18420000 \left(\frac{L_s}{L_m} - 0.375\right) \cdot \left(\frac{X_s}{L_m} + 0.3125\right) - 2475000 \left(\frac{X_s}{L_m} + 0.3125\right)^2 \ldots \\ & + \text{third\_order\_terms} + \text{fourth\_order\_terms} \end{aligned} \tag{14}$$

5.1.2 Analytical Model Results for Longitudinal Side Hull Cresting

The interaction profiles for the upward vertical forces produced during side hull cresting are shown below in Figure 24.

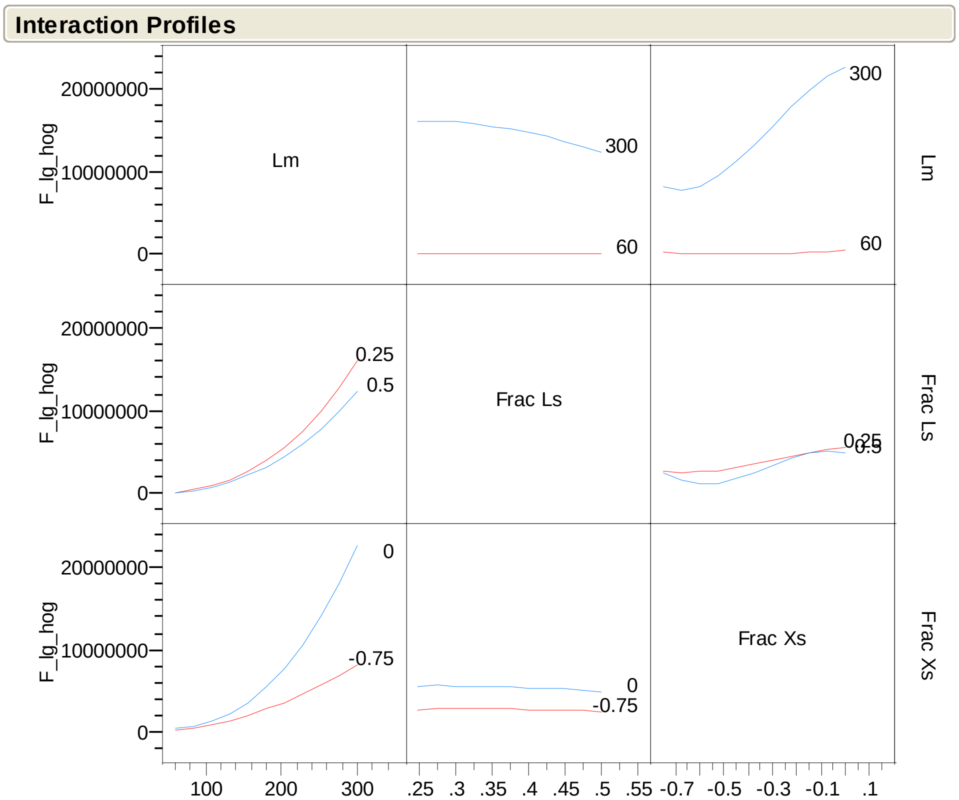


**Figure 24 – Longitudinal Wave Side Hull Cresting Independant Variable Interaction**

The interaction plots for side hull cresting is analogous to that of side hull troughing, and the relationships between the independent variables are essentially the same as that of side hull troughing.

The fit equation for the upward force on the side hull cross structure is partially shown in equation (15) with the full equation shown in Appendix D.

$$F_{crest} = -2703000 + 58190 L_m + -3016000 \frac{L_s}{L_m} + 9039000 \frac{X_s}{L_m} + 269.00 \left(L_m - 180\right)^2 \ldots$$
$$+ -50870 \left(\frac{L_s}{L_m} - 0.375\right) \cdot \left(L_m - 180\right) + 118600 \left(\frac{X_s}{L_m} + 0.3125\right) \cdot \left(L_m - 180\right) \ldots$$
$$+ 19850000 \left(\frac{L_s}{L_m} - 0.375\right) \cdot \left(\frac{X_s}{L_m} + 0.3125\right) \ldots$$
$$+ \text{third\_order\_terms} + \text{fourth\_order\_terms} \tag{15}$$

### 5.1.3 Analytical Model Results for Longitudinal Positive Phase Twisting

The polynomial equation fit results for the positive phase twisting of the cross structure in longitudinal waves is shown below in the interaction plot of Figure 25.

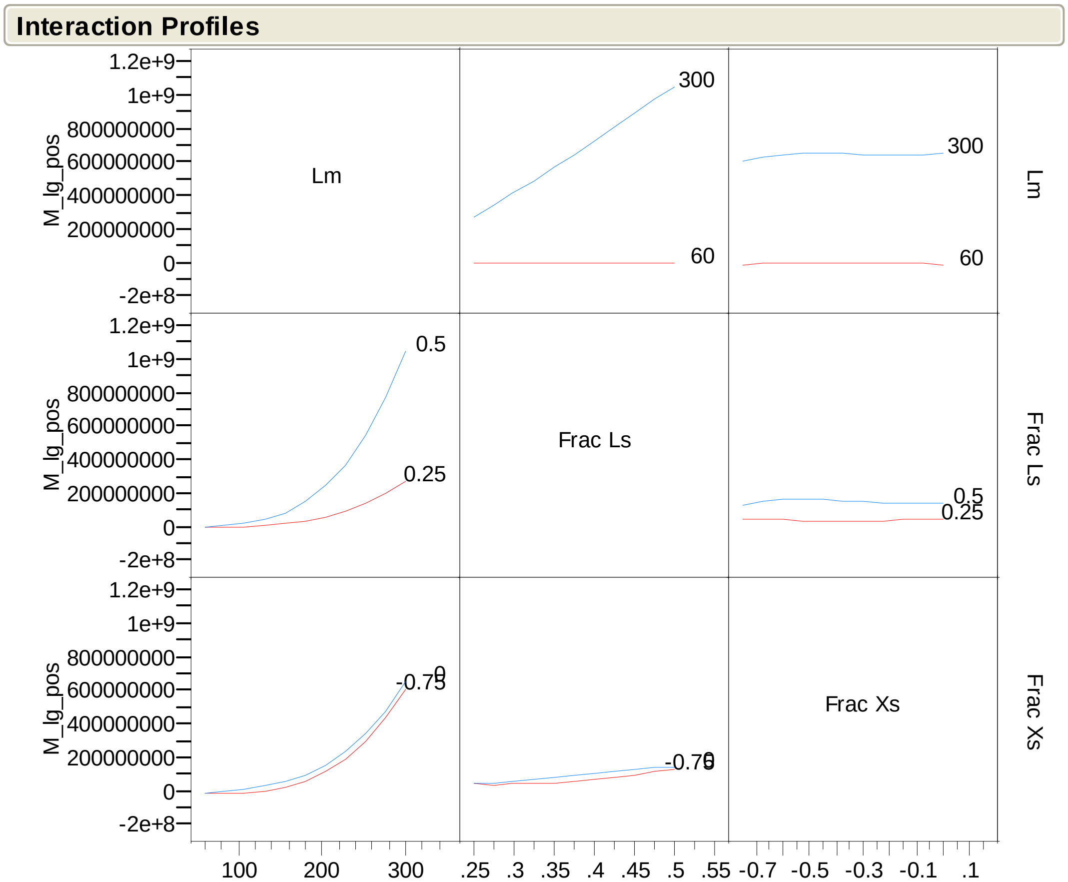


**Figure 25 – Longitudinal Wave Side Hull Positive Twisting Independant Variable Interaction**

Like the interaction plots for longitudinal cresting and troughing, the moments produced in positive phase twisting increases markedly as main hull length increases as is expected from the wavelengths of the susceptible sea states. From the bottom row of Figure 25 it is observed that the longitudinal placement of the side hulls has virtually no effect on the positive phase twisting moments. However, from the second row of the interaction plot, it can be seen that as the length of the side hull increases the twisting moment increases drastically. This result is not unreasonable since the length of the side hull increases the length of the moment arm for positive phase twisting.

The partial fit equation shown for positive phase twisting is shown equation (16) with the full equation shown in Appendix D.

$$
\begin{aligned}
M_{pos} = {} & -454800000 + 1990000 L_m + 507700000 \frac{L_s}{L_m} + -13040000 \frac{X_s}{L_m} + 15350 \left(L_m - 180\right)^2 \ldots \\
& + 10620000 \left(\frac{L_s}{L_m} - 0.375\right) \cdot \left(L_m - 180\right) + -178900 \left(\frac{X_s}{L_m} + 0.3125\right) \cdot \left(L_m - 180\right) \ldots \\
& + -412500000 \left(\frac{L_s}{L_m} - 0.375\right) \cdot \left(\frac{X_s}{L_m} + 0.3125\right) \ldots \\
& + \text{third\_order\_terms} + \text{fourth\_order\_terms}
\end{aligned}
\tag{16}
$$

### 5.1.4 Analytical Model Results for Longitudinal Negative Twisting

The polynomial equation fit results for the negative phase twisting of the cross structure in longitudinal waves is shown below in the interaction plot of Figure 26.

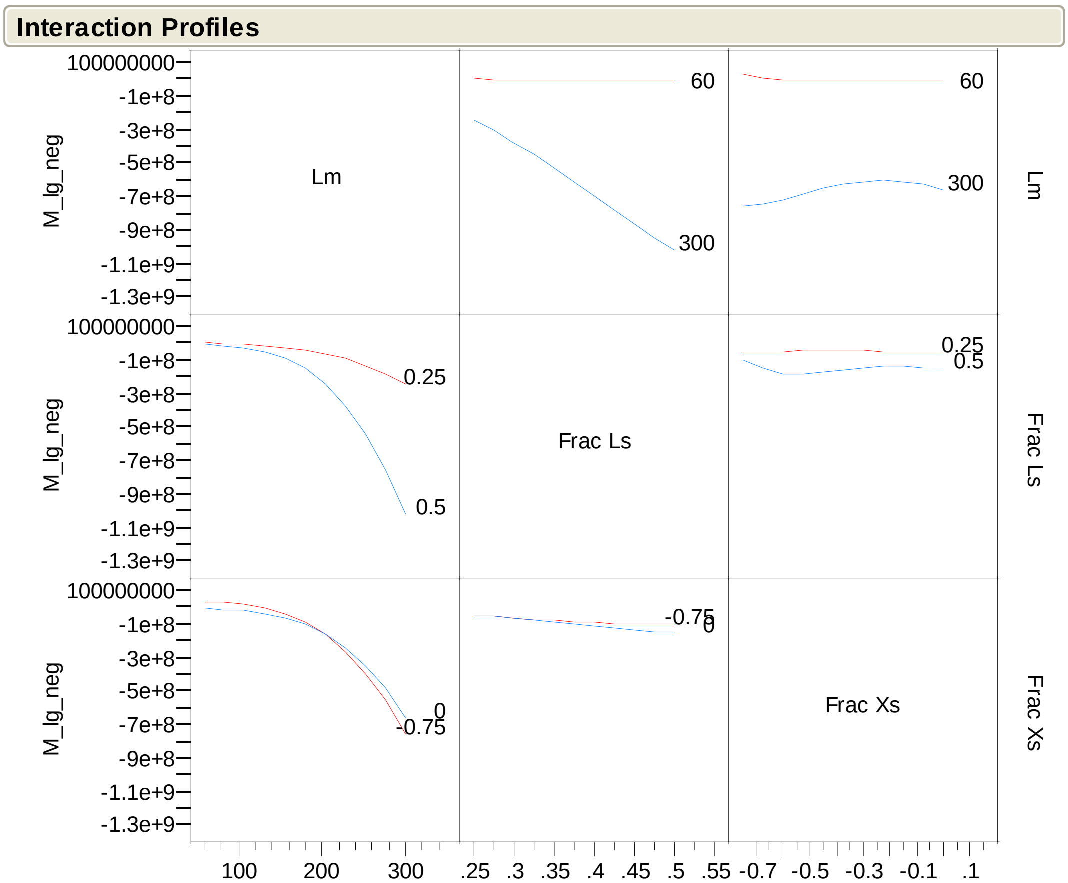


**Figure 26 – Longitudinal Wave Side Hull Negative Twisting Independant Variable Interaction**

The results for negative phase twisting are analogous to positive phase twisting maintaining similar trends between the independent variables.

The partial fit equation shown for positive phase twisting is shown equation (17) with the full equation shown in Appendix D.

$$M_{neg} = 470200000 + -1843000 L_m + -549900000 \frac{L_s}{L_m} + 52640000 \frac{X_s}{L_m} + -15260 \left(L_m - 180\right)^2 \ldots$$
$$+ -10820000 \left(\frac{L_s}{L_m} - 0.375\right) \cdot \left(L_m - 180\right) + 741500 \left(\frac{X_s}{L_m} + 0.3125\right) \cdot \left(L_m - 180\right) \ldots$$
$$+ 842000000 \left(\frac{L_s}{L_m} - 0.375\right) \cdot \left(\frac{X_s}{L_m} + 0.3125\right) + -430100000 \left(\frac{X_s}{L_m} + 0.3125\right)^2 \ldots$$
$$+ third\_order\_terms + fourth\_order\_terms \tag{17}$$

5.1.5 Analytical Model Results for Transverse Sagging

The results for transverse sagging are shown for the interaction plot below in Figure 27. For clarity the values in Appendix D were converted to utilize transverse dimensions stated in main and side hull beams from the fixed relations in Table 11. The interaction plots indicate that, as suspected, the upward forces on the cross structure due to a transverse sagging condition increases as the outer hull spacing increases. Another result from the interaction profile is that as the side hulls beam widens then forces on the cross structure lessens. Finally, as experienced in the previous loading cases as the size of the overall ship increases the forces experienced increase due to the statistical nature of the sea states.

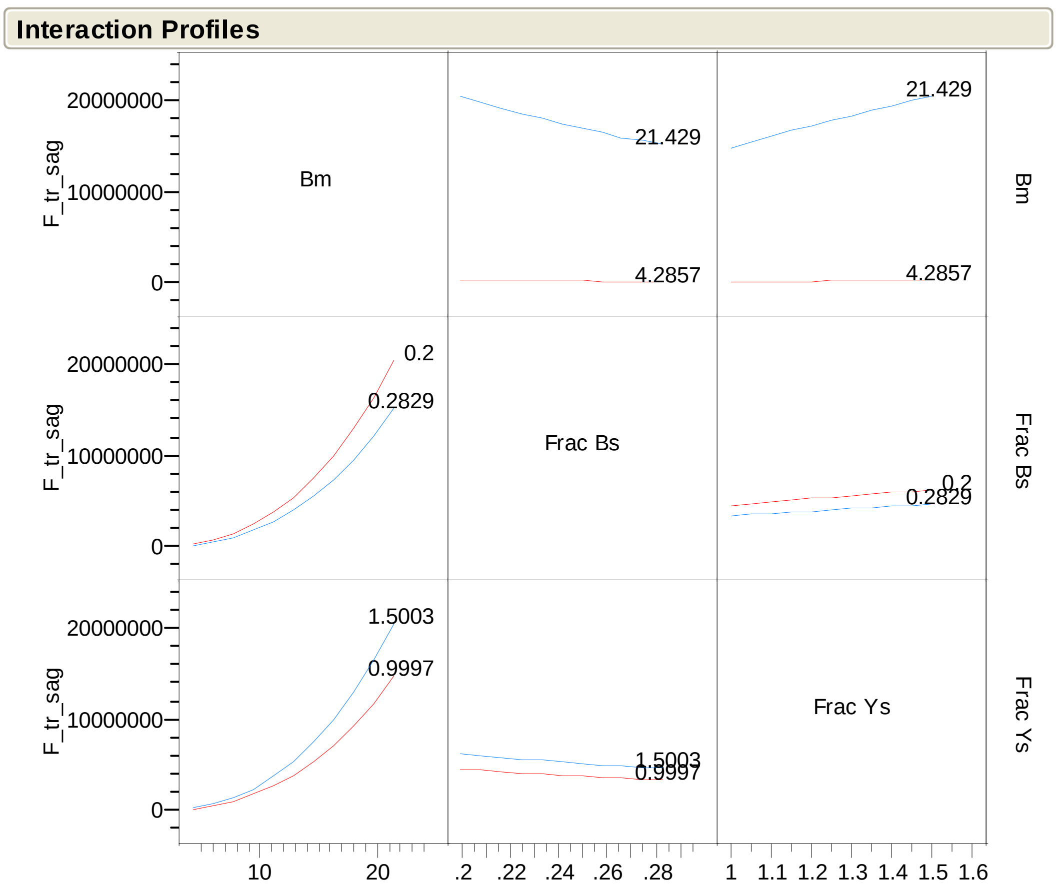


**Figure 27 – Transverse Sagging Wave Side Hull Independant Variable Interaction**

The partial fit equation shown for transverse sagging is shown equation (18) with the full equation shown in Appendix D.

$$F_{tr\_sag} = -7051000 + 951100 B_m + -17730000 \frac{B_s}{B_m} + 3046000 \frac{Y_s}{B_m} + 55500 \left(B_m - 12.86\right)^2 \ldots$$
$$+ -3537000 \left(\frac{B_s}{B_m} - 0.2357\right) \cdot \left(B_m - 12.86\right) + 60540000 \left(\frac{B_s}{B_m} - 0.2357\right)^2 \ldots$$
$$+ 592100 \left(B_m - 12.86\right) \cdot \left(\frac{Y_s}{B_m} - 1.25\right) + -10590000 \left(\frac{B_s}{B_m} - 0.2357\right) \cdot \left(\frac{Y_s}{B_m} - 1.25\right) \ldots$$
$$+ \text{third\_order\_terms} + \text{fourth\_order\_terms} \tag{18}$$

### 5.1.6 Analytical Model Results for Transverse Hogging

A polynomial fit equation for the downward forces produced during transverse hogging was unable to be fitted to the data in Appendix B even using forth order terms. This situation arises from the fact that there is a discontinuity in the downward force applied in a transverse hogging condition. When the transverse wave height is small enough that the outer hulls do not leave the water the loss of buoyancy due to wave height is linear. However, when the wave height becomes large enough, the side hulls leave the water and the loss of buoyancy after that point regardless of the wave height remains constant. Hence, a good fit for an overall downward force due to transverse hogging over a large range of values was not able to be found. Alternatively, the structural designer of a trimaran should design to the standard of the side hulls completely broaching the water as is discussed in references [5] through [10].

## 5.2 Comparison and Discussion of Analytical and MAESTRO Results

An example of the results of the MAESTRO structural analyses of the analytical force predictions compared to the full quasi-static linear wave theory balance analysis from 4.2.5 is shown below in Table 18 and Table 19 with the full results for all load cases and modules included in Appendix E through Appendix J.

**Table 18 – Adequacy Parameters with analytically Predicted Forces (Longitudinal Troughing)**

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.826 | 0.938 | 0.927 | 0.933 | 1.000 | 1.000 | 0.965 | 0.965 | 1.000 | 1.000 | 0.807 |
| 2 | 0.883 | 0.978 | 0.939 | 0.913 | 1.000 | 1.000 | 0.945 | 0.945 | 1.000 | 1.000 | 0.882 |
| 3 | 0.971 | 0.996 | 0.986 | 0.985 | 1.000 | 1.000 | 0.990 | 0.990 | 1.000 | 1.000 | 0.923 |
| 4 | 0.939 | 0.990 | 0.955 | 0.991 | 0.998 | 0.998 | 0.995 | 0.995 | 1.000 | 1.000 | 0.932 |
| 5 | 0.979 | 1.000 | 0.983 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.979 |
| 6 | 0.957 | 0.988 | 0.976 | 0.994 | 1.000 | 1.000 | 0.996 | 0.996 | 1.000 | 1.000 | 0.901 |
| 7 | 0.913 | 0.990 | 0.940 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.906 |

**Table 19 – Adequacy Parameters with MAESTRO Wave Balance (Longitudinal Troughing)**

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.848 | 0.943 | 0.937 | 0.939 | 1.000 | 1.000 | 0.969 | 0.969 | 1.000 | 1.000 | 0.831 |
| 2 | 0.898 | 0.980 | 0.944 | 0.918 | 1.000 | 1.000 | 0.948 | 0.948 | 1.000 | 1.000 | 0.897 |
| 3 | 0.972 | 0.997 | 0.988 | 0.986 | 1.000 | 1.000 | 0.991 | 0.991 | 1.000 | 1.000 | 0.940 |
| 4 | 0.949 | 0.987 | 0.964 | 0.991 | 1.000 | 1.000 | 0.995 | 0.995 | 1.000 | 1.000 | 0.944 |
| 5 | 0.977 | 1.000 | 0.983 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.977 |
| 6 | 0.967 | 0.986 | 0.983 | 0.995 | 1.000 | 1.000 | 0.997 | 0.997 | 1.000 | 1.000 | 0.923 |
| 7 | 0.918 | 0.967 | 0.945 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.908 |

Appendix E through Appendix J show the adequacy parameters for the panel and frame failure modes for each strake in the cross-deck structure from Figure 21. From the way that the adequacy parameter is defined, a lower adequacy parameter means that the evaluated strake is closer to failure for the analyzed failure mode.

Since a lower adequacy parameter means closer to failure, for the analytical model to be a conservative estimate of the cross-deck structural loading of the trimaran, every adequacy parameter for the analytical model must be less than the corresponding MAESTRO model adequacy parameter. While the adequacy parameters in Appendix E through Appendix J do compare to a first order, the analytical model is not consistently the conservative estimate for every failure mode for every strake of the cross-deck structure.

The fact that the analytical model does not conservatively predict the failure adequacy parameters is not surprising. Many simplifications to the analytical model were made in order to make it possible to investigate the basic nature of global loading of the cross-deck structural forces experienced by trimarans over a large range of hull sizes and hull spacing configurations. The simplification most affecting the performance of the analytical model compared to the fully wave balanced MAESTRO model was the assumption that the hulls were rigid and rigidly connected. The hull deflections in the realistic fully wave balanced models were the primary source of the difference between the two models.

While it is unfortunate that the analytical model is not a truly conservative estimate of the cross-deck structural loading of trimarans for every loading case and failure mode, the results of the two methods did compare to a first order of magnitude with each other. Since the analytical model can predict forces to a first order of magnitude, it can be a useful tool for early stage design estimates of trimaran cross deck structural loading as functions of the basic hull parameters and dimensions restated again in Table 20 and Table 21.

**Table 20 – Structural Loading from Sections 3.1.2, 3.1.3, and 3.1.4**

| | |
|---|---|
| $FB_{lg}$ | the vertical force on cross-structure in longitudinal waves (troughing and cresting) |
| $MB_{lg}$ | the moment on cross-structure in longitudinal waves (longitudinal twisting) |
| $FB_{tr}$ | the vertical force in transverse waves (transverse hogging/sagging) |

**Table 21 – Relevant Trimaran Parameters Affecting Design Loading**

| | |
|---|---|
| $B_m$ | the main hull's beam |
| $L_m$ | the main hull's length |
| $T_m$ | the main hull's draft |
| $F_m$ | the main hull's freeboard (also side hull freeboard) |
| $B_s$ | the side hull's beam |
| $L_s$ | the side hull's length |
| $T_s$ | the side hull's draft |
| $X_s$ | the longitudinal position of the side hull wrt main hull amidships |
| $Y_s$ | the transverse position of the side hull wrt main hull centerline |

Since the goal of this work was to provide the trimaran designer with a way to estimate the cross-deck structural loading, this work is considered a qualified success.

# Chapter 6 Conclusions

This main product of this work was the curve fits in Appendix D that predict trimaran cross-deck structure loading in applicable load cases of longitudinal troughing/cresting, longitudinal positive/negative twisting, and transverse hogging/sagging. These fitted curve of design loadings allows an initial design stage loading estimate for cross deck structural loading given general characteristics of length and spacing of a trimaran's hulls. The actual equations derived from the analytical model are useful for first approximations of loading to the cross-deck structure of a trimaran but are not necessarily always conservative. Flexure of the main hull of the trimaran is the main cause of the analytical model's un-conservative structural loading predictions.

A concurrent result of the fourth order polynomial fitted equations were the interaction profile plots shown in Figure 23 through Figure 27. The interaction profile plots show how the main design variables of the trimaran interact with each other to affect the cross-deck global structural loading. These plots are a useful visual qualitative tool to determine which trimaran configurations experience less cross-deck structural loading.

The fourth order polynomial curve fitted equations and the interaction profile plots combined with other characteristics of good trimaran design including stability, roll, and resistance characteristics will aid the trimaran ship designer in optimizing an overall trimaran ship design.

# Chapter 7 Recommendations for Future Work

The first and probably most important area to continue further work in the area of trimaran cross-deck structural design would be to have an analytical model that accounted for forward speed effects of the ship moving through the water. While this is not extremely complicated to perform, it was not included in this work simply because MAESTRO does not have the capability verify the results, and the entire goal of this work was to derive an analytical model for cross-deck structural loading that could be compared with a more rigorous analysis such as finite element analysis.

An improvement to the analytical model in this work would be to account for side hull flare, slamming of waves into the cross deck structure, and incident waves encountered at oblique angles. Accounting for flare in the side hulls would be beneficial because both [1] and [19] reference the need to have side hull flare for stability and sea-keeping reasons. Using triangular side hulls instead of box barge side hulls would be a relatively simple correction to the analytical model and could be done to make side hull flare angle an additional parameter that could be varied while calculating design forces. Wave slamming of cross-deck structures and obliquely angled waves encounters on the other hand is more complicated and would require extensive modifications to the current analytical model.

Finally, general recommendations for study in the area of trimaran structural design in general would be to determine the dynamic whipping response of the relatively long and slender hulls that are characteristic of trimarans. An accompanying topic to the whipping response of slender hulls would be an investigation into active structural control to include the cost and power requirements for very high speed applications.

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# Appendix A. MathCAD Analytical Model

All the equations and formula required to complete the analytical model of the "box" trimaran are included in this Appendix. The essential explanations of the working of the analytical model are included in section 4.1.1. Where appropriate, each applicable section refers to the main text's explanation.

Explained in section 4.1.1.1

$ss_{orig} :=$

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | 0.5 | $5.9\cdot10^{-4}$ | $4.03\cdot10^{-3}$ | $1.06\cdot10^{-2}$ | $1.57\cdot10^{-2}$ | $1.63\cdot10^{-2}$ | $1.36\cdot10^{-2}$ | $9.82\cdot10^{-3}$ | $6.43\cdot10^{-3}$ | $3.95\cdot10^{-3}$ |
| 2 | 1.5 | $9\cdot10^{-5}$ | $2.12\cdot10^{-3}$ | $1.23\cdot10^{-2}$ | $3.22\cdot10^{-2}$ | $5.11\cdot10^{-2}$ | $5.81\cdot10^{-2}$ | $5.28\cdot10^{-2}$ | $4.1\cdot10^{-2}$ | $2.85\cdot10^{-2}$ |
| 3 | 2.5 | 0 | $8\cdot10^{-5}$ | $1.46\cdot10^{-3}$ | $8.31\cdot10^{-3}$ | $2.29\cdot10^{-2}$ | $3.9\cdot10^{-2}$ | $4.71\cdot10^{-2}$ | $4.46\cdot10^{-2}$ | $3.53\cdot10^{-2}$ |
| 4 | 3.5 | 0 | 0 | $6\cdot10^{-5}$ | $8.5\cdot10^{-4}$ | $4.81\cdot10^{-3}$ | $1.37\cdot10^{-2}$ | $2.41\cdot10^{-2}$ | $2.96\cdot10^{-2}$ | $2.8\cdot10^{-2}$ |
| 5 | 4.5 | 0 | 0 | 0 | $4\cdot10^{-5}$ | $5.7\cdot10^{-4}$ | $3.15\cdot10^{-3}$ | $8.98\cdot10^{-3}$ | $1.56\cdot10^{-2}$ | $1.88\cdot10^{-2}$ |
| 6 | 5.5 | 0 | 0 | 0 | 0 | $3\cdot10^{-5}$ | $3.9\cdot10^{-4}$ | $2.07\cdot10^{-3}$ | $5.71\cdot10^{-3}$ | $9.5\cdot10^{-3}$ |
| 7 | 6.5 | 0 | 0 | 0 | 0 | 0 | $2\cdot10^{-5}$ | $2.7\cdot10^{-4}$ | $1.36\cdot10^{-3}$ | $3.47\cdot10^{-3}$ |
| 8 | 7.5 | 0 | 0 | 0 | 0 | 0 | 0 | $2\cdot10^{-5}$ | $2\cdot10^{-4}$ | $8.8\cdot10^{-4}$ |
| 9 | 8.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $2\cdot10^{-5}$ | $1.5\cdot10^{-4}$ |
| 10 | 9.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $2\cdot10^{-5}$ |
| 11 | 10.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 11.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 12.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 13.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 14.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | | | | | | | | | | |

| | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 21 |
| 1 | $2.32\cdot10^{-3}$ | $1.32\cdot10^{-3}$ | $7.4\cdot10^{-4}$ | $4.1\cdot10^{-4}$ | $2.2\cdot10^{-4}$ | $1.2\cdot10^{-4}$ | $7\cdot10^{-5}$ | $4\cdot10^{-5}$ | $2\cdot10^{-5}$ |
| 2 | $1.82\cdot10^{-2}$ | $1.1\cdot10^{-2}$ | $6.34\cdot10^{-3}$ | $3.55\cdot10^{-3}$ | $1.94\cdot10^{-3}$ | $1.05\cdot10^{-3}$ | $5.6\cdot10^{-4}$ | $3\cdot10^{-4}$ | $1.6\cdot10^{-4}$ |
| 3 | $2.45\cdot10^{-2}$ | $1.54\cdot10^{-2}$ | $9.01\cdot10^{-3}$ | $4.97\cdot10^{-3}$ | $2.63\cdot10^{-3}$ | $1.35\cdot10^{-3}$ | $6.7\cdot10^{-4}$ | $3.3\cdot10^{-4}$ | $1.6\cdot10^{-4}$ |
| 4 | $2.16\cdot10^{-2}$ | $1.44\cdot10^{-2}$ | $8.49\cdot10^{-3}$ | $4.58\cdot10^{-3}$ | $2.31\cdot10^{-3}$ | $1.1\cdot10^{-3}$ | $5\cdot10^{-4}$ | $2.2\cdot10^{-4}$ | $10\cdot10^{-5}$ |
| 5 | $1.7\cdot10^{-2}$ | $1.23\cdot10^{-2}$ | $7.48\cdot10^{-3}$ | $3.98\cdot10^{-3}$ | $1.91\cdot10^{-3}$ | $8.4\cdot10^{-4}$ | $3.5\cdot10^{-4}$ | $1.3\cdot10^{-4}$ | $5\cdot10^{-5}$ |
| 6 | $1.07\cdot10^{-2}$ | $8.85\cdot10^{-3}$ | $5.75\cdot10^{-3}$ | $3.09\cdot10^{-3}$ | $1.42\cdot10^{-3}$ | $5.8\cdot10^{-4}$ | $2.1\cdot10^{-4}$ | $7\cdot10^{-5}$ | $2\cdot10^{-5}$ |
| 7 | $5.28\cdot10^{-3}$ | $5.33\cdot10^{-3}$ | $3.87\cdot10^{-3}$ | $2.17\cdot10^{-3}$ | $9.8\cdot10^{-4}$ | $3.7\cdot10^{-4}$ | $1.2\cdot10^{-4}$ | $4\cdot10^{-5}$ | $10\cdot10^{-6}$ |
| 8 | $1.97\cdot10^{-3}$ | $2.61\cdot10^{-3}$ | $2.26\cdot10^{-3}$ | $1.38\cdot10^{-3}$ | $6.4\cdot10^{-4}$ | $2.3\cdot10^{-4}$ | $7\cdot10^{-5}$ | $2\cdot10^{-5}$ | 0 |
| 9 | $5.4\cdot10^{-4}$ | $1.01\cdot10^{-3}$ | $1.11\cdot10^{-3}$ | $7.8\cdot10^{-4}$ | $3.9\cdot10^{-4}$ | $1.4\cdot10^{-4}$ | $4\cdot10^{-5}$ | $10\cdot10^{-6}$ | 0 |
| 10 | $1.1\cdot10^{-4}$ | $3\cdot10^{-4}$ | $4.5\cdot10^{-4}$ | $3.9\cdot10^{-4}$ | $2.2\cdot10^{-4}$ | $8\cdot10^{-5}$ | $2\cdot10^{-5}$ | $10\cdot10^{-6}$ | 0 |
| 11 | $2\cdot10^{-5}$ | $7\cdot10^{-5}$ | $1.5\cdot10^{-4}$ | $1.6\cdot10^{-4}$ | $1.1\cdot10^{-4}$ | $5\cdot10^{-5}$ | $10\cdot10^{-6}$ | 0 | 0 |
| 12 | 0 | $10\cdot10^{-6}$ | $4\cdot10^{-5}$ | $6\cdot10^{-5}$ | $5\cdot10^{-5}$ | $2\cdot10^{-5}$ | $10\cdot10^{-6}$ | 0 | 0 |
| 13 | 0 | 0 | $10\cdot10^{-6}$ | $2\cdot10^{-5}$ | $2\cdot10^{-5}$ | $10\cdot10^{-6}$ | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | $10\cdot10^{-6}$ | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | | | | | | | | | |

Explained in section 4.1.1.2

$B := \left(\text{rows}\left(ss_{orig}\right) - 1\right)$ $\quad$ $D := \left(\text{cols}\left(ss_{orig}\right) - 1\right)$

$t := 1..2B$ $\quad$ $r := 1..D$

$T_{\lambda} := \text{submatrix}\left(ss_{orig}, 0, 0, 0, 19\right)^{T}\cdot\text{sec}$ $\quad$ $h_{w_t} := (t - .5)\cdot m$

$$\lambda_r := \frac{g}{2\cdot\pi}\cdot\left(T_{\lambda_r}\right)^2$$

(This equation explained in Section 4.1.1.3)

$$p_{ray}(H,t) := 4\cdot\frac{H}{\left(h_{w_t}\right)^2}\cdot e^{-2\cdot\left[\frac{H^2}{\left(h_{w_t}\right)^2}\right]}$$

$$
ss := \left|
\begin{array}{l}
new_{2\cdot B,D} \leftarrow 0 \\
\text{for } q \in 1..D \\
\quad \text{for } p \in 1..B \\
\quad\quad \text{if } ss\ orig_{p,q} \neq 0 \\
\quad\quad\quad \left| \begin{array}{l}
\text{for } n \in 1..2\cdot p \\
\quad \left| \begin{array}{l}
tmp \leftarrow ss\ orig_{p,q} \cdot \displaystyle\int_{h\ w_n - .5\cdot m}^{h\ w_n + .5\cdot m} p\ _{ray}(H,p)\, dH \\
new_{n,q} \leftarrow new_{n,q} + tmp
\end{array}\right. \\
0
\end{array}\right. \\
new
\end{array}
\right.
$$

ss =

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | $6.43\cdot10^{-4}$ | $5.3\cdot10^{-3}$ | $1.83\cdot10^{-2}$ | $3.71\cdot10^{-2}$ | $5.35\cdot10^{-2}$ | $6.09\cdot10^{-2}$ | $5.84\cdot10^{-2}$ | $4.92\cdot10^{-2}$ | $3.72\cdot10^{-2}$ | $2.56\cdot10^{-2}$ | $1.63\cdot10^{-2}$ | $9.59\cdot10^{-3}$ | $5.31\cdot10^{-3}$ | $2.79\cdot10^{-3}$ | $1.42\cdot10^{-3}$ | $7.15\cdot10^{-4}$ | $3.6\cdot10^{-4}$ | $1.8\cdot10^{-4}$ | $1.75\cdot10^{-4}$ |
| 2 | 0 | $3.46\cdot10^{-5}$ | $8.48\cdot10^{-4}$ | $5.39\cdot10^{-3}$ | $1.63\cdot10^{-2}$ | $3.15\cdot10^{-2}$ | $4.5\cdot10^{-2}$ | $5.17\cdot10^{-2}$ | $5.02\cdot10^{-2}$ | $4.24\cdot10^{-2}$ | $3.17\cdot10^{-2}$ | $2.12\cdot10^{-2}$ | $1.28\cdot10^{-2}$ | $7.04\cdot10^{-3}$ | $3.6\cdot10^{-3}$ | $1.75\cdot10^{-3}$ | $8.23\cdot10^{-4}$ | $3.85\cdot10^{-4}$ | $1.82\cdot10^{-4}$ | $1.64\cdot10^{-4}$ |
| 3 | 0 | $2.54\cdot10^{-6}$ | $7.76\cdot10^{-5}$ | $6.89\cdot10^{-4}$ | $3.01\cdot10^{-3}$ | $8.09\cdot10^{-3}$ | $1.52\cdot10^{-2}$ | $2.18\cdot10^{-2}$ | $2.52\cdot10^{-2}$ | $2.45\cdot10^{-2}$ | $2.03\cdot10^{-2}$ | $1.45\cdot10^{-2}$ | $9.03\cdot10^{-3}$ | $4.96\cdot10^{-3}$ | $2.46\cdot10^{-3}$ | $1.12\cdot10^{-3}$ | $4.86\cdot10^{-4}$ | $2.07\cdot10^{-4}$ | $8.83\cdot10^{-5}$ | $6.84\cdot10^{-5}$ |
| 4 | 0 | $3.01\cdot10^{-8}$ | $4.72\cdot10^{-6}$ | $8.68\cdot10^{-5}$ | $5.69\cdot10^{-4}$ | $2.05\cdot10^{-3}$ | $4.85\cdot10^{-3}$ | $8.47\cdot10^{-3}$ | $1.15\cdot10^{-2}$ | $1.28\cdot10^{-2}$ | $1.17\cdot10^{-2}$ | $8.94\cdot10^{-3}$ | $5.79\cdot10^{-3}$ | $3.21\cdot10^{-3}$ | $1.56\cdot10^{-3}$ | $6.72\cdot10^{-4}$ | $2.7\cdot10^{-4}$ | $1.05\cdot10^{-4}$ | $3.99\cdot10^{-5}$ | $2.67\cdot10^{-5}$ |
| 5 | 0 | 0 | $4.51\cdot10^{-7}$ | $1.16\cdot10^{-5}$ | $9.97\cdot10^{-5}$ | $4.75\cdot10^{-4}$ | $1.44\cdot10^{-3}$ | $3.08\cdot10^{-3}$ | $4.96\cdot10^{-3}$ | $6.26\cdot10^{-3}$ | $6.34\cdot10^{-3}$ | $5.23\cdot10^{-3}$ | $3.55\cdot10^{-3}$ | $2\cdot10^{-3}$ | $9.6\cdot10^{-4}$ | $3.96\cdot10^{-4}$ | $1.48\cdot10^{-4}$ | $5.32\cdot10^{-5}$ | $1.74\cdot10^{-5}$ | $10\cdot10^{-6}$ |
| 6 | 0 | 0 | $2.6\cdot10^{-8}$ | $1.32\cdot10^{-6}$ | $1.69\cdot10^{-5}$ | $1.1\cdot10^{-4}$ | $4.23\cdot10^{-4}$ | $1.1\cdot10^{-3}$ | $2.07\cdot10^{-3}$ | $2.97\cdot10^{-3}$ | $3.33\cdot10^{-3}$ | $2.96\cdot10^{-3}$ | $2.12\cdot10^{-3}$ | $1.23\cdot10^{-3}$ | $5.87\cdot10^{-4}$ | $2.34\cdot10^{-4}$ | $8.18\cdot10^{-5}$ | $2.76\cdot10^{-5}$ | $7.49\cdot10^{-6}$ | $3.71\cdot10^{-6}$ |
| 7 | 0 | 0 | 0 | $1.48\cdot10^{-7}$ | $2.92\cdot10^{-6}$ | $2.52\cdot10^{-5}$ | $1.21\cdot10^{-4}$ | $3.8\cdot10^{-4}$ | $8.37\cdot10^{-4}$ | $1.36\cdot10^{-3}$ | $1.69\cdot10^{-3}$ | $1.63\cdot10^{-3}$ | $1.23\cdot10^{-3}$ | $7.38\cdot10^{-4}$ | $3.57\cdot10^{-4}$ | $1.39\cdot10^{-4}$ | $4.57\cdot10^{-5}$ | $1.46\cdot10^{-5}$ | $3.18\cdot10^{-6}$ | $1.33\cdot10^{-6}$ |
| 8 | 0 | 0 | 0 | $1.84\cdot10^{-8}$ | $5.05\cdot10^{-7}$ | $5.7\cdot10^{-6}$ | $3.41\cdot10^{-5}$ | $1.28\cdot10^{-4}$ | $3.3\cdot10^{-4}$ | $6.1\cdot10^{-4}$ | $8.4\cdot10^{-4}$ | $8.78\cdot10^{-4}$ | $7.07\cdot10^{-4}$ | $4.39\cdot10^{-4}$ | $2.16\cdot10^{-4}$ | $8.26\cdot10^{-5}$ | $2.59\cdot10^{-5}$ | $7.86\cdot10^{-6}$ | $1.33\cdot10^{-6}$ | $4.51\cdot10^{-7}$ |
| 9 | 0 | 0 | 0 | 0 | $5.85\cdot10^{-8}$ | $1.13\cdot10^{-6}$ | $8.97\cdot10^{-6}$ | $4.16\cdot10^{-5}$ | $1.26\cdot10^{-4}$ | $2.65\cdot10^{-4}$ | $4.07\cdot10^{-4}$ | $4.63\cdot10^{-4}$ | $3.98\cdot10^{-4}$ | $2.58\cdot10^{-4}$ | $1.3\cdot10^{-4}$ | $4.93\cdot10^{-5}$ | $1.48\cdot10^{-5}$ | $4.28\cdot10^{-6}$ | $5.37\cdot10^{-7}$ | $1.42\cdot10^{-7}$ |
| 10 | 0 | 0 | 0 | 0 | $1.14\cdot10^{-8}$ | $2.63\cdot10^{-7}$ | $2.47\cdot10^{-6}$ | $1.36\cdot10^{-5}$ | $4.76\cdot10^{-5}$ | $1.14\cdot10^{-4}$ | $1.94\cdot10^{-4}$ | $2.4\cdot10^{-4}$ | $2.21\cdot10^{-4}$ | $1.5\cdot10^{-4}$ | $7.84\cdot10^{-5}$ | $2.95\cdot10^{-5}$ | $8.56\cdot10^{-6}$ | $2.34\cdot10^{-6}$ | $2.1\cdot10^{-7}$ | $4.23\cdot10^{-8}$ |
| 11 | 0 | 0 | 0 | 0 | 0 | $3.03\cdot10^{-8}$ | $5.04\cdot10^{-7}$ | $3.89\cdot10^{-6}$ | $1.69\cdot10^{-5}$ | $4.7\cdot10^{-5}$ | $9.01\cdot10^{-5}$ | $1.22\cdot10^{-4}$ | $1.21\cdot10^{-4}$ | $8.65\cdot10^{-5}$ | $4.69\cdot10^{-5}$ | $1.76\cdot10^{-5}$ | $4.96\cdot10^{-6}$ | $1.28\cdot10^{-6}$ | $7.56\cdot10^{-8}$ | $1.01\cdot10^{-8}$ |
| 12 | 0 | 0 | 0 | 0 | 0 | $7.86\cdot10^{-9}$ | $1.45\cdot10^{-7}$ | $1.28\cdot10^{-6}$ | $6.28\cdot10^{-6}$ | $1.97\cdot10^{-5}$ | $4.18\cdot10^{-5}$ | $6.16\cdot10^{-5}$ | $6.57\cdot10^{-5}$ | $4.95\cdot10^{-5}$ | $2.8\cdot10^{-5}$ | $1.06\cdot10^{-5}$ | $2.9\cdot10^{-6}$ | $6.95\cdot10^{-7}$ | $2.68\cdot10^{-8}$ | $2.62\cdot10^{-9}$ |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | $1.52\cdot10^{-8}$ | $2.76\cdot10^{-7}$ | $1.92\cdot10^{-6}$ | $7.48\cdot10^{-6}$ | $1.84\cdot10^{-5}$ | $3.01\cdot10^{-5}$ | $3.49\cdot10^{-5}$ | $2.78\cdot10^{-5}$ | $1.66\cdot10^{-5}$ | $6.27\cdot10^{-6}$ | $1.68\cdot10^{-6}$ | $3.68\cdot10^{-7}$ | $7.6\cdot10^{-9}$ | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | $4.84\cdot10^{-9}$ | $9.57\cdot10^{-8}$ | $7.3\cdot10^{-7}$ | $3.12\cdot10^{-6}$ | $8.44\cdot10^{-6}$ | $1.49\cdot10^{-5}$ | $1.87\cdot10^{-5}$ | $1.57\cdot10^{-5}$ | $9.82\cdot10^{-6}$ | $3.73\cdot10^{-6}$ | $9.84\cdot10^{-7}$ | $1.95\cdot10^{-7}$ | $2.42\cdot10^{-9}$ | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $1.21\cdot10^{-8}$ | $1.7\cdot10^{-7}$ | $1.02\cdot10^{-6}$ | $3.42\cdot10^{-6}$ | $6.88\cdot10^{-6}$ | $9.57\cdot10^{-6}$ | $8.61\cdot10^{-6}$ | $5.71\cdot10^{-6}$ | $2.18\cdot10^{-6}$ | $5.63\cdot10^{-7}$ | $9.8\cdot10^{-8}$ | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $4.48\cdot10^{-9}$ | $6.75\cdot10^{-8}$ | $4.36\cdot10^{-7}$ | $1.57\cdot10^{-6}$ | $3.38\cdot10^{-6}$ | $5.07\cdot10^{-6}$ | $4.8\cdot10^{-6}$ | $3.37\cdot10^{-6}$ | $1.28\cdot10^{-6}$ | $3.26\cdot10^{-7}$ | $4.98\cdot10^{-8}$ | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $1\cdot10^{-8}$ | $1.11\cdot10^{-7}$ | $5.53\cdot10^{-7}$ | $1.43\cdot10^{-6}$ | $2.47\cdot10^{-6}$ | $2.53\cdot10^{-6}$ | $1.92\cdot10^{-6}$ | $7.23\cdot10^{-7}$ | $1.81\cdot10^{-7}$ | $2.28\cdot10^{-8}$ | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $4.16\cdot10^{-9}$ | $4.91\cdot10^{-8}$ | $2.6\cdot10^{-7}$ | $7.04\cdot10^{-7}$ | $1.3\cdot10^{-6}$ | $1.4\cdot10^{-6}$ | $1.12\cdot10^{-6}$ | $4.18\cdot10^{-7}$ | $1.03\cdot10^{-7}$ | $1.1\cdot10^{-8}$ | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $8.52\cdot10^{-9}$ | $7.43\cdot10^{-8}$ | $2.56\cdot10^{-7}$ | $5.85\cdot10^{-7}$ | $6.96\cdot10^{-7}$ | $6.19\cdot10^{-7}$ | $2.26\cdot10^{-7}$ | $5.41\cdot10^{-8}$ | $4.26\cdot10^{-9}$ | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $3.88\cdot10^{-9}$ | $3.59\cdot10^{-8}$ | $1.28\cdot10^{-7}$ | $3.11\cdot10^{-7}$ | $3.83\cdot10^{-7}$ | $3.61\cdot10^{-7}$ | $1.28\cdot10^{-7}$ | $3.01\cdot10^{-8}$ | $1.94\cdot10^{-9}$ | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $7.41\cdot10^{-9}$ | $3.68\cdot10^{-8}$ | $1.24\cdot10^{-7}$ | $1.73\cdot10^{-7}$ | $1.89\cdot10^{-7}$ | $6.47\cdot10^{-8}$ | $1.46\cdot10^{-8}$ | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $3.63\cdot10^{-9}$ | $1.88\cdot10^{-8}$ | $6.65\cdot10^{-8}$ | $9.54\cdot10^{-8}$ | $1.1\cdot10^{-7}$ | $3.62\cdot10^{-8}$ | $7.89\cdot10^{-9}$ | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $3.27\cdot10^{-9}$ | $2.2\cdot10^{-8}$ | $3.75\cdot10^{-8}$ | $5.34\cdot10^{-8}$ | $1.55\cdot10^{-8}$ | $3.27\cdot10^{-9}$ | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $1.71\cdot10^{-9}$ | $1.2\cdot10^{-8}$ | $2.06\cdot10^{-8}$ | $3.1\cdot10^{-8}$ | $8.6\cdot10^{-9}$ | $1.71\cdot10^{-9}$ | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $2.93\cdot10^{-9}$ | $5.85\cdot10^{-9}$ | $1.33\cdot10^{-8}$ | $2.93\cdot10^{-9}$ | 0 | 0 | 0 | 0 |
| 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $1.61\cdot10^{-9}$ | $3.22\cdot10^{-9}$ | $7.72\cdot10^{-9}$ | $1.61\cdot10^{-9}$ | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $2.65\cdot10^{-9}$ | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $1.52\cdot10^{-9}$ | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

$$
pmax := \left|
\begin{array}{l}
\text{for } q \in 1..D \\
\quad \left| \begin{array}{l}
\text{for } p \in 1..2B \\
\quad tmp \leftarrow p \ \text{ if } ss_{p,q} \neq 0 \\
pmax_q \leftarrow tmp
\end{array}\right. \\
pmax
\end{array}
\right.
$$

Explained in Section 4.1.1.3

$$
H_{wave\_lg}\left(x,p,q,\phi,X_s\right) := \frac{h_{w_p}}{2}\cdot\sin\left[\frac{2\cdot\pi}{\lambda_q}\cdot\left(x - X_s\right) - \phi\right]
\qquad
\phi_{lg} := \begin{pmatrix} 0 \\ 90 \\ 180 \\ 270 \end{pmatrix}\cdot deg
\qquad
\phi_{lg} = \begin{pmatrix} pos\_twist \\ trough \\ neg\_twist \\ crest \end{pmatrix}
$$

$$H_{wave\_tr}(y,p,q,\phi) := \frac{h_{w_p}}{2}\cdot\cos\left[\frac{2\cdot\pi}{\lambda_q}\cdot(y) - \phi\right] \qquad \phi_{tr} := \begin{pmatrix}0\\180\end{pmatrix}\cdot deg \qquad \phi_{tr} = \begin{pmatrix}hog\\sag\end{pmatrix}$$

Explained in Section 4.1.1.4

$$\text{motion\_lg}(p,q,\phi,X_s,X_{cf},T_s,L_s,B_s,F_m,T_m,B_m,L_m) :=$$

$$\begin{array}{l}
\Delta T \leftarrow 0\cdot m\\
\Theta_{pitch} \leftarrow 0\\
\Delta P \leftarrow 1\cdot m^4\\
\Delta V \leftarrow 1\cdot m^3\\
count \leftarrow 0\\
\text{while } \left(|\Delta V| > 10^{-3}\cdot m^3\right) \vee \left(|\Delta P| > 10^{-3}\cdot m^4\right)\\
\quad \Delta V \leftarrow B_m\cdot\displaystyle\int_{\frac{-L_m}{2}}^{\frac{L_m}{2}} \left[\begin{array}{ll} F_m & \text{if } \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] > F_m\\ -T_m & \text{if } \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] < -T_m\\ \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] & \text{otherwise}\end{array}\right] dx \ldots\\
\qquad + 2\cdot B_s\cdot\displaystyle\int_{X_s-\frac{L_s}{2}}^{X_s+\frac{L_s}{2}} \left[\begin{array}{ll} F_m & \text{if } \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] > F_m\\ -T_s & \text{if } \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] < -T_s\\ \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] & \text{otherwise}\end{array}\right] dx\\
\quad \Delta P \leftarrow B_m\cdot\displaystyle\int_{\frac{-L_m}{2}}^{\frac{L_m}{2}} \left[\begin{array}{ll} F_m & \text{if } \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] > F_m\\ -T_m & \text{if } \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] < -T_m\\ \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] & \text{otherwise}\end{array}\right]\cdot(x - X_{cf})\, dx \ldots\\
\qquad + 2\cdot B_s\cdot\displaystyle\int_{X_s-\frac{L_s}{2}}^{X_s+\frac{L_s}{2}} \left[\begin{array}{ll} F_m & \text{if } \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] > F_m\\ -T_s & \text{if } \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] < -T_s\\ \left[H_{wave_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] & \text{otherwise}\end{array}\right]\cdot(x - X_{cf})\, dx\\
\quad tmp1 \leftarrow \dfrac{\Delta V}{B_m\cdot L_m + 2\cdot B_s\cdot L_s}\\
\quad tmp2 \leftarrow \dfrac{\Delta P}{B_m\cdot\left(\frac{L_m}{2}\right)^3}\\
\quad \Delta T \leftarrow \Delta T + tmp1\\
\quad \Theta_{pitch} \leftarrow \Theta_{pitch} + tmp2\\
\quad count \leftarrow count + 1\\
\quad M \leftarrow \begin{pmatrix}\frac{\Delta T}{m}\\ \Theta_{pitch}\end{pmatrix}\\
\quad \text{if } count \geq 100\\
\qquad M \leftarrow \text{motion_lg}(p-1,q,\phi,X_s,X_{cf},T_s,L_s,B_s,F_m,T_m,B_m,L_m)\\
\qquad \text{break}\\
M
\end{array}$$

$$\text{motion\_tr}(p,q,\phi,Y_s,T_s,L_s,B_s,F_m,T_m,B_m,L_m) := \left| \begin{array}{l} \Delta T \leftarrow 0\cdot m \\ \Delta V \leftarrow 1\cdot m^3 \\ \text{count} \leftarrow 0 \\ \text{while } \left(|\Delta V| > 10^{-3}\cdot m^3\right) \\ \quad \left| \begin{array}{l} \Delta V \leftarrow L_m\cdot \displaystyle\int_{\frac{-B_m}{2}}^{\frac{B_m}{2}} \left| \begin{array}{ll} F_m & \text{if } \left(H_{wave\_tr}(y,p,q,\phi) - \Delta T\right) > F_m \\ -T_m & \text{if } \left(H_{wave\_tr}(y,p,q,\phi) - \Delta T\right) < -T_m \\ \left(H_{wave\_tr}(y,p,q,\phi) - \Delta T\right) & \text{otherwise} \end{array}\right. dy \ldots \\ \qquad + 2\cdot L_s\cdot \displaystyle\int_{Y_s-\frac{B_s}{2}}^{Y_s+\frac{B_s}{2}} \left| \begin{array}{ll} F_m & \text{if } \left(H_{wave\_tr}(y,p,q,\phi) - \Delta T\right) > F_m \\ -T_s & \text{if } \left(H_{wave\_tr}(y,p,q,\phi) - \Delta T\right) < -T_s \\ \left(H_{wave\_tr}(y,p,q,\phi) - \Delta T\right) & \text{otherwise} \end{array}\right. dy \\ \text{tmp1} \leftarrow \dfrac{\Delta V}{B_m\cdot L_m + 2\cdot B_s\cdot L_s} \\ \Delta T \leftarrow \Delta T + \text{tmp1} \\ M \leftarrow \dfrac{\Delta T}{m} \\ \text{count} \leftarrow \text{count} + 1 \\ \text{if count} \geq 100 \\ \quad \left| \begin{array}{l} M \leftarrow \text{motion\_tr}(p-1,q,\phi,Y_s,T_s,L_s,B_s,F_m,T_m,B_m,L_m) \\ \text{break} \end{array}\right. \end{array}\right. \\ M \end{array}\right.$$

# Explained in Section 4.1.1.5

$$FB_{lg}(p,q,\phi,X_s,X_{cf},T_s,L_s,B_s,F_m,T_m,B_m,L_m) := \left| \begin{array}{l} \text{mot} \leftarrow \text{motion\_lg}(p,q,\phi,X_s,X_{cf},T_s,L_s,B_s,F_m,T_m,B_m,L_m) \\ \Delta T \leftarrow \text{mot}_0\cdot m \\ \Theta_{pitch} \leftarrow \text{mot}_1 \\ FB_s \leftarrow \dfrac{\text{lton}}{35\cdot ft^3}\cdot\left[ B_s\cdot \displaystyle\int_{X_s-\frac{L_s}{2}}^{X_s+\frac{L_s}{2}} \left[ \left| \begin{array}{ll} F_m & \text{if } \left[H_{wave\_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] > F_m \\ -T_s & \text{if } \left[H_{wave\_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] < -T_s \\ \left[H_{wave\_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf})\cdot\sin(\Theta_{pitch})\right] & \text{otherwise} \end{array}\right. \right] dx \right] \\ FB_s \end{array}\right.$$

$$MB_{lg}(p,q,\phi,X_s,X_{cf},T_s,L_s,B_s,F_m,T_m,B_m,L_m) := \left| \begin{array}{l} mot \leftarrow motion\_lg(p,q,\phi,X_s,X_{cf},T_s,L_s,B_s,F_m,T_m,B_m,L_m) \\ \Delta T \leftarrow mot_0 \cdot m \\ \Theta_{pitch} \leftarrow mot_1 \\ MB_s \leftarrow \frac{lton}{35 \cdot ft^3} \cdot \left[ B_s \cdot \int_{X_s - \frac{L_s}{2}}^{X_s + \frac{L_s}{2}} \left[ \left| \begin{array}{ll} F_m & \text{if } \left[ H_{wave\_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf}) \cdot \sin(\Theta_{pitch}) \right] > F_m \\ -T_s & \text{if } \left[ H_{wave\_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf}) \cdot \sin(\Theta_{pitch}) \right] < -T_s \\ \left[ H_{wave\_lg}(x,p,q,\phi,X_s) - \Delta T - (x - X_{cf}) \cdot \sin(\Theta_{pitch}) \right] & \text{otherwise} \end{array} \right. \right] \cdot (x - X_s)\, dx \right] \\ MB_s \end{array} \right.$$

$$FB_{tr}(p,q,\phi,Y_s,T_s,L_s,B_s,F_m,T_m,B_m,L_m) := \left| \begin{array}{l} mot \leftarrow motion\_tr(p,q,\phi,Y_s,T_s,L_s,B_s,F_m,T_m,B_m,L_m) \\ \Delta T \leftarrow mot \cdot m \\ FB_s \leftarrow \frac{lton}{35 \cdot ft^3} \cdot \left[ L_s \cdot \int_{Y_s - \frac{B_s}{2}}^{Y_s + \frac{B_s}{2}} \left| \begin{array}{ll} F_m & \text{if } \left( H_{wave\_tr}(y,p,q,\phi) - \Delta T \right) > F_m \\ -T_s & \text{if } \left( H_{wave\_tr}(y,p,q,\phi) - \Delta T \right) < -T_s \\ \left( H_{wave\_tr}(y,p,q,\phi) - \Delta T \right) & \text{otherwise} \end{array} \right. dy \right] \\ FB_s \end{array} \right.$$

## Explained in Section 4.1.1.6

$\beta := 5$

$$dmax\_lg(L_m) := \left| \begin{array}{l} dmax \leftarrow 0 \\ \text{for } n \in 1..D \\ \quad dmax \leftarrow n \ \text{ if } \lambda_n < L_m \\ dmax \leftarrow dmax + 3 \end{array} \right.$$

$$q\_lg\_sag\_FB(X_s,X_{cf},T_s,L_s,B_s,F_m,T_m,B_m,L_m) := \left| \begin{array}{l} q_{max} \leftarrow 0 \\ F \leftarrow 0 \\ \text{for } q \in 1..dmax\_lg(L_m) \\ \quad \left| \begin{array}{l} p \leftarrow pmax_q \\ Ftemp \leftarrow \left| FB_{lg}(p,q,\phi_{lg_1},X_s,X_{cf},T_s,L_s,B_s,F_m,T_m,B_m,L_m) \right| \\ \text{if } Ftemp > F \\ \quad \left| \begin{array}{l} q_{max} \leftarrow q \\ F \leftarrow Ftemp \end{array} \right. \end{array} \right. \\ q_{max} \end{array} \right.$$

$$\text{design\_lg\_sag\_FB}_s\left(X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) :=$$

$$\begin{array}{l}
\text{mean} \leftarrow 0 \\
\text{m2} \leftarrow 0 \\
\text{design} \leftarrow 0 \\
q \leftarrow \text{q_lg_sag_FB}\left(X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) \\
\text{sum} \leftarrow \sum_{p=1}^{\text{pmax}_q} ss_{p,q} \\
\text{for } p \in 1..\text{pmax}_q \\
\quad \text{if } ss_{p,q} \neq 0 \\
\quad\quad F \leftarrow FB_{lg}\left(p, q, \phi_{lg_1}, X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) \\
\quad\quad \text{mean} \leftarrow \text{mean} + |F| \cdot \dfrac{ss_{p,q}}{\text{sum}} \\
\quad\quad \text{m2} \leftarrow \text{m2} + (F)^2 \cdot \dfrac{ss_{p,q}}{\text{sum}} \\
\text{design} \leftarrow -\left[\text{mean} + \beta \cdot \sqrt{\text{m2} - (\text{mean})^2}\right] \\
\text{design}
\end{array}$$

$$\text{q\_lg\_hog\_FB}\left(X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) :=$$

$$\begin{array}{l}
q_{max} \leftarrow 0 \\
F \leftarrow 0 \\
\text{for } q \in 1..\text{dmax_lg}\left(L_m\right) \\
\quad p \leftarrow \text{pmax}_q \\
\quad \text{Ftemp} \leftarrow \left|FB_{lg}\left(p, q, \phi_{lg_3}, X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right)\right| \\
\quad \text{if Ftemp} > F \\
\quad\quad q_{max} \leftarrow q \\
\quad\quad F \leftarrow \text{Ftemp} \\
q_{max}
\end{array}$$

$$design\_lg\_hog\_FB_s(X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m) :=$$

$$\begin{array}{l} mean \leftarrow 0 \\ m2 \leftarrow 0 \\ design \leftarrow 0 \\ q \leftarrow q\_lg\_hog\_FB(X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m) \\ sum \leftarrow \displaystyle\sum_{p=1}^{pmax_q} ss_{p,q} \\ \text{for } p \in 1..pmax_q \\ \quad \text{if } ss_{p,q} \neq 0 \\ \quad\quad \left| \begin{array}{l} F \leftarrow FB_{lg}(p, q, \phi_{lg_3}, X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m) \\ mean \leftarrow mean + |F| \cdot \dfrac{ss_{p,q}}{sum} \\ m2 \leftarrow m2 + (F)^2 \cdot \dfrac{ss_{p,q}}{sum} \end{array} \right. \\ design \leftarrow mean + \beta \cdot \sqrt{m2 - (mean)^2} \\ design \end{array}$$

$$q\_twist\_MB\_pos(X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m) :=$$

$$\begin{array}{l} q_{max} \leftarrow 0 \\ F \leftarrow 0 \\ \text{for } q \in 1..dmax\_lg(L_m) \\ \quad \left| \begin{array}{l} p \leftarrow pmax_q \\ Ftemp \leftarrow \left| MB_{lg}(p, q, \phi_{lg_0}, X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m) \right| \\ \text{if } Ftemp > F \\ \quad \left| \begin{array}{l} q_{max} \leftarrow q \\ F \leftarrow Ftemp \end{array} \right. \end{array} \right. \\ q_{max} \end{array}$$

$$
\text{design\_twist\_MB\_pos}\left(X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) :=
\left|
\begin{array}{l}
mean \leftarrow 0 \\
m2 \leftarrow 0 \\
design \leftarrow 0 \\
q \leftarrow \text{q\_twist\_MB\_pos}\left(X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) \\
sum \leftarrow \displaystyle\sum_{p=1}^{pmax_q} ss_{p,q} \\
\text{for } p \in 1..pmax_q \\
\quad \text{if } ss_{p,q} \neq 0 \\
\quad\quad \left|
\begin{array}{l}
F \leftarrow MB_{lg}\left(p, q, \phi_{lg_0}, X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) \\
mean \leftarrow mean + |F| \cdot \dfrac{ss_{p,q}}{sum} \\
m2 \leftarrow m2 + (F)^2 \cdot \dfrac{ss_{p,q}}{sum}
\end{array}
\right. \\
design \leftarrow mean + \beta \cdot \sqrt{m2 - (mean)^2} \\
design
\end{array}
\right.
$$

$$
\text{q\_twist\_MB\_neg}\left(X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) :=
\left|
\begin{array}{l}
q_{max} \leftarrow 0 \\
F \leftarrow 0 \\
\text{for } q \in 1..\text{dmax\_lg}\left(L_m\right) \\
\quad \left|
\begin{array}{l}
p \leftarrow pmax_q \\
Ftemp \leftarrow \left|MB_{lg}\left(p, q, \phi_{lg_2}, X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right)\right| \\
\text{if } Ftemp > F \\
\quad \left|
\begin{array}{l}
q_{max} \leftarrow q \\
F \leftarrow Ftemp
\end{array}
\right.
\end{array}
\right. \\
q_{max}
\end{array}
\right.
$$

$$
\text{design\_twist\_MB\_neg}\left(X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) :=
\left|
\begin{array}{l}
mean \leftarrow 0 \\
m2 \leftarrow 0 \\
design \leftarrow 0 \\
q \leftarrow \text{q\_twist\_MB\_neg}\left(X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) \\
sum \leftarrow \displaystyle\sum_{p=1}^{pmax_q} ss_{p,q} \\
\text{for } p \in 1..pmax_q \\
\quad \text{if } ss_{p,q} \neq 0 \\
\quad\quad \left|
\begin{array}{l}
F \leftarrow MB_{lg}\left(p, q, \phi_{lg_2}, X_s, X_{cf}, T_s, L_s, B_s, F_m, T_m, B_m, L_m\right) \\
mean \leftarrow mean + |F| \cdot \dfrac{ss_{p,q}}{sum} \\
m2 \leftarrow m2 + (F)^2 \cdot \dfrac{ss_{p,q}}{sum}
\end{array}
\right. \\
design \leftarrow -\left[mean + \beta \cdot \sqrt{m2 - (mean)^2}\right] \\
design
\end{array}
\right.
$$

```
dmax_tr(Y_s) := | dmax_tr ← 0
                | for n ∈ 1..D
                |   dmax_tr ← n  if λ_n < 2·Y_s
                | dmax_tr ← dmax_tr + 3

q_tr_sag_FB(Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m) := | q_max ← 0
                | F ← 0
                | for q ∈ 1..dmax_tr(Y_s)
                |   | p ← pmax_q
                |   | Ftemp ← |FB_tr(p, q, φtr_1, Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m)|
                |   | if Ftemp > F
                |   |   | q_max ← q
                |   |   | F ← Ftemp
                | q_max

design_tr_sag_FB_s(Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m) := | mean ← 0
                | m2 ← 0
                | design ← 0
                | q ← q_tr_sag_FB(Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m)
                | sum ← Σ_{p=1}^{pmax_q} ss_{p,q}
                | for p ∈ 1..pmax_q
                |   if ss_{p,q} ≠ 0
                |     | F ← FB_tr(p, q, φtr_1, Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m)
                |     | mean ← mean + |F|·ss_{p,q}/sum
                |     | m2 ← m2 + (F)^2·ss_{p,q}/sum
                | design ← [mean + β·√(m2 − (mean)^2)]
                | design
```

```
q_tr_hog_FB(Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m) := | q_max ← 0
                                                      | F ← 0
                                                      | for q ∈ 1..dmax_tr(Y_s)
                                                      |    | p ← pmax_q
                                                      |    | Ftemp ← |FB_tr(p, q, φ_tr_0, Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m)|
                                                      |    | if Ftemp > F
                                                      |    |    | q_max ← q
                                                      |    |    | F ← Ftemp
                                                      | q_max
```

```
design_tr_hog_FB_s(Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m) := | mean ← 0
                                                            | m2 ← 0
                                                            | design ← 0
                                                            | q ← q_tr_hog_FB(Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m)
                                                            | sum ← Σ_{p=1}^{pmax_q} ss_{p,q}
                                                            | for p ∈ 1..pmax_q
                                                            |   if ss_{p,q} ≠ 0
                                                            |      | F ← FB_tr(p, q, φ_tr_0, Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m)
                                                            |      | mean ← mean + |F|·(ss_{p,q} / sum)
                                                            |      | m2 ← m2 + (F)^2·(ss_{p,q} / sum)
                                                            | design ← -[mean + β·√(m2 − (mean)^2)]
                                                            | design
```

# Explained in Section 4.1.1.7

```
file_root := "C:\Documents and Settings\jlrhoads\My Documents\rhoads thesis data\"

file_base(L_m) := num2str(L_m / m)        file_ext := ".prn"        cc(a, b) := concat(a, b)

fullname_lg(L_m) := file_root cc [[file_base(L_m) cc ("_lg" cc file_ext)]]

fullname_tr(L_m) := file_root cc [[file_base(L_m) cc ("_tr" cc file_ext)]]
```

```
for j ∈ 0..12                                                        =
    L_m ← (60 + 20·j)·m
    B_m ← L_m / 14
    T_m ← B_m / 2
    D_m ← 2.4·T_m
    F_m ← D_m − T_m
    data_lg ← (0 0 0 0 0 0 0 0)
    data_tr ← (0 0 0 0 0 0)
    WRITEPRN(fullname_lg(L_m), data_lg)
    WRITEPRN(fullname_tr(L_m), data_tr)
    for n ∈ 0..5
        L_s ← L_m·(0.25 + n·.05)
        T_s ← sqrt( (L_m·B_m·T_m / L_s)·0.04 )
        B_s ← T_s
        for i ∈ 0..5
            X_smax ← −(L_m/2 − L_s/2)
            X_inc ← X_smax / 5
            X_s ← X_inc·i
            X_cf ← (B_m·L_m·0·m + 2B_s·L_s·X_s) / (B_m·L_m + 2B_s·L_s)
            data_lg[0,0] ← L_m / m
            data_lg[0,1] ← L_s / m
            data_lg[0,2] ← B_s / m
            data_lg[0,3] ← X_s / m
            data_lg[0,4] ← design_lg_sag_FB_s(X_s, X_cf, T_s, L_s, B_s, F_m, T_m, B_m, L_m) / N
            data_lg[0,5] ← design_lg_hog_FB_s(X_s, X_cf, T_s, L_s, B_s, F_m, T_m, B_m, L_m) / N
            data_lg[0,6] ← design_twist_MB_pos(X_s, X_cf, T_s, L_s, B_s, F_m, T_m, B_m, L_m) / (N·m)
            data_lg[0,7] ← design_twist_MB_neg(X_s, X_cf, T_s, L_s, B_s, F_m, T_m, B_m, L_m) / (N·m)
            APPENDPRN(fullname_lg(L_m), data_lg)
        for i ∈ 0..5
            Y_s ← B_m·(1 + i·0.1)
            data_tr[0,0] ← L_m / m
            data_tr[0,1] ← L_s / m
            data_tr[0,2] ← B_s / m
            data_tr[0,3] ← Y_s / m
            data_tr[0,4] ← design_tr_sag_FB_s(Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m) / N
            data_tr[0,5] ← design_tr_hog_FB_s(Y_s, T_s, L_s, B_s, F_m, T_m, B_m, L_m) / N
            APPENDPRN(fullname_tr(L_m), data_tr)
"done"
```

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# Appendix B.  MathCAD Analytical Results Tables

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 60 | 15 | 1.212 | 0 | -2.63E+05 | 3.22E+05 | 8.52E+05 | -8.52E+05 |
| 60 | 15 | 1.212 | -4.5 | -2.54E+05 | 2.62E+05 | 8.48E+05 | -7.95E+05 |
| 60 | 15 | 1.212 | -9 | -2.28E+05 | 2.32E+05 | 8.29E+05 | -7.84E+05 |
| 60 | 15 | 1.212 | -13.5 | -1.88E+05 | 1.90E+05 | 8.05E+05 | -7.77E+05 |
| 60 | 15 | 1.212 | -18 | -1.48E+05 | 1.48E+05 | 7.95E+05 | -8.25E+05 |
| 60 | 15 | 1.212 | -22.5 | -1.21E+05 | 1.35E+05 | 8.02E+05 | -8.85E+05 |
| 60 | 18 | 1.107 | 0 | -2.55E+05 | 3.31E+05 | 1.23E+06 | -1.23E+06 |
| 60 | 18 | 1.107 | -4.2 | -2.47E+05 | 2.59E+05 | 1.24E+06 | -1.04E+06 |
| 60 | 18 | 1.107 | -8.4 | -2.23E+05 | 2.29E+05 | 1.22E+06 | -1.02E+06 |
| 60 | 18 | 1.107 | -12.6 | -1.86E+05 | 1.89E+05 | 1.18E+06 | -1.01E+06 |
| 60 | 18 | 1.107 | -16.8 | -1.45E+05 | 1.46E+05 | 1.16E+06 | -1.21E+06 |
| 60 | 18 | 1.107 | -21 | -1.14E+05 | 1.21E+05 | 1.14E+06 | -1.32E+06 |
| 60 | 21 | 1.024 | 0 | -3.09E+05 | 3.33E+05 | 1.64E+06 | -1.64E+06 |
| 60 | 21 | 1.024 | -3.9 | -2.93E+05 | 3.09E+05 | 1.65E+06 | -1.59E+06 |
| 60 | 21 | 1.024 | -7.8 | -2.09E+05 | 2.19E+05 | 1.64E+06 | -1.19E+06 |
| 60 | 21 | 1.024 | -11.7 | -1.76E+05 | 1.84E+05 | 1.60E+06 | -1.17E+06 |
| 60 | 21 | 1.024 | -15.6 | -1.37E+05 | 1.29E+05 | 1.56E+06 | -1.61E+06 |
| 60 | 21 | 1.024 | -19.5 | -1.07E+05 | 1.08E+05 | 1.53E+06 | -1.79E+06 |
| 60 | 24 | 0.9583 | 0 | -2.99E+05 | 3.27E+05 | 2.04E+06 | -2.04E+06 |
| 60 | 24 | 0.9583 | -3.6 | -2.84E+05 | 3.06E+05 | 2.06E+06 | -1.99E+06 |
| 60 | 24 | 0.9583 | -7.2 | -2.43E+05 | 2.53E+05 | 2.06E+06 | -1.92E+06 |
| 60 | 24 | 0.9583 | -10.8 | -1.59E+05 | 1.88E+05 | 2.02E+06 | -1.85E+06 |
| 60 | 24 | 0.9583 | -14.4 | -1.28E+05 | 1.29E+05 | 1.96E+06 | -2.00E+06 |
| 60 | 24 | 0.9583 | -18 | -9.53E+04 | 9.63E+04 | 1.92E+06 | -2.24E+06 |
| 60 | 27 | 0.9035 | 0 | -2.84E+05 | 3.16E+05 | 2.42E+06 | -2.42E+06 |
| 60 | 27 | 0.9035 | -3.3 | -2.71E+05 | 2.97E+05 | 2.45E+06 | -2.36E+06 |
| 60 | 27 | 0.9035 | -6.6 | -2.34E+05 | 2.50E+05 | 2.44E+06 | -2.28E+06 |
| 60 | 27 | 0.9035 | -9.9 | -1.82E+05 | 1.10E+05 | 2.40E+06 | -2.20E+06 |
| 60 | 27 | 0.9035 | -13.2 | -1.26E+05 | 1.30E+05 | 2.34E+06 | -2.36E+06 |
| 60 | 27 | 0.9035 | -16.5 | -1.66E+04 | 8.86E+04 | 2.29E+06 | -2.65E+06 |
| 60 | 30 | 0.8571 | 0 | -8.61E+04 | 2.99E+05 | 2.75E+06 | -2.75E+06 |
| 60 | 30 | 0.8571 | -3 | -7.52E+04 | 2.83E+05 | 2.78E+06 | -2.68E+06 |
| 60 | 30 | 0.8571 | -6 | -4.98E+04 | 2.42E+05 | 2.77E+06 | -2.60E+06 |
| 60 | 30 | 0.8571 | -9 | -2.70E+04 | 1.87E+05 | 2.73E+06 | -2.50E+06 |
| 60 | 30 | 0.8571 | -12 | -1.96E+04 | 1.31E+05 | 2.66E+06 | -2.69E+06 |
| 60 | 30 | 0.8571 | -15 | -2.83E+04 | 8.55E+04 | 2.59E+06 | -3.00E+06 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 60 | 15 | 1.212 | 4.286 | 1.73E+05 | -1.69E+05 |
| 60 | 15 | 1.212 | 4.714 | 1.97E+05 | -1.90E+05 |
| 60 | 15 | 1.212 | 5.143 | 2.19E+05 | -2.09E+05 |
| 60 | 15 | 1.212 | 5.571 | 2.38E+05 | -2.24E+05 |
| 60 | 15 | 1.212 | 6 | 2.52E+05 | -2.37E+05 |
| 60 | 15 | 1.212 | 6.429 | 2.62E+05 | -2.45E+05 |
| 60 | 18 | 1.107 | 4.286 | 1.87E+05 | -1.81E+05 |
| 60 | 18 | 1.107 | 4.714 | 2.14E+05 | -2.04E+05 |
| 60 | 18 | 1.107 | 5.143 | 2.38E+05 | -2.24E+05 |
| 60 | 18 | 1.107 | 5.571 | 2.58E+05 | -2.39E+05 |
| 60 | 18 | 1.107 | 6 | 2.74E+05 | -2.48E+05 |
| 60 | 18 | 1.107 | 6.429 | 2.84E+05 | -2.49E+05 |
| 60 | 21 | 1.024 | 4.286 | 2.00E+05 | -1.92E+05 |
| 60 | 21 | 1.024 | 4.714 | 2.29E+05 | -2.16E+05 |
| 60 | 21 | 1.024 | 5.143 | 2.54E+05 | -2.36E+05 |
| 60 | 21 | 1.024 | 5.571 | 2.76E+05 | -2.47E+05 |
| 60 | 21 | 1.024 | 6 | 2.93E+05 | -2.49E+05 |
| 60 | 21 | 1.024 | 6.429 | 3.04E+05 | -2.48E+05 |
| 60 | 24 | 0.9583 | 4.286 | 2.12E+05 | -2.02E+05 |
| 60 | 24 | 0.9583 | 4.714 | 2.42E+05 | -2.27E+05 |
| 60 | 24 | 0.9583 | 5.143 | 2.69E+05 | -2.44E+05 |
| 60 | 24 | 0.9583 | 5.571 | 2.92E+05 | -2.49E+05 |
| 60 | 24 | 0.9583 | 6 | 3.10E+05 | -2.48E+05 |
| 60 | 24 | 0.9583 | 6.429 | 3.22E+05 | -2.47E+05 |
| 60 | 27 | 0.9035 | 4.286 | 2.22E+05 | -2.11E+05 |
| 60 | 27 | 0.9035 | 4.714 | 2.55E+05 | -2.35E+05 |
| 60 | 27 | 0.9035 | 5.143 | 2.83E+05 | -2.47E+05 |
| 60 | 27 | 0.9035 | 5.571 | 3.07E+05 | -2.48E+05 |
| 60 | 27 | 0.9035 | 6 | 3.26E+05 | -2.47E+05 |
| 60 | 27 | 0.9035 | 6.429 | 3.38E+05 | -2.46E+05 |
| 60 | 30 | 0.8571 | 4.286 | 2.33E+05 | -2.20E+05 |
| 60 | 30 | 0.8571 | 4.714 | 2.66E+05 | -2.41E+05 |
| 60 | 30 | 0.8571 | 5.143 | 2.96E+05 | -2.48E+05 |
| 60 | 30 | 0.8571 | 5.571 | 3.21E+05 | -2.47E+05 |
| 60 | 30 | 0.8571 | 6 | 3.41E+05 | -2.46E+05 |
| 60 | 30 | 0.8571 | 6.429 | 3.54E+05 | -2.45E+05 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 80 | 20 | 1.616 | 0 | -6.02E+05 | 6.17E+05 | 2.49E+06 | -2.49E+06 |
| 80 | 20 | 1.616 | -6 | -5.72E+05 | 5.83E+05 | 2.24E+06 | -2.41E+06 |
| 80 | 20 | 1.616 | -12 | -4.93E+05 | 4.97E+05 | 2.25E+06 | -2.22E+06 |
| 80 | 20 | 1.616 | -18 | -3.96E+05 | 3.97E+05 | 2.26E+06 | -1.82E+06 |
| 80 | 20 | 1.616 | -24 | -3.23E+05 | 3.23E+05 | 2.17E+06 | -2.29E+06 |
| 80 | 20 | 1.616 | -30 | -2.97E+05 | 2.97E+05 | 2.32E+06 | -2.47E+06 |
| 80 | 24 | 1.475 | 0 | -5.97E+05 | 6.17E+05 | 3.47E+06 | -3.47E+06 |
| 80 | 24 | 1.475 | -5.6 | -5.68E+05 | 5.85E+05 | 3.31E+06 | -3.36E+06 |
| 80 | 24 | 1.475 | -11.2 | -4.93E+05 | 5.01E+05 | 3.33E+06 | -3.08E+06 |
| 80 | 24 | 1.475 | -16.8 | -3.98E+05 | 4.00E+05 | 3.35E+06 | -2.87E+06 |
| 80 | 24 | 1.475 | -22.4 | -3.17E+05 | 3.18E+05 | 2.93E+06 | -3.38E+06 |
| 80 | 24 | 1.475 | -28 | -2.78E+05 | 2.78E+05 | 3.13E+06 | -3.70E+06 |
| 80 | 28 | 1.366 | 0 | -5.75E+05 | 5.98E+05 | 4.39E+06 | -4.39E+06 |
| 80 | 28 | 1.366 | -5.2 | -6.28E+05 | 5.69E+05 | 4.48E+06 | -4.25E+06 |
| 80 | 28 | 1.366 | -10.4 | -4.78E+05 | 4.90E+05 | 4.53E+06 | -3.89E+06 |
| 80 | 28 | 1.366 | -15.6 | -3.87E+05 | 3.92E+05 | 4.56E+06 | -3.57E+06 |
| 80 | 28 | 1.366 | -20.8 | -3.02E+05 | 3.04E+05 | 4.55E+06 | -4.54E+06 |
| 80 | 28 | 1.366 | -26 | -2.52E+05 | 2.17E+05 | 3.78E+06 | -5.04E+06 |
| 80 | 32 | 1.278 | 0 | -6.51E+05 | 6.88E+05 | 5.61E+06 | -5.61E+06 |
| 80 | 32 | 1.278 | -4.8 | -6.16E+05 | 6.45E+05 | 5.68E+06 | -4.96E+06 |
| 80 | 32 | 1.278 | -9.6 | -4.50E+05 | 4.66E+05 | 5.76E+06 | -4.52E+06 |
| 80 | 32 | 1.278 | -14.4 | -3.64E+05 | 3.94E+05 | 5.80E+06 | -5.03E+06 |
| 80 | 32 | 1.278 | -19.2 | -2.80E+05 | 2.67E+05 | 5.81E+06 | -5.71E+06 |
| 80 | 32 | 1.278 | -24 | -2.20E+05 | 1.95E+05 | 5.76E+06 | -6.39E+06 |
| 80 | 36 | 1.205 | 0 | -6.23E+05 | 6.65E+05 | 6.74E+06 | -6.74E+06 |
| 80 | 36 | 1.205 | -4.4 | -5.92E+05 | 6.27E+05 | 6.83E+06 | -5.38E+06 |
| 80 | 36 | 1.205 | -8.8 | -5.07E+05 | 5.28E+05 | 6.93E+06 | -6.49E+06 |
| 80 | 36 | 1.205 | -13.2 | -1.25E+05 | 3.97E+05 | 7.00E+06 | -6.46E+06 |
| 80 | 36 | 1.205 | -17.6 | -6.85E+04 | 2.70E+05 | 7.02E+06 | -6.80E+06 |
| 80 | 36 | 1.205 | -22 | -4.50E+04 | 1.80E+05 | 6.99E+06 | -7.63E+06 |
| 80 | 40 | 1.143 | 0 | -5.84E+05 | 6.31E+05 | 7.73E+06 | -7.73E+06 |
| 80 | 40 | 1.143 | -4 | -5.58E+05 | 5.99E+05 | 7.85E+06 | -7.57E+06 |
| 80 | 40 | 1.143 | -8 | -4.84E+05 | 4.90E+05 | 7.96E+06 | -7.44E+06 |
| 80 | 40 | 1.143 | -12 | -1.28E+05 | 3.95E+05 | 8.06E+06 | -7.38E+06 |
| 80 | 40 | 1.143 | -16 | -8.05E+04 | 2.74E+05 | 8.11E+06 | -7.75E+06 |
| 80 | 40 | 1.143 | -20 | -2.42E+04 | 1.74E+05 | 8.10E+06 | -8.65E+06 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 80 | 20 | 1.616 | 5.714 | 4.04E+05 | -3.98E+05 |
| 80 | 20 | 1.616 | 6.286 | 4.32E+05 | -4.21E+05 |
| 80 | 20 | 1.616 | 6.857 | 4.45E+05 | -4.32E+05 |
| 80 | 20 | 1.616 | 7.429 | 4.66E+05 | -4.29E+05 |
| 80 | 20 | 1.616 | 8 | 5.17E+05 | -4.13E+05 |
| 80 | 20 | 1.616 | 8.571 | 5.65E+05 | -3.83E+05 |
| 80 | 24 | 1.475 | 5.714 | 4.38E+05 | -4.26E+05 |
| 80 | 24 | 1.475 | 6.286 | 4.69E+05 | -4.52E+05 |
| 80 | 24 | 1.475 | 6.857 | 4.83E+05 | -4.63E+05 |
| 80 | 24 | 1.475 | 7.429 | 5.04E+05 | -4.60E+05 |
| 80 | 24 | 1.475 | 8 | 5.60E+05 | -4.43E+05 |
| 80 | 24 | 1.475 | 8.571 | 6.12E+05 | -4.12E+05 |
| 80 | 28 | 1.366 | 5.714 | 4.68E+05 | -4.51E+05 |
| 80 | 28 | 1.366 | 6.286 | 5.02E+05 | -4.79E+05 |
| 80 | 28 | 1.366 | 6.857 | 5.17E+05 | -4.92E+05 |
| 80 | 28 | 1.366 | 7.429 | 5.39E+05 | -4.88E+05 |
| 80 | 28 | 1.366 | 8 | 5.99E+05 | -4.69E+05 |
| 80 | 28 | 1.366 | 8.571 | 6.54E+05 | -4.36E+05 |
| 80 | 32 | 1.278 | 5.714 | 4.96E+05 | -4.75E+05 |
| 80 | 32 | 1.278 | 6.286 | 5.32E+05 | -5.04E+05 |
| 80 | 32 | 1.278 | 6.857 | 5.47E+05 | -5.18E+05 |
| 80 | 32 | 1.278 | 7.429 | 5.71E+05 | -5.14E+05 |
| 80 | 32 | 1.278 | 8 | 6.34E+05 | -4.94E+05 |
| 80 | 32 | 1.278 | 8.571 | 6.93E+05 | -4.58E+05 |
| 80 | 36 | 1.205 | 5.714 | 5.22E+05 | -4.96E+05 |
| 80 | 36 | 1.205 | 6.286 | 5.59E+05 | -5.28E+05 |
| 80 | 36 | 1.205 | 6.857 | 5.76E+05 | -5.42E+05 |
| 80 | 36 | 1.205 | 7.429 | 6.00E+05 | -5.38E+05 |
| 80 | 36 | 1.205 | 8 | 6.66E+05 | -5.16E+05 |
| 80 | 36 | 1.205 | 8.571 | 7.28E+05 | -4.79E+05 |
| 80 | 40 | 1.143 | 5.714 | 5.46E+05 | -5.17E+05 |
| 80 | 40 | 1.143 | 6.286 | 5.85E+05 | -5.49E+05 |
| 80 | 40 | 1.143 | 6.857 | 6.02E+05 | -5.65E+05 |
| 80 | 40 | 1.143 | 7.429 | 6.27E+05 | -5.61E+05 |
| 80 | 40 | 1.143 | 8 | 6.96E+05 | -5.38E+05 |
| 80 | 40 | 1.143 | 8.571 | 7.61E+05 | -4.98E+05 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 100 | 25 | 2.02 | 0 | -1.14E+06 | 1.17E+06 | 5.59E+06 | -5.59E+06 |
| 100 | 25 | 2.02 | -7.5 | -1.07E+06 | 1.09E+06 | 5.43E+06 | -4.73E+06 |
| 100 | 25 | 2.02 | -15 | -8.95E+05 | 8.99E+05 | 4.82E+06 | -4.85E+06 |
| 100 | 25 | 2.02 | -22.5 | -6.95E+05 | 6.95E+05 | 4.70E+06 | -4.87E+06 |
| 100 | 25 | 2.02 | -30 | -5.74E+05 | 5.74E+05 | 4.63E+06 | -5.05E+06 |
| 100 | 25 | 2.02 | -37.5 | -5.80E+05 | 5.80E+05 | 4.70E+06 | -5.52E+06 |
| 100 | 30 | 1.844 | 0 | -1.15E+06 | 1.18E+06 | 8.03E+06 | -8.03E+06 |
| 100 | 30 | 1.844 | -7 | -1.09E+06 | 1.11E+06 | 7.83E+06 | -7.80E+06 |
| 100 | 30 | 1.844 | -14 | -9.14E+05 | 9.22E+05 | 7.15E+06 | -6.16E+06 |
| 100 | 30 | 1.844 | -21 | -7.10E+05 | 7.12E+05 | 7.47E+06 | -6.23E+06 |
| 100 | 30 | 1.844 | -28 | -5.65E+05 | 5.66E+05 | 6.55E+06 | -7.44E+06 |
| 100 | 30 | 1.844 | -35 | -5.34E+05 | 5.34E+05 | 6.76E+06 | -8.24E+06 |
| 100 | 35 | 1.707 | 0 | -1.12E+06 | 1.16E+06 | 1.05E+07 | -1.05E+07 |
| 100 | 35 | 1.707 | -6.5 | -1.07E+06 | 1.09E+06 | 1.03E+07 | -1.02E+07 |
| 100 | 35 | 1.707 | -13 | -9.06E+05 | 9.20E+05 | 9.77E+06 | -9.51E+06 |
| 100 | 35 | 1.707 | -19.5 | -7.07E+05 | 7.11E+05 | 1.02E+07 | -6.99E+06 |
| 100 | 35 | 1.707 | -26 | -5.45E+05 | 5.46E+05 | 8.47E+06 | -1.01E+07 |
| 100 | 35 | 1.707 | -32.5 | -4.79E+05 | 4.79E+05 | 8.58E+06 | -1.13E+07 |
| 100 | 40 | 1.597 | 0 | -1.19E+06 | 1.11E+06 | 1.29E+07 | -1.29E+07 |
| 100 | 40 | 1.597 | -6 | -1.02E+06 | 1.05E+06 | 1.26E+07 | -1.25E+07 |
| 100 | 40 | 1.597 | -12 | -8.75E+05 | 8.95E+05 | 1.25E+07 | -1.17E+07 |
| 100 | 40 | 1.597 | -18 | -6.85E+05 | 6.94E+05 | 1.31E+07 | -1.25E+07 |
| 100 | 40 | 1.597 | -24 | -5.15E+05 | 5.18E+05 | 1.35E+07 | -1.27E+07 |
| 100 | 40 | 1.597 | -30 | -4.18E+05 | 3.21E+05 | 1.01E+07 | -1.43E+07 |
| 100 | 45 | 1.506 | 0 | -1.15E+06 | 1.05E+06 | 1.49E+07 | -1.49E+07 |
| 100 | 45 | 1.506 | -5.5 | -1.09E+06 | 1.13E+06 | 1.46E+07 | -1.45E+07 |
| 100 | 45 | 1.506 | -11 | -8.20E+05 | 9.51E+05 | 1.52E+07 | -1.35E+07 |
| 100 | 45 | 1.506 | -16.5 | -6.49E+05 | 7.22E+05 | 1.59E+07 | -1.50E+07 |
| 100 | 45 | 1.506 | -22 | -4.77E+05 | 4.75E+05 | 1.65E+07 | -1.52E+07 |
| 100 | 45 | 1.506 | -27.5 | -3.76E+04 | 3.03E+05 | 1.68E+07 | -1.72E+07 |
| 100 | 50 | 1.429 | 0 | -1.08E+06 | 9.57E+05 | 1.63E+07 | -1.63E+07 |
| 100 | 50 | 1.429 | -5 | -1.03E+06 | 1.08E+06 | 1.70E+07 | -1.59E+07 |
| 100 | 50 | 1.429 | -10 | -2.19E+05 | 9.27E+05 | 1.76E+07 | -1.47E+07 |
| 100 | 50 | 1.429 | -15 | -1.30E+05 | 6.79E+05 | 1.84E+07 | -1.72E+07 |
| 100 | 50 | 1.429 | -20 | -7.48E+04 | 4.88E+05 | 1.91E+07 | -1.73E+07 |
| 100 | 50 | 1.429 | -25 | -7.57E+04 | 3.02E+05 | 1.97E+07 | -1.96E+07 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 100 | 25 | 2.02 | 7.143 | 6.58E+05 | -6.41E+05 |
| 100 | 25 | 2.02 | 7.857 | 7.60E+05 | -7.59E+05 |
| 100 | 25 | 2.02 | 8.571 | 8.54E+05 | -8.51E+05 |
| 100 | 25 | 2.02 | 9.286 | 9.38E+05 | -9.31E+05 |
| 100 | 25 | 2.02 | 10 | 1.01E+06 | -9.99E+05 |
| 100 | 25 | 2.02 | 10.71 | 1.06E+06 | -1.05E+06 |
| 100 | 30 | 1.844 | 7.143 | 7.13E+05 | -6.96E+05 |
| 100 | 30 | 1.844 | 7.857 | 8.23E+05 | -6.67E+05 |
| 100 | 30 | 1.844 | 8.571 | 9.25E+05 | -9.20E+05 |
| 100 | 30 | 1.844 | 9.286 | 1.02E+06 | -1.01E+06 |
| 100 | 30 | 1.844 | 10 | 1.09E+06 | -1.08E+06 |
| 100 | 30 | 1.844 | 10.71 | 1.15E+06 | -1.13E+06 |
| 100 | 35 | 1.707 | 7.143 | 7.62E+05 | -7.44E+05 |
| 100 | 35 | 1.707 | 7.857 | 8.80E+05 | -7.14E+05 |
| 100 | 35 | 1.707 | 8.571 | 9.89E+05 | -9.81E+05 |
| 100 | 35 | 1.707 | 9.286 | 1.09E+06 | -1.07E+06 |
| 100 | 35 | 1.707 | 10 | 1.17E+06 | -1.14E+06 |
| 100 | 35 | 1.707 | 10.71 | 1.23E+06 | -1.19E+06 |
| 100 | 40 | 1.597 | 7.143 | 8.07E+05 | -7.81E+05 |
| 100 | 40 | 1.597 | 7.857 | 9.32E+05 | -7.53E+05 |
| 100 | 40 | 1.597 | 8.571 | 1.05E+06 | -6.79E+05 |
| 100 | 40 | 1.597 | 9.286 | 1.15E+06 | -1.12E+06 |
| 100 | 40 | 1.597 | 10 | 1.24E+06 | -1.19E+06 |
| 100 | 40 | 1.597 | 10.71 | 1.30E+06 | -1.24E+06 |
| 100 | 45 | 1.506 | 7.143 | 8.48E+05 | -8.14E+05 |
| 100 | 45 | 1.506 | 7.857 | 9.80E+05 | -7.86E+05 |
| 100 | 45 | 1.506 | 8.571 | 1.10E+06 | -7.12E+05 |
| 100 | 45 | 1.506 | 9.286 | 1.21E+06 | -1.17E+06 |
| 100 | 45 | 1.506 | 10 | 1.30E+06 | -1.24E+06 |
| 100 | 45 | 1.506 | 10.71 | 1.37E+06 | -1.29E+06 |
| 100 | 50 | 1.429 | 7.143 | 8.87E+05 | -8.46E+05 |
| 100 | 50 | 1.429 | 7.857 | 1.02E+06 | -8.17E+05 |
| 100 | 50 | 1.429 | 8.571 | 1.15E+06 | -7.42E+05 |
| 100 | 50 | 1.429 | 9.286 | 1.26E+06 | -1.21E+06 |
| 100 | 50 | 1.429 | 10 | 1.36E+06 | -1.28E+06 |
| 100 | 50 | 1.429 | 10.71 | 1.43E+06 | -1.34E+06 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 120 | 30 | 2.424 | 0 | -1.56E+06 | 1.94E+06 | 1.03E+07 | -1.03E+07 |
| 120 | 30 | 2.424 | -9 | -1.50E+06 | 1.51E+06 | 1.01E+07 | -9.99E+06 |
| 120 | 30 | 2.424 | -18 | -1.45E+06 | 1.35E+06 | 9.79E+06 | -9.30E+06 |
| 120 | 30 | 2.424 | -27 | -1.11E+06 | 1.11E+06 | 9.43E+06 | -8.17E+06 |
| 120 | 30 | 2.424 | -36 | -8.82E+05 | 8.83E+05 | 9.24E+06 | -9.55E+06 |
| 120 | 30 | 2.424 | -45 | -9.39E+05 | 9.38E+05 | 9.84E+06 | -1.06E+07 |
| 120 | 36 | 2.213 | 0 | -1.95E+06 | 1.98E+06 | 1.50E+07 | -1.50E+07 |
| 120 | 36 | 2.213 | -8.4 | -1.83E+06 | 1.85E+06 | 1.49E+07 | -1.38E+07 |
| 120 | 36 | 2.213 | -16.8 | -1.51E+06 | 1.33E+06 | 1.44E+07 | -1.28E+07 |
| 120 | 36 | 2.213 | -25.2 | -1.13E+06 | 1.10E+06 | 1.39E+07 | -1.21E+07 |
| 120 | 36 | 2.213 | -33.6 | -8.75E+05 | 8.75E+05 | 1.35E+07 | -1.41E+07 |
| 120 | 36 | 2.213 | -42 | -8.53E+05 | 8.53E+05 | 1.34E+07 | -1.58E+07 |
| 120 | 42 | 2.049 | 0 | -1.92E+06 | 1.97E+06 | 2.01E+07 | -2.01E+07 |
| 120 | 42 | 2.049 | -7.8 | -1.81E+06 | 1.85E+06 | 2.00E+07 | -1.72E+07 |
| 120 | 42 | 2.049 | -15.6 | -1.52E+06 | 1.53E+06 | 1.94E+07 | -1.58E+07 |
| 120 | 42 | 2.049 | -23.4 | -1.15E+06 | 1.15E+06 | 1.87E+07 | -1.48E+07 |
| 120 | 42 | 2.049 | -31.2 | -8.56E+05 | 8.57E+05 | 1.81E+07 | -1.91E+07 |
| 120 | 42 | 2.049 | -39 | -7.59E+05 | 7.59E+05 | 1.79E+07 | -2.16E+07 |
| 120 | 48 | 1.917 | 0 | -1.86E+06 | 1.92E+06 | 2.53E+07 | -2.53E+07 |
| 120 | 48 | 1.917 | -7.2 | -1.76E+06 | 1.81E+06 | 2.51E+07 | -2.48E+07 |
| 120 | 48 | 1.917 | -14.4 | -1.49E+06 | 1.52E+06 | 2.45E+07 | -2.40E+07 |
| 120 | 48 | 1.917 | -21.6 | -1.14E+06 | 1.15E+06 | 2.36E+07 | -2.30E+07 |
| 120 | 48 | 1.917 | -28.8 | -8.28E+05 | 8.30E+05 | 2.28E+07 | -2.60E+07 |
| 120 | 48 | 1.917 | -36 | -6.66E+05 | 6.67E+05 | 2.23E+07 | -2.75E+07 |
| 120 | 54 | 1.807 | 0 | -1.88E+06 | 1.83E+06 | 3.00E+07 | -3.00E+07 |
| 120 | 54 | 1.807 | -6.6 | -1.78E+06 | 1.73E+06 | 2.99E+07 | -2.95E+07 |
| 120 | 54 | 1.807 | -13.2 | -1.43E+06 | 1.47E+06 | 2.92E+07 | -2.85E+07 |
| 120 | 54 | 1.807 | -19.8 | -1.11E+06 | 1.12E+06 | 2.82E+07 | -2.73E+07 |
| 120 | 54 | 1.807 | -26.4 | -7.91E+05 | 7.97E+05 | 2.71E+07 | -3.12E+07 |
| 120 | 54 | 1.807 | -33 | -9.56E+04 | 5.82E+05 | 2.64E+07 | -3.30E+07 |
| 120 | 60 | 1.714 | 0 | -1.78E+06 | 1.70E+06 | 3.39E+07 | -3.39E+07 |
| 120 | 60 | 1.714 | -6 | -1.70E+06 | 1.62E+06 | 3.38E+07 | -3.33E+07 |
| 120 | 60 | 1.714 | -12 | -1.34E+06 | 1.51E+06 | 3.31E+07 | -3.22E+07 |
| 120 | 60 | 1.714 | -18 | -3.60E+05 | 1.16E+06 | 3.53E+07 | -3.09E+07 |
| 120 | 60 | 1.714 | -24 | -2.12E+05 | 7.87E+05 | 3.79E+07 | -3.58E+07 |
| 120 | 60 | 1.714 | -30 | -7.88E+04 | 4.68E+05 | 4.00E+07 | -3.78E+07 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 120 | 30 | 2.424 | 8.571 | 1.18E+06 | -1.18E+06 |
| 120 | 30 | 2.424 | 9.429 | 1.32E+06 | -1.32E+06 |
| 120 | 30 | 2.424 | 10.29 | 1.44E+06 | -1.43E+06 |
| 120 | 30 | 2.424 | 11.14 | 1.52E+06 | -1.51E+06 |
| 120 | 30 | 2.424 | 12 | 1.56E+06 | -1.55E+06 |
| 120 | 30 | 2.424 | 12.86 | 1.56E+06 | -1.55E+06 |
| 120 | 36 | 2.213 | 8.571 | 1.28E+06 | -1.28E+06 |
| 120 | 36 | 2.213 | 9.429 | 1.43E+06 | -1.43E+06 |
| 120 | 36 | 2.213 | 10.29 | 1.56E+06 | -1.55E+06 |
| 120 | 36 | 2.213 | 11.14 | 1.64E+06 | -1.63E+06 |
| 120 | 36 | 2.213 | 12 | 1.69E+06 | -1.68E+06 |
| 120 | 36 | 2.213 | 12.86 | 1.69E+06 | -1.68E+06 |
| 120 | 42 | 2.049 | 8.571 | 1.37E+06 | -1.37E+06 |
| 120 | 42 | 2.049 | 9.429 | 1.53E+06 | -1.53E+06 |
| 120 | 42 | 2.049 | 10.29 | 1.67E+06 | -1.65E+06 |
| 120 | 42 | 2.049 | 11.14 | 1.76E+06 | -1.74E+06 |
| 120 | 42 | 2.049 | 12 | 1.81E+06 | -1.79E+06 |
| 120 | 42 | 2.049 | 12.86 | 1.81E+06 | -1.79E+06 |
| 120 | 48 | 1.917 | 8.571 | 1.45E+06 | -1.45E+06 |
| 120 | 48 | 1.917 | 9.429 | 1.62E+06 | -1.61E+06 |
| 120 | 48 | 1.917 | 10.29 | 1.76E+06 | -1.75E+06 |
| 120 | 48 | 1.917 | 11.14 | 1.86E+06 | -1.84E+06 |
| 120 | 48 | 1.917 | 12 | 1.91E+06 | -1.89E+06 |
| 120 | 48 | 1.917 | 12.86 | 1.91E+06 | -1.90E+06 |
| 120 | 54 | 1.807 | 8.571 | 1.53E+06 | -1.52E+06 |
| 120 | 54 | 1.807 | 9.429 | 1.71E+06 | -1.69E+06 |
| 120 | 54 | 1.807 | 10.29 | 1.85E+06 | -1.83E+06 |
| 120 | 54 | 1.807 | 11.14 | 1.96E+06 | -1.92E+06 |
| 120 | 54 | 1.807 | 12 | 2.01E+06 | -1.97E+06 |
| 120 | 54 | 1.807 | 12.86 | 2.01E+06 | -1.97E+06 |
| 120 | 60 | 1.714 | 8.571 | 1.59E+06 | -1.58E+06 |
| 120 | 60 | 1.714 | 9.429 | 1.79E+06 | -1.77E+06 |
| 120 | 60 | 1.714 | 10.29 | 1.94E+06 | -1.91E+06 |
| 120 | 60 | 1.714 | 11.14 | 2.05E+06 | -1.99E+06 |
| 120 | 60 | 1.714 | 12 | 2.10E+06 | -2.03E+06 |
| 120 | 60 | 1.714 | 12.86 | 2.10E+06 | -2.03E+06 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 140 | 35 | 2.828 | 0 | -2.66E+06 | 2.68E+06 | 1.87E+07 | -1.87E+07 |
| 140 | 35 | 2.828 | -10.5 | -2.51E+06 | 2.52E+06 | 1.66E+07 | -1.59E+07 |
| 140 | 35 | 2.828 | -21 | -2.13E+06 | 2.14E+06 | 1.68E+07 | -1.60E+07 |
| 140 | 35 | 2.828 | -31.5 | -1.70E+06 | 1.70E+06 | 1.70E+07 | -1.60E+07 |
| 140 | 35 | 2.828 | -42 | -1.39E+06 | 1.39E+06 | 1.54E+07 | -1.79E+07 |
| 140 | 35 | 2.828 | -52.5 | -1.30E+06 | 1.32E+06 | 1.63E+07 | -1.89E+07 |
| 140 | 42 | 2.582 | 0 | -2.65E+06 | 2.68E+06 | 2.68E+07 | -2.68E+07 |
| 140 | 42 | 2.582 | -9.8 | -2.52E+06 | 2.54E+06 | 2.46E+07 | -2.60E+07 |
| 140 | 42 | 2.582 | -19.6 | -2.15E+06 | 2.16E+06 | 2.49E+07 | -2.06E+07 |
| 140 | 42 | 2.582 | -29.4 | -1.71E+06 | 1.72E+06 | 2.52E+07 | -2.07E+07 |
| 140 | 42 | 2.582 | -39.2 | -1.37E+06 | 1.37E+06 | 2.16E+07 | -2.66E+07 |
| 140 | 42 | 2.582 | -49 | -1.22E+06 | 1.18E+06 | 2.26E+07 | -2.72E+07 |
| 140 | 49 | 2.39 | 0 | -3.00E+06 | 2.61E+06 | 3.51E+07 | -3.51E+07 |
| 140 | 49 | 2.39 | -9.1 | -2.82E+06 | 2.48E+06 | 3.35E+07 | -3.41E+07 |
| 140 | 49 | 2.39 | -18.2 | -2.11E+06 | 2.12E+06 | 3.39E+07 | -3.14E+07 |
| 140 | 49 | 2.39 | -27.3 | -1.68E+06 | 1.69E+06 | 3.44E+07 | -2.35E+07 |
| 140 | 49 | 2.39 | -36.4 | -1.31E+06 | 1.31E+06 | 3.46E+07 | -3.61E+07 |
| 140 | 49 | 2.39 | -45.5 | -1.10E+06 | 1.05E+06 | 2.83E+07 | -3.71E+07 |
| 140 | 56 | 2.236 | 0 | -2.93E+06 | 3.00E+06 | 4.28E+07 | -4.28E+07 |
| 140 | 56 | 2.236 | -8.4 | -2.76E+06 | 2.35E+06 | 4.27E+07 | -4.15E+07 |
| 140 | 56 | 2.236 | -16.8 | -2.32E+06 | 2.03E+06 | 4.33E+07 | -3.83E+07 |
| 140 | 56 | 2.236 | -25.2 | -1.74E+06 | 1.61E+06 | 4.39E+07 | -4.27E+07 |
| 140 | 56 | 2.236 | -33.6 | -1.21E+06 | 1.21E+06 | 4.43E+07 | -4.59E+07 |
| 140 | 56 | 2.236 | -42 | -9.65E+05 | 9.32E+05 | 4.43E+07 | -4.73E+07 |
| 140 | 63 | 2.108 | 0 | -2.85E+06 | 2.88E+06 | 4.89E+07 | -4.89E+07 |
| 140 | 63 | 2.108 | -7.7 | -2.65E+06 | 2.73E+06 | 5.16E+07 | -4.75E+07 |
| 140 | 63 | 2.108 | -15.4 | -2.26E+06 | 2.30E+06 | 5.23E+07 | -4.38E+07 |
| 140 | 63 | 2.108 | -23.1 | -1.73E+06 | 1.72E+06 | 5.31E+07 | -5.13E+07 |
| 140 | 63 | 2.108 | -30.8 | -1.20E+06 | 1.20E+06 | 5.37E+07 | -5.51E+07 |
| 140 | 63 | 2.108 | -38.5 | -8.32E+05 | 8.35E+05 | 5.39E+07 | -6.06E+07 |
| 140 | 70 | 2 | 0 | -2.71E+06 | 2.72E+06 | 5.88E+07 | -5.88E+07 |
| 140 | 70 | 2 | -7 | -2.59E+06 | 2.58E+06 | 5.94E+07 | -5.14E+07 |
| 140 | 70 | 2 | -14 | -2.16E+06 | 2.22E+06 | 6.03E+07 | -5.85E+07 |
| 140 | 70 | 2 | -21 | -1.68E+06 | 1.71E+06 | 6.13E+07 | -5.90E+07 |
| 140 | 70 | 2 | -28 | -1.28E+05 | 1.19E+06 | 6.21E+07 | -6.33E+07 |
| 140 | 70 | 2 | -35 | -1.73E+05 | 7.69E+05 | 6.26E+07 | -6.97E+07 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 140 | 35 | 2.828 | 10 | 1.83E+06 | -1.83E+06 |
| 140 | 35 | 2.828 | 11 | 1.97E+06 | -1.97E+06 |
| 140 | 35 | 2.828 | 12 | 2.04E+06 | -2.04E+06 |
| 140 | 35 | 2.828 | 13 | 2.11E+06 | -2.04E+06 |
| 140 | 35 | 2.828 | 14 | 2.31E+06 | -1.97E+06 |
| 140 | 35 | 2.828 | 15 | 2.49E+06 | -1.83E+06 |
| 140 | 42 | 2.582 | 10 | 1.99E+06 | -1.98E+06 |
| 140 | 42 | 2.582 | 11 | 2.14E+06 | -2.13E+06 |
| 140 | 42 | 2.582 | 12 | 2.21E+06 | -2.21E+06 |
| 140 | 42 | 2.582 | 13 | 2.29E+06 | -2.21E+06 |
| 140 | 42 | 2.582 | 14 | 2.50E+06 | -2.13E+06 |
| 140 | 42 | 2.582 | 15 | 2.69E+06 | -1.98E+06 |
| 140 | 49 | 2.39 | 10 | 2.12E+06 | -2.12E+06 |
| 140 | 49 | 2.39 | 11 | 2.29E+06 | -2.28E+06 |
| 140 | 49 | 2.39 | 12 | 2.37E+06 | -2.36E+06 |
| 140 | 49 | 2.39 | 13 | 2.45E+06 | -2.36E+06 |
| 140 | 49 | 2.39 | 14 | 2.68E+06 | -2.28E+06 |
| 140 | 49 | 2.39 | 15 | 2.88E+06 | -2.12E+06 |
| 140 | 56 | 2.236 | 10 | 2.25E+06 | -2.24E+06 |
| 140 | 56 | 2.236 | 11 | 2.42E+06 | -2.41E+06 |
| 140 | 56 | 2.236 | 12 | 2.51E+06 | -2.50E+06 |
| 140 | 56 | 2.236 | 13 | 2.59E+06 | -2.49E+06 |
| 140 | 56 | 2.236 | 14 | 2.84E+06 | -2.41E+06 |
| 140 | 56 | 2.236 | 15 | 3.05E+06 | -2.24E+06 |
| 140 | 63 | 2.108 | 10 | 2.37E+06 | -2.36E+06 |
| 140 | 63 | 2.108 | 11 | 2.55E+06 | -2.53E+06 |
| 140 | 63 | 2.108 | 12 | 2.64E+06 | -2.62E+06 |
| 140 | 63 | 2.108 | 13 | 2.72E+06 | -2.62E+06 |
| 140 | 63 | 2.108 | 14 | 2.98E+06 | -2.53E+06 |
| 140 | 63 | 2.108 | 15 | 3.21E+06 | -2.35E+06 |
| 140 | 70 | 2 | 10 | 2.48E+06 | -2.46E+06 |
| 140 | 70 | 2 | 11 | 2.67E+06 | -2.64E+06 |
| 140 | 70 | 2 | 12 | 2.76E+06 | -2.74E+06 |
| 140 | 70 | 2 | 13 | 2.85E+06 | -2.74E+06 |
| 140 | 70 | 2 | 14 | 3.12E+06 | -2.64E+06 |
| 140 | 70 | 2 | 15 | 3.35E+06 | -2.46E+06 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 160 | 40 | 3.232 | 0 | -4.08E+06 | 4.10E+06 | 2.93E+07 | -2.93E+07 |
| 160 | 40 | 3.232 | -12 | -3.81E+06 | 3.82E+06 | 2.89E+07 | -2.82E+07 |
| 160 | 40 | 3.232 | -24 | -3.12E+06 | 2.83E+06 | 2.77E+07 | -2.49E+07 |
| 160 | 40 | 3.232 | -36 | -2.39E+06 | 2.34E+06 | 2.65E+07 | -2.46E+07 |
| 160 | 40 | 3.232 | -48 | -1.97E+06 | 1.97E+06 | 2.57E+07 | -2.88E+07 |
| 160 | 40 | 3.232 | -60 | -2.03E+06 | 2.03E+06 | 2.75E+07 | -3.12E+07 |
| 160 | 48 | 2.951 | 0 | -4.13E+06 | 4.17E+06 | 4.30E+07 | -4.30E+07 |
| 160 | 48 | 2.951 | -11.2 | -3.87E+06 | 3.90E+06 | 4.24E+07 | -3.92E+07 |
| 160 | 48 | 2.951 | -22.4 | -3.22E+06 | 3.23E+06 | 4.08E+07 | -3.62E+07 |
| 160 | 48 | 2.951 | -33.6 | -2.46E+06 | 2.46E+06 | 3.89E+07 | -3.01E+07 |
| 160 | 48 | 2.951 | -44.8 | -1.94E+06 | 1.94E+06 | 3.77E+07 | -4.26E+07 |
| 160 | 48 | 2.951 | -56 | -1.86E+06 | 1.86E+06 | 3.76E+07 | -4.67E+07 |
| 160 | 56 | 2.732 | 0 | -4.06E+06 | 4.12E+06 | 5.76E+07 | -5.76E+07 |
| 160 | 56 | 2.732 | -10.4 | -3.83E+06 | 3.87E+06 | 5.70E+07 | -4.94E+07 |
| 160 | 56 | 2.732 | -20.8 | -3.22E+06 | 3.24E+06 | 5.49E+07 | -4.53E+07 |
| 160 | 56 | 2.732 | -31.2 | -2.47E+06 | 2.47E+06 | 5.65E+07 | -5.18E+07 |
| 160 | 56 | 2.732 | -41.6 | -1.88E+06 | 1.88E+06 | 5.05E+07 | -5.79E+07 |
| 160 | 56 | 2.732 | -52 | -1.67E+06 | 1.67E+06 | 4.99E+07 | -6.42E+07 |
| 160 | 64 | 2.556 | 0 | -4.27E+06 | 3.98E+06 | 7.22E+07 | -7.22E+07 |
| 160 | 64 | 2.556 | -9.6 | -4.03E+06 | 3.76E+06 | 7.15E+07 | -7.10E+07 |
| 160 | 64 | 2.556 | -19.2 | -3.14E+06 | 3.17E+06 | 6.91E+07 | -6.83E+07 |
| 160 | 64 | 2.556 | -28.8 | -2.43E+06 | 2.44E+06 | 7.25E+07 | -6.50E+07 |
| 160 | 64 | 2.556 | -38.4 | -1.80E+06 | 1.80E+06 | 7.62E+07 | -7.36E+07 |
| 160 | 64 | 2.556 | -48 | -1.46E+06 | 1.46E+06 | 6.18E+07 | -8.22E+07 |
| 160 | 72 | 2.409 | 0 | -4.11E+06 | 3.76E+06 | 8.55E+07 | -8.55E+07 |
| 160 | 72 | 2.409 | -8.8 | -3.90E+06 | 3.56E+06 | 8.47E+07 | -8.41E+07 |
| 160 | 72 | 2.409 | -17.6 | -3.32E+06 | 3.04E+06 | 8.21E+07 | -8.09E+07 |
| 160 | 72 | 2.409 | -26.4 | -2.33E+06 | 2.35E+06 | 8.82E+07 | -8.53E+07 |
| 160 | 72 | 2.409 | -35.2 | -1.69E+06 | 1.70E+06 | 9.29E+07 | -8.85E+07 |
| 160 | 72 | 2.409 | -44 | -1.26E+06 | 1.10E+06 | 9.63E+07 | -9.93E+07 |
| 160 | 80 | 2.286 | 0 | -3.87E+06 | 3.47E+06 | 9.63E+07 | -9.63E+07 |
| 160 | 80 | 2.286 | -8 | -3.69E+06 | 3.81E+06 | 9.55E+07 | -9.47E+07 |
| 160 | 80 | 2.286 | -16 | -3.20E+06 | 3.27E+06 | 9.27E+07 | -9.12E+07 |
| 160 | 80 | 2.286 | -24 | -2.48E+06 | 2.51E+06 | 1.02E+08 | -9.84E+07 |
| 160 | 80 | 2.286 | -32 | -3.66E+05 | 1.72E+06 | 1.08E+08 | -1.02E+08 |
| 160 | 80 | 2.286 | -40 | -1.16E+05 | 1.06E+06 | 1.13E+08 | -1.14E+08 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 160 | 40 | 3.232 | 11.43 | 2.51E+06 | -2.51E+06 |
| 160 | 40 | 3.232 | 12.57 | 2.58E+06 | -2.56E+06 |
| 160 | 40 | 3.232 | 13.71 | 2.88E+06 | -2.49E+06 |
| 160 | 40 | 3.232 | 14.86 | 3.15E+06 | -3.15E+06 |
| 160 | 40 | 3.232 | 16 | 3.37E+06 | -3.37E+06 |
| 160 | 40 | 3.232 | 17.14 | 3.54E+06 | -3.53E+06 |
| 160 | 48 | 2.951 | 11.43 | 2.73E+06 | -2.72E+06 |
| 160 | 48 | 2.951 | 12.57 | 2.79E+06 | -2.78E+06 |
| 160 | 48 | 2.951 | 13.71 | 3.12E+06 | -2.70E+06 |
| 160 | 48 | 2.951 | 14.86 | 3.42E+06 | -2.50E+06 |
| 160 | 48 | 2.951 | 16 | 3.66E+06 | -3.64E+06 |
| 160 | 48 | 2.951 | 17.14 | 3.83E+06 | -3.82E+06 |
| 160 | 56 | 2.732 | 11.43 | 2.92E+06 | -2.92E+06 |
| 160 | 56 | 2.732 | 12.57 | 2.98E+06 | -2.98E+06 |
| 160 | 56 | 2.732 | 13.71 | 3.34E+06 | -2.90E+06 |
| 160 | 56 | 2.732 | 14.86 | 3.65E+06 | -2.68E+06 |
| 160 | 56 | 2.732 | 16 | 3.91E+06 | -3.89E+06 |
| 160 | 56 | 2.732 | 17.14 | 4.10E+06 | -4.08E+06 |
| 160 | 64 | 2.556 | 11.43 | 3.09E+06 | -3.09E+06 |
| 160 | 64 | 2.556 | 12.57 | 3.16E+06 | -3.16E+06 |
| 160 | 64 | 2.556 | 13.71 | 3.54E+06 | -3.07E+06 |
| 160 | 64 | 2.556 | 14.86 | 3.87E+06 | -2.84E+06 |
| 160 | 64 | 2.556 | 16 | 4.14E+06 | -4.11E+06 |
| 160 | 64 | 2.556 | 17.14 | 4.34E+06 | -4.30E+06 |
| 160 | 72 | 2.409 | 11.43 | 3.26E+06 | -3.25E+06 |
| 160 | 72 | 2.409 | 12.57 | 3.32E+06 | -3.32E+06 |
| 160 | 72 | 2.409 | 13.71 | 3.72E+06 | -3.23E+06 |
| 160 | 72 | 2.409 | 14.86 | 4.07E+06 | -2.98E+06 |
| 160 | 72 | 2.409 | 16 | 4.35E+06 | -2.61E+06 |
| 160 | 72 | 2.409 | 17.14 | 4.56E+06 | -4.50E+06 |
| 160 | 80 | 2.286 | 11.43 | 3.41E+06 | -3.39E+06 |
| 160 | 80 | 2.286 | 12.57 | 3.47E+06 | -3.46E+06 |
| 160 | 80 | 2.286 | 13.71 | 3.89E+06 | -3.37E+06 |
| 160 | 80 | 2.286 | 14.86 | 4.25E+06 | -3.12E+06 |
| 160 | 80 | 2.286 | 16 | 4.55E+06 | -2.73E+06 |
| 160 | 80 | 2.286 | 17.14 | 4.77E+06 | -4.69E+06 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 180 | 45 | 3.637 | 0 | -5.14E+06 | 5.82E+06 | 4.65E+07 | -4.65E+07 |
| 180 | 45 | 3.637 | -13.5 | -4.86E+06 | 4.87E+06 | 4.21E+07 | -4.04E+07 |
| 180 | 45 | 3.637 | -27 | -4.15E+06 | 4.15E+06 | 4.24E+07 | -3.93E+07 |
| 180 | 45 | 3.637 | -40.5 | -3.31E+06 | 3.31E+06 | 4.26E+07 | -3.91E+07 |
| 180 | 45 | 3.637 | -54 | -2.70E+06 | 2.70E+06 | 3.83E+07 | -4.29E+07 |
| 180 | 45 | 3.637 | -67.5 | -2.48E+06 | 2.71E+06 | 4.03E+07 | -4.74E+07 |
| 180 | 54 | 3.32 | 0 | -5.12E+06 | 5.96E+06 | 6.69E+07 | -6.69E+07 |
| 180 | 54 | 3.32 | -12.6 | -5.51E+06 | 4.88E+06 | 6.24E+07 | -6.49E+07 |
| 180 | 54 | 3.32 | -25.2 | -4.18E+06 | 4.19E+06 | 6.28E+07 | -5.19E+07 |
| 180 | 54 | 3.32 | -37.8 | -3.34E+06 | 3.34E+06 | 6.31E+07 | -5.13E+07 |
| 180 | 54 | 3.32 | -50.4 | -2.66E+06 | 2.66E+06 | 6.31E+07 | -6.33E+07 |
| 180 | 54 | 3.32 | -63 | -2.33E+06 | 2.45E+06 | 5.60E+07 | -7.09E+07 |
| 180 | 63 | 3.073 | 0 | -5.88E+06 | 5.95E+06 | 8.81E+07 | -8.81E+07 |
| 180 | 63 | 3.073 | -11.7 | -5.52E+06 | 4.75E+06 | 8.49E+07 | -8.55E+07 |
| 180 | 63 | 3.073 | -23.4 | -4.57E+06 | 4.10E+06 | 8.55E+07 | -7.92E+07 |
| 180 | 63 | 3.073 | -35.1 | -3.40E+06 | 3.27E+06 | 8.60E+07 | -5.99E+07 |
| 180 | 63 | 3.073 | -46.8 | -2.54E+06 | 2.48E+06 | 8.62E+07 | -8.60E+07 |
| 180 | 63 | 3.073 | -58.5 | -2.11E+06 | 2.18E+06 | 8.57E+07 | -9.72E+07 |
| 180 | 72 | 2.875 | 0 | -5.87E+06 | 5.81E+06 | 1.08E+08 | -1.08E+08 |
| 180 | 72 | 2.875 | -10.8 | -5.40E+06 | 5.47E+06 | 1.08E+08 | -1.05E+08 |
| 180 | 72 | 2.875 | -21.6 | -4.54E+06 | 3.90E+06 | 1.09E+08 | -9.70E+07 |
| 180 | 72 | 2.875 | -32.4 | -3.42E+06 | 3.43E+06 | 1.10E+08 | -1.08E+08 |
| 180 | 72 | 2.875 | -43.2 | -2.43E+06 | 2.43E+06 | 1.10E+08 | -1.18E+08 |
| 180 | 72 | 2.875 | -54 | -1.92E+06 | 1.39E+06 | 1.10E+08 | -1.24E+08 |
| 180 | 81 | 2.711 | 0 | -5.70E+06 | 5.56E+06 | 1.30E+08 | -1.30E+08 |
| 180 | 81 | 2.711 | -9.9 | -5.40E+06 | 5.26E+06 | 1.31E+08 | -1.21E+08 |
| 180 | 81 | 2.711 | -19.8 | -4.40E+06 | 4.46E+06 | 1.32E+08 | -1.12E+08 |
| 180 | 81 | 2.711 | -29.7 | -3.37E+06 | 3.39E+06 | 1.33E+08 | -1.30E+08 |
| 180 | 81 | 2.711 | -39.6 | -2.36E+06 | 2.37E+06 | 1.33E+08 | -1.42E+08 |
| 180 | 81 | 2.711 | -49.5 | -1.69E+06 | 1.69E+06 | 1.33E+08 | -1.50E+08 |
| 180 | 90 | 2.571 | 0 | -5.21E+06 | 5.22E+06 | 1.49E+08 | -1.49E+08 |
| 180 | 90 | 2.571 | -9 | -5.16E+06 | 4.96E+06 | 1.50E+08 | -1.31E+08 |
| 180 | 90 | 2.571 | -18 | -4.46E+06 | 4.26E+06 | 1.52E+08 | -1.48E+08 |
| 180 | 90 | 2.571 | -27 | -3.25E+06 | 3.29E+06 | 1.53E+08 | -1.49E+08 |
| 180 | 90 | 2.571 | -36 | -2.28E+06 | 2.30E+06 | 1.54E+08 | -1.64E+08 |
| 180 | 90 | 2.571 | -45 | -3.27E+05 | 1.52E+06 | 1.54E+08 | -1.73E+08 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 180 | 45 | 3.637 | 12.86 | 3.27E+06 | -3.08E+06 |
| 180 | 45 | 3.637 | 14.14 | 3.69E+06 | -3.69E+06 |
| 180 | 45 | 3.637 | 15.43 | 4.05E+06 | -4.04E+06 |
| 180 | 45 | 3.637 | 16.71 | 4.32E+06 | -4.31E+06 |
| 180 | 45 | 3.637 | 18 | 4.49E+06 | -4.49E+06 |
| 180 | 45 | 3.637 | 19.29 | 4.48E+06 | -4.56E+06 |
| 180 | 54 | 3.32 | 12.86 | 3.55E+06 | -3.35E+06 |
| 180 | 54 | 3.32 | 14.14 | 4.00E+06 | -4.00E+06 |
| 180 | 54 | 3.32 | 15.43 | 4.39E+06 | -4.38E+06 |
| 180 | 54 | 3.32 | 16.71 | 4.68E+06 | -4.67E+06 |
| 180 | 54 | 3.32 | 18 | 4.87E+06 | -4.86E+06 |
| 180 | 54 | 3.32 | 19.29 | 4.85E+06 | -4.93E+06 |
| 180 | 63 | 3.073 | 12.86 | 3.79E+06 | -3.59E+06 |
| 180 | 63 | 3.073 | 14.14 | 4.28E+06 | -3.41E+06 |
| 180 | 63 | 3.073 | 15.43 | 4.69E+06 | -4.68E+06 |
| 180 | 63 | 3.073 | 16.71 | 5.00E+06 | -4.99E+06 |
| 180 | 63 | 3.073 | 18 | 5.21E+06 | -5.19E+06 |
| 180 | 63 | 3.073 | 19.29 | 5.19E+06 | -5.27E+06 |
| 180 | 72 | 2.875 | 12.86 | 4.02E+06 | -3.80E+06 |
| 180 | 72 | 2.875 | 14.14 | 4.53E+06 | -3.61E+06 |
| 180 | 72 | 2.875 | 15.43 | 4.97E+06 | -4.96E+06 |
| 180 | 72 | 2.875 | 16.71 | 5.30E+06 | -5.28E+06 |
| 180 | 72 | 2.875 | 18 | 5.51E+06 | -5.49E+06 |
| 180 | 72 | 2.875 | 19.29 | 5.49E+06 | -5.58E+06 |
| 180 | 81 | 2.711 | 12.86 | 4.22E+06 | -4.00E+06 |
| 180 | 81 | 2.711 | 14.14 | 4.77E+06 | -3.80E+06 |
| 180 | 81 | 2.711 | 15.43 | 5.22E+06 | -5.21E+06 |
| 180 | 81 | 2.711 | 16.71 | 5.57E+06 | -5.55E+06 |
| 180 | 81 | 2.711 | 18 | 5.80E+06 | -5.77E+06 |
| 180 | 81 | 2.711 | 19.29 | 5.78E+06 | -5.86E+06 |
| 180 | 90 | 2.571 | 12.86 | 4.41E+06 | -4.19E+06 |
| 180 | 90 | 2.571 | 14.14 | 4.98E+06 | -3.98E+06 |
| 180 | 90 | 2.571 | 15.43 | 5.46E+06 | -5.44E+06 |
| 180 | 90 | 2.571 | 16.71 | 5.83E+06 | -5.79E+06 |
| 180 | 90 | 2.571 | 18 | 6.06E+06 | -6.02E+06 |
| 180 | 90 | 2.571 | 19.29 | 6.04E+06 | -6.10E+06 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 200 | 50 | 4.041 | 0 | -7.41E+06 | 7.44E+06 | 6.70E+07 | -6.70E+07 |
| 200 | 50 | 4.041 | -15 | -6.92E+06 | 6.94E+06 | 6.53E+07 | -6.45E+07 |
| 200 | 50 | 4.041 | -30 | -5.69E+06 | 5.17E+06 | 6.29E+07 | -5.69E+07 |
| 200 | 50 | 4.041 | -45 | -4.37E+06 | 4.27E+06 | 6.04E+07 | -5.72E+07 |
| 200 | 50 | 4.041 | -60 | -3.60E+06 | 3.60E+06 | 5.69E+07 | -6.64E+07 |
| 200 | 50 | 4.041 | -75 | -3.70E+06 | 3.70E+06 | 6.12E+07 | -7.12E+07 |
| 200 | 60 | 3.689 | 0 | -7.50E+06 | 7.54E+06 | 9.43E+07 | -9.43E+07 |
| 200 | 60 | 3.689 | -14 | -7.04E+06 | 7.07E+06 | 9.59E+07 | -9.09E+07 |
| 200 | 60 | 3.689 | -28 | -5.85E+06 | 5.86E+06 | 9.26E+07 | -8.33E+07 |
| 200 | 60 | 3.689 | -42 | -4.49E+06 | 4.49E+06 | 9.44E+07 | -7.26E+07 |
| 200 | 60 | 3.689 | -56 | -3.55E+06 | 3.55E+06 | 8.62E+07 | -9.85E+07 |
| 200 | 60 | 3.689 | -70 | -3.40E+06 | 3.40E+06 | 8.59E+07 | -1.07E+08 |
| 200 | 70 | 3.415 | 0 | -7.97E+06 | 7.45E+06 | 1.31E+08 | -1.31E+08 |
| 200 | 70 | 3.415 | -13 | -7.46E+06 | 7.01E+06 | 1.29E+08 | -1.16E+08 |
| 200 | 70 | 3.415 | -26 | -5.85E+06 | 5.87E+06 | 1.25E+08 | -1.06E+08 |
| 200 | 70 | 3.415 | -39 | -4.50E+06 | 4.51E+06 | 1.29E+08 | -1.28E+08 |
| 200 | 70 | 3.415 | -52 | -3.44E+06 | 3.44E+06 | 1.16E+08 | -1.34E+08 |
| 200 | 70 | 3.415 | -65 | -3.04E+06 | 3.04E+06 | 1.14E+08 | -1.47E+08 |
| 200 | 80 | 3.194 | 0 | -7.67E+06 | 7.18E+06 | 1.64E+08 | -1.64E+08 |
| 200 | 80 | 3.194 | -12 | -7.37E+06 | 6.78E+06 | 1.62E+08 | -1.38E+08 |
| 200 | 80 | 3.194 | -24 | -5.71E+06 | 5.74E+06 | 1.58E+08 | -1.25E+08 |
| 200 | 80 | 3.194 | -36 | -4.41E+06 | 4.42E+06 | 1.66E+08 | -1.63E+08 |
| 200 | 80 | 3.194 | -48 | -3.27E+06 | 3.28E+06 | 1.74E+08 | -1.71E+08 |
| 200 | 80 | 3.194 | -60 | -2.66E+06 | 2.66E+06 | 1.42E+08 | -1.89E+08 |
| 200 | 90 | 3.012 | 0 | -7.47E+06 | 6.76E+06 | 1.95E+08 | -1.95E+08 |
| 200 | 90 | 3.012 | -11 | -7.13E+06 | 7.23E+06 | 1.93E+08 | -1.92E+08 |
| 200 | 90 | 3.012 | -22 | -6.05E+06 | 5.48E+06 | 1.88E+08 | -1.86E+08 |
| 200 | 90 | 3.012 | -33 | -4.57E+06 | 4.25E+06 | 2.01E+08 | -1.97E+08 |
| 200 | 90 | 3.012 | -44 | -3.11E+06 | 3.08E+06 | 2.12E+08 | -2.06E+08 |
| 200 | 90 | 3.012 | -55 | -2.29E+06 | 2.09E+06 | 2.19E+08 | -2.29E+08 |
| 200 | 100 | 2.857 | 0 | -7.15E+06 | 6.22E+06 | 2.20E+08 | -2.20E+08 |
| 200 | 100 | 2.857 | -10 | -5.65E+06 | 6.89E+06 | 2.18E+08 | -2.17E+08 |
| 200 | 100 | 2.857 | -20 | -4.89E+06 | 5.91E+06 | 2.22E+08 | -2.10E+08 |
| 200 | 100 | 2.857 | -30 | -4.51E+06 | 4.55E+06 | 2.34E+08 | -2.27E+08 |
| 200 | 100 | 2.857 | -40 | -3.10E+06 | 3.12E+06 | 2.46E+08 | -2.38E+08 |
| 200 | 100 | 2.857 | -50 | -3.80E+05 | 1.97E+06 | 2.56E+08 | -2.65E+08 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 200 | 50 | 4.041 | 14.29 | 4.49E+06 | -4.49E+06 |
| 200 | 50 | 4.041 | 15.71 | 4.96E+06 | -4.95E+06 |
| 200 | 50 | 4.041 | 17.14 | 5.29E+06 | -5.29E+06 |
| 200 | 50 | 4.041 | 18.57 | 5.47E+06 | -5.47E+06 |
| 200 | 50 | 4.041 | 20 | 5.70E+06 | -5.50E+06 |
| 200 | 50 | 4.041 | 21.43 | 6.14E+06 | -5.36E+06 |
| 200 | 60 | 3.689 | 14.29 | 4.87E+06 | -4.87E+06 |
| 200 | 60 | 3.689 | 15.71 | 5.37E+06 | -5.37E+06 |
| 200 | 60 | 3.689 | 17.14 | 5.73E+06 | -5.73E+06 |
| 200 | 60 | 3.689 | 18.57 | 5.93E+06 | -5.93E+06 |
| 200 | 60 | 3.689 | 20 | 6.17E+06 | -5.96E+06 |
| 200 | 60 | 3.689 | 21.43 | 6.65E+06 | -5.81E+06 |
| 200 | 70 | 3.415 | 14.29 | 5.21E+06 | -5.21E+06 |
| 200 | 70 | 3.415 | 15.71 | 5.75E+06 | -5.75E+06 |
| 200 | 70 | 3.415 | 17.14 | 6.13E+06 | -6.13E+06 |
| 200 | 70 | 3.415 | 18.57 | 6.35E+06 | -6.34E+06 |
| 200 | 70 | 3.415 | 20 | 6.60E+06 | -6.37E+06 |
| 200 | 70 | 3.415 | 21.43 | 7.11E+06 | -6.22E+06 |
| 200 | 80 | 3.194 | 14.29 | 5.52E+06 | -5.51E+06 |
| 200 | 80 | 3.194 | 15.71 | 6.09E+06 | -6.08E+06 |
| 200 | 80 | 3.194 | 17.14 | 6.50E+06 | -6.49E+06 |
| 200 | 80 | 3.194 | 18.57 | 6.73E+06 | -6.71E+06 |
| 200 | 80 | 3.194 | 20 | 6.99E+06 | -6.74E+06 |
| 200 | 80 | 3.194 | 21.43 | 7.53E+06 | -6.58E+06 |
| 200 | 90 | 3.012 | 14.29 | 5.80E+06 | -5.80E+06 |
| 200 | 90 | 3.012 | 15.71 | 6.40E+06 | -6.39E+06 |
| 200 | 90 | 3.012 | 17.14 | 6.84E+06 | -6.82E+06 |
| 200 | 90 | 3.012 | 18.57 | 7.07E+06 | -7.05E+06 |
| 200 | 90 | 3.012 | 20 | 7.35E+06 | -7.08E+06 |
| 200 | 90 | 3.012 | 21.43 | 7.92E+06 | -6.91E+06 |
| 200 | 100 | 2.857 | 14.29 | 6.07E+06 | -6.06E+06 |
| 200 | 100 | 2.857 | 15.71 | 6.70E+06 | -6.68E+06 |
| 200 | 100 | 2.857 | 17.14 | 7.15E+06 | -7.12E+06 |
| 200 | 100 | 2.857 | 18.57 | 7.40E+06 | -7.37E+06 |
| 200 | 100 | 2.857 | 20 | 7.68E+06 | -7.40E+06 |
| 200 | 100 | 2.857 | 21.43 | 8.27E+06 | -7.22E+06 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 220 | 55 | 4.445 | 0 | -8.92E+06 | 9.98E+06 | 9.69E+07 | -9.69E+07 |
| 220 | 55 | 4.445 | -16.5 | -8.42E+06 | 8.43E+06 | 9.42E+07 | -8.70E+07 |
| 220 | 55 | 4.445 | -33 | -7.15E+06 | 7.16E+06 | 8.87E+07 | -7.74E+07 |
| 220 | 55 | 4.445 | -49.5 | -5.70E+06 | 5.70E+06 | 8.96E+07 | -7.61E+07 |
| 220 | 55 | 4.445 | -66 | -4.65E+06 | 4.65E+06 | 8.23E+07 | -9.10E+07 |
| 220 | 55 | 4.445 | -82.5 | -4.34E+06 | 4.69E+06 | 8.36E+07 | -1.00E+08 |
| 220 | 66 | 4.057 | 0 | -1.02E+07 | 1.02E+07 | 1.40E+08 | -1.40E+08 |
| 220 | 66 | 4.057 | -15.4 | -9.47E+06 | 8.47E+06 | 1.30E+08 | -1.19E+08 |
| 220 | 66 | 4.057 | -30.8 | -7.73E+06 | 7.24E+06 | 1.32E+08 | -1.11E+08 |
| 220 | 66 | 4.057 | -46.2 | -5.75E+06 | 5.76E+06 | 1.33E+08 | -9.25E+07 |
| 220 | 66 | 4.057 | -61.6 | -4.58E+06 | 4.58E+06 | 1.33E+08 | -1.35E+08 |
| 220 | 66 | 4.057 | -77 | -4.06E+06 | 4.25E+06 | 1.17E+08 | -1.50E+08 |
| 220 | 77 | 3.756 | 0 | -1.01E+07 | 1.02E+07 | 1.86E+08 | -1.86E+08 |
| 220 | 77 | 3.756 | -14.3 | -9.48E+06 | 8.26E+06 | 1.77E+08 | -1.81E+08 |
| 220 | 77 | 3.756 | -28.6 | -7.85E+06 | 7.10E+06 | 1.79E+08 | -1.36E+08 |
| 220 | 77 | 3.756 | -42.9 | -5.85E+06 | 5.65E+06 | 1.81E+08 | -1.80E+08 |
| 220 | 77 | 3.756 | -57.2 | -4.38E+06 | 4.39E+06 | 1.82E+08 | -1.83E+08 |
| 220 | 77 | 3.756 | -71.5 | -3.67E+06 | 3.78E+06 | 1.82E+08 | -2.05E+08 |
| 220 | 88 | 3.514 | 0 | -1.01E+07 | 9.94E+06 | 2.30E+08 | -2.30E+08 |
| 220 | 88 | 3.514 | -13.2 | -9.27E+06 | 9.36E+06 | 2.26E+08 | -2.24E+08 |
| 220 | 88 | 3.514 | -26.4 | -7.79E+06 | 7.83E+06 | 2.29E+08 | -2.10E+08 |
| 220 | 88 | 3.514 | -39.6 | -5.87E+06 | 5.39E+06 | 2.32E+08 | -2.28E+08 |
| 220 | 88 | 3.514 | -52.8 | -4.19E+06 | 4.19E+06 | 2.33E+08 | -2.48E+08 |
| 220 | 88 | 3.514 | -66 | -3.32E+06 | 3.32E+06 | 2.33E+08 | -2.63E+08 |
| 220 | 99 | 3.313 | 0 | -9.35E+06 | 9.50E+06 | 2.67E+08 | -2.67E+08 |
| 220 | 99 | 3.313 | -12.1 | -9.28E+06 | 8.99E+06 | 2.74E+08 | -2.60E+08 |
| 220 | 99 | 3.313 | -24.2 | -7.56E+06 | 7.62E+06 | 2.77E+08 | -2.44E+08 |
| 220 | 99 | 3.313 | -36.3 | -5.78E+06 | 5.80E+06 | 2.80E+08 | -2.75E+08 |
| 220 | 99 | 3.313 | -48.4 | -4.07E+06 | 4.07E+06 | 2.83E+08 | -3.00E+08 |
| 220 | 99 | 3.313 | -60.5 | -2.92E+06 | 2.93E+06 | 2.84E+08 | -3.19E+08 |
| 220 | 110 | 3.143 | 0 | -8.98E+06 | 8.90E+06 | 3.13E+08 | -3.13E+08 |
| 220 | 110 | 3.143 | -11 | -7.78E+06 | 8.46E+06 | 3.15E+08 | -2.87E+08 |
| 220 | 110 | 3.143 | -22 | -6.72E+06 | 7.73E+06 | 3.19E+08 | -2.69E+08 |
| 220 | 110 | 3.143 | -33 | -5.89E+06 | 5.62E+06 | 3.23E+08 | -3.16E+08 |
| 220 | 110 | 3.143 | -44 | -3.99E+06 | 3.93E+06 | 3.27E+08 | -3.47E+08 |
| 220 | 110 | 3.143 | -55 | -4.37E+05 | 2.61E+06 | 3.29E+08 | -3.68E+08 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 220 | 55 | 4.445 | 15.71 | 5.84E+06 | -5.84E+06 |
| 220 | 55 | 4.445 | 17.29 | 6.27E+06 | -6.27E+06 |
| 220 | 55 | 4.445 | 18.86 | 6.32E+06 | -6.48E+06 |
| 220 | 55 | 4.445 | 20.43 | 6.96E+06 | -6.46E+06 |
| 220 | 55 | 4.445 | 22 | 7.52E+06 | -6.21E+06 |
| 220 | 55 | 4.445 | 23.57 | 7.96E+06 | -7.96E+06 |
| 220 | 66 | 4.057 | 15.71 | 6.33E+06 | -6.33E+06 |
| 220 | 66 | 4.057 | 17.29 | 6.80E+06 | -6.80E+06 |
| 220 | 66 | 4.057 | 18.86 | 6.85E+06 | -7.03E+06 |
| 220 | 66 | 4.057 | 20.43 | 7.55E+06 | -7.01E+06 |
| 220 | 66 | 4.057 | 22 | 8.14E+06 | -6.73E+06 |
| 220 | 66 | 4.057 | 23.57 | 8.63E+06 | -6.23E+06 |
| 220 | 77 | 3.756 | 15.71 | 6.77E+06 | -6.77E+06 |
| 220 | 77 | 3.756 | 17.29 | 7.27E+06 | -7.27E+06 |
| 220 | 77 | 3.756 | 18.86 | 7.32E+06 | -7.52E+06 |
| 220 | 77 | 3.756 | 20.43 | 8.07E+06 | -7.50E+06 |
| 220 | 77 | 3.756 | 22 | 8.71E+06 | -7.20E+06 |
| 220 | 77 | 3.756 | 23.57 | 9.22E+06 | -6.66E+06 |
| 220 | 88 | 3.514 | 15.71 | 7.18E+06 | -7.17E+06 |
| 220 | 88 | 3.514 | 17.29 | 7.71E+06 | -7.71E+06 |
| 220 | 88 | 3.514 | 18.86 | 7.75E+06 | -7.97E+06 |
| 220 | 88 | 3.514 | 20.43 | 8.54E+06 | -7.94E+06 |
| 220 | 88 | 3.514 | 22 | 9.22E+06 | -7.63E+06 |
| 220 | 88 | 3.514 | 23.57 | 9.77E+06 | -7.06E+06 |
| 220 | 99 | 3.313 | 15.71 | 7.55E+06 | -7.54E+06 |
| 220 | 99 | 3.313 | 17.29 | 8.11E+06 | -8.10E+06 |
| 220 | 99 | 3.313 | 18.86 | 8.15E+06 | -8.38E+06 |
| 220 | 99 | 3.313 | 20.43 | 8.98E+06 | -8.35E+06 |
| 220 | 99 | 3.313 | 22 | 9.70E+06 | -8.03E+06 |
| 220 | 99 | 3.313 | 23.57 | 1.03E+07 | -7.42E+06 |
| 220 | 110 | 3.143 | 15.71 | 7.89E+06 | -7.89E+06 |
| 220 | 110 | 3.143 | 17.29 | 8.48E+06 | -8.47E+06 |
| 220 | 110 | 3.143 | 18.86 | 8.52E+06 | -8.75E+06 |
| 220 | 110 | 3.143 | 20.43 | 9.39E+06 | -8.73E+06 |
| 220 | 110 | 3.143 | 22 | 1.01E+07 | -8.39E+06 |
| 220 | 110 | 3.143 | 23.57 | 1.07E+07 | -7.76E+06 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 240 | 60 | 4.849 | 0 | -1.22E+07 | 1.22E+07 | 1.33E+08 | -1.33E+08 |
| 240 | 60 | 4.849 | -18 | -1.14E+07 | 1.14E+07 | 1.27E+08 | -1.28E+08 |
| 240 | 60 | 4.849 | -36 | -9.33E+06 | 8.63E+06 | 1.24E+08 | -1.11E+08 |
| 240 | 60 | 4.849 | -54 | -7.13E+06 | 7.07E+06 | 1.20E+08 | -1.11E+08 |
| 240 | 60 | 4.849 | -72 | -5.87E+06 | 5.87E+06 | 1.18E+08 | -1.30E+08 |
| 240 | 60 | 4.849 | -90 | -6.06E+06 | 6.06E+06 | 1.18E+08 | -1.39E+08 |
| 240 | 72 | 4.426 | 0 | -1.24E+07 | 1.24E+07 | 1.90E+08 | -1.90E+08 |
| 240 | 72 | 4.426 | -16.8 | -1.16E+07 | 1.16E+07 | 1.87E+08 | -1.83E+08 |
| 240 | 72 | 4.426 | -33.6 | -9.61E+06 | 9.61E+06 | 1.82E+08 | -1.46E+08 |
| 240 | 72 | 4.426 | -50.4 | -7.34E+06 | 7.34E+06 | 1.77E+08 | -1.45E+08 |
| 240 | 72 | 4.426 | -67.2 | -5.80E+06 | 5.80E+06 | 1.73E+08 | -1.93E+08 |
| 240 | 72 | 4.426 | -84 | -5.56E+06 | 5.56E+06 | 1.61E+08 | -2.09E+08 |
| 240 | 84 | 4.098 | 0 | -1.30E+07 | 1.23E+07 | 2.54E+08 | -2.54E+08 |
| 240 | 84 | 4.098 | -15.6 | -1.22E+07 | 1.15E+07 | 2.53E+08 | -2.38E+08 |
| 240 | 84 | 4.098 | -31.2 | -9.63E+06 | 9.64E+06 | 2.47E+08 | -2.18E+08 |
| 240 | 84 | 4.098 | -46.8 | -7.38E+06 | 7.38E+06 | 2.53E+08 | -2.51E+08 |
| 240 | 84 | 4.098 | -62.4 | -5.62E+06 | 5.62E+06 | 2.34E+08 | -2.63E+08 |
| 240 | 84 | 4.098 | -78 | -4.97E+06 | 4.97E+06 | 2.31E+08 | -2.88E+08 |
| 240 | 96 | 3.833 | 0 | -1.25E+07 | 1.18E+07 | 3.21E+08 | -3.21E+08 |
| 240 | 96 | 3.833 | -14.4 | -1.20E+07 | 1.12E+07 | 3.19E+08 | -2.87E+08 |
| 240 | 96 | 3.833 | -28.8 | -1.00E+07 | 9.44E+06 | 3.13E+08 | -2.63E+08 |
| 240 | 96 | 3.833 | -43.2 | -7.41E+06 | 7.26E+06 | 3.25E+08 | -3.21E+08 |
| 240 | 96 | 3.833 | -57.6 | -5.36E+06 | 5.36E+06 | 3.42E+08 | -3.36E+08 |
| 240 | 96 | 3.833 | -72 | -4.35E+06 | 4.35E+06 | 2.90E+08 | -3.70E+08 |
| 240 | 108 | 3.614 | 0 | -1.21E+07 | 1.12E+07 | 3.83E+08 | -3.83E+08 |
| 240 | 108 | 3.614 | -13.2 | -1.15E+07 | 1.18E+07 | 3.81E+08 | -3.79E+08 |
| 240 | 108 | 3.614 | -26.4 | -9.86E+06 | 9.03E+06 | 3.74E+08 | -3.71E+08 |
| 240 | 108 | 3.614 | -39.6 | -7.44E+06 | 6.99E+06 | 3.95E+08 | -3.88E+08 |
| 240 | 108 | 3.614 | -52.8 | -5.07E+06 | 5.05E+06 | 4.17E+08 | -4.07E+08 |
| 240 | 108 | 3.614 | -66 | -3.75E+06 | 3.42E+06 | 4.33E+08 | -4.18E+08 |
| 240 | 120 | 3.429 | 0 | -9.46E+06 | 1.18E+07 | 4.35E+08 | -4.35E+08 |
| 240 | 120 | 3.429 | -12 | -1.03E+07 | 1.12E+07 | 4.34E+08 | -4.31E+08 |
| 240 | 120 | 3.429 | -24 | -7.81E+06 | 9.59E+06 | 4.26E+08 | -4.22E+08 |
| 240 | 120 | 3.429 | -36 | -7.33E+06 | 7.38E+06 | 4.59E+08 | -4.49E+08 |
| 240 | 120 | 3.429 | -48 | -5.05E+06 | 5.07E+06 | 4.85E+08 | -4.70E+08 |
| 240 | 120 | 3.429 | -60 | -6.92E+05 | 3.21E+06 | 5.07E+08 | -5.21E+08 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 240 | 60 | 4.849 | 17.14 | 7.22E+06 | -7.22E+06 |
| 240 | 60 | 4.849 | 18.86 | 7.39E+06 | -7.50E+06 |
| 240 | 60 | 4.849 | 20.57 | 8.22E+06 | -7.46E+06 |
| 240 | 60 | 4.849 | 22.29 | 8.92E+06 | -8.92E+06 |
| 240 | 60 | 4.849 | 24 | 9.46E+06 | -9.46E+06 |
| 240 | 60 | 4.849 | 25.71 | 9.82E+06 | -9.82E+06 |
| 240 | 72 | 4.426 | 17.14 | 7.83E+06 | -7.83E+06 |
| 240 | 72 | 4.426 | 18.86 | 8.01E+06 | -8.14E+06 |
| 240 | 72 | 4.426 | 20.57 | 8.91E+06 | -8.10E+06 |
| 240 | 72 | 4.426 | 22.29 | 9.67E+06 | -7.71E+06 |
| 240 | 72 | 4.426 | 24 | 1.03E+07 | -1.03E+07 |
| 240 | 72 | 4.426 | 25.71 | 1.07E+07 | -1.06E+07 |
| 240 | 84 | 4.098 | 17.14 | 8.38E+06 | -8.38E+06 |
| 240 | 84 | 4.098 | 18.86 | 8.57E+06 | -8.72E+06 |
| 240 | 84 | 4.098 | 20.57 | 9.53E+06 | -8.67E+06 |
| 240 | 84 | 4.098 | 22.29 | 1.03E+07 | -8.25E+06 |
| 240 | 84 | 4.098 | 24 | 1.10E+07 | -1.10E+07 |
| 240 | 84 | 4.098 | 25.71 | 1.14E+07 | -1.14E+07 |
| 240 | 96 | 3.833 | 17.14 | 8.89E+06 | -8.88E+06 |
| 240 | 96 | 3.833 | 18.86 | 9.07E+06 | -9.24E+06 |
| 240 | 96 | 3.833 | 20.57 | 1.01E+07 | -9.19E+06 |
| 240 | 96 | 3.833 | 22.29 | 1.10E+07 | -8.74E+06 |
| 240 | 96 | 3.833 | 24 | 1.16E+07 | -7.92E+06 |
| 240 | 96 | 3.833 | 25.71 | 1.21E+07 | -1.20E+07 |
| 240 | 108 | 3.614 | 17.14 | 9.35E+06 | -9.34E+06 |
| 240 | 108 | 3.614 | 18.86 | 9.54E+06 | -9.72E+06 |
| 240 | 108 | 3.614 | 20.57 | 1.06E+07 | -9.67E+06 |
| 240 | 108 | 3.614 | 22.29 | 1.15E+07 | -9.20E+06 |
| 240 | 108 | 3.614 | 24 | 1.22E+07 | -8.34E+06 |
| 240 | 108 | 3.614 | 25.71 | 1.27E+07 | -1.27E+07 |
| 240 | 120 | 3.429 | 17.14 | 9.78E+06 | -9.77E+06 |
| 240 | 120 | 3.429 | 18.86 | 9.97E+06 | -1.02E+07 |
| 240 | 120 | 3.429 | 20.57 | 1.11E+07 | -1.01E+07 |
| 240 | 120 | 3.429 | 22.29 | 1.20E+07 | -9.62E+06 |
| 240 | 120 | 3.429 | 24 | 1.28E+07 | -8.72E+06 |
| 240 | 120 | 3.429 | 25.71 | 1.33E+07 | -1.32E+07 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 260 | 65 | 5.253 | 0 | -1.43E+07 | 1.56E+07 | 1.73E+08 | -1.73E+08 |
| 260 | 65 | 5.253 | -19.5 | -1.35E+07 | 1.35E+07 | 1.74E+08 | -1.67E+08 |
| 260 | 65 | 5.253 | -39 | -1.13E+07 | 1.13E+07 | 1.65E+08 | -1.47E+08 |
| 260 | 65 | 5.253 | -58.5 | -8.95E+06 | 8.95E+06 | 1.67E+08 | -1.48E+08 |
| 260 | 65 | 5.253 | -78 | -7.35E+06 | 7.35E+06 | 1.50E+08 | -1.76E+08 |
| 260 | 65 | 5.253 | -97.5 | -7.06E+06 | 7.29E+06 | 1.61E+08 | -1.83E+08 |
| 260 | 78 | 4.795 | 0 | -1.59E+07 | 1.60E+07 | 2.60E+08 | -2.60E+08 |
| 260 | 78 | 4.795 | -18.2 | -1.48E+07 | 1.36E+07 | 2.54E+08 | -2.33E+08 |
| 260 | 78 | 4.795 | -36.4 | -1.21E+07 | 1.15E+07 | 2.43E+08 | -2.14E+08 |
| 260 | 78 | 4.795 | -54.6 | -9.08E+06 | 9.08E+06 | 2.48E+08 | -1.88E+08 |
| 260 | 78 | 4.795 | -72.8 | -7.23E+06 | 7.23E+06 | 2.51E+08 | -2.47E+08 |
| 260 | 78 | 4.795 | -91 | -6.57E+06 | 6.59E+06 | 2.21E+08 | -2.74E+08 |
| 260 | 91 | 4.439 | 0 | -1.59E+07 | 1.60E+07 | 3.47E+08 | -3.47E+08 |
| 260 | 91 | 4.439 | -16.9 | -1.49E+07 | 1.33E+07 | 3.40E+08 | -2.96E+08 |
| 260 | 91 | 4.439 | -33.8 | -1.23E+07 | 1.14E+07 | 3.31E+08 | -2.71E+08 |
| 260 | 91 | 4.439 | -50.7 | -9.13E+06 | 8.95E+06 | 3.39E+08 | -3.37E+08 |
| 260 | 91 | 4.439 | -67.6 | -6.94E+06 | 6.94E+06 | 3.44E+08 | -3.36E+08 |
| 260 | 91 | 4.439 | -84.5 | -5.93E+06 | 5.86E+06 | 2.88E+08 | -3.76E+08 |
| 260 | 104 | 4.153 | 0 | -1.47E+07 | 1.56E+07 | 4.32E+08 | -4.32E+08 |
| 260 | 104 | 4.153 | -15.6 | -1.48E+07 | 1.47E+07 | 4.16E+08 | -4.24E+08 |
| 260 | 104 | 4.153 | -31.2 | -1.22E+07 | 1.09E+07 | 4.24E+08 | -4.02E+08 |
| 260 | 104 | 4.153 | -46.8 | -9.18E+06 | 8.61E+06 | 4.33E+08 | -4.28E+08 |
| 260 | 104 | 4.153 | -62.4 | -6.53E+06 | 6.53E+06 | 4.41E+08 | -4.60E+08 |
| 260 | 104 | 4.153 | -78 | -5.16E+06 | 5.16E+06 | 4.44E+08 | -4.83E+08 |
| 260 | 117 | 3.915 | 0 | -1.44E+07 | 1.49E+07 | 5.08E+08 | -5.08E+08 |
| 260 | 117 | 3.915 | -14.3 | -1.44E+07 | 1.41E+07 | 5.04E+08 | -4.98E+08 |
| 260 | 117 | 3.915 | -28.6 | -1.22E+07 | 1.19E+07 | 5.13E+08 | -4.74E+08 |
| 260 | 117 | 3.915 | -42.9 | -9.06E+06 | 9.08E+06 | 5.25E+08 | -5.17E+08 |
| 260 | 117 | 3.915 | -57.2 | -6.35E+06 | 6.36E+06 | 5.36E+08 | -5.57E+08 |
| 260 | 117 | 3.915 | -71.5 | -4.55E+06 | 4.55E+06 | 5.42E+08 | -5.86E+08 |
| 260 | 130 | 3.714 | 0 | -1.38E+07 | 1.40E+07 | 5.67E+08 | -5.67E+08 |
| 260 | 130 | 3.714 | -13 | -1.18E+07 | 1.33E+07 | 5.82E+08 | -5.57E+08 |
| 260 | 130 | 3.714 | -26 | -1.02E+07 | 1.19E+07 | 5.93E+08 | -5.30E+08 |
| 260 | 130 | 3.714 | -39 | -9.12E+06 | 9.16E+06 | 6.07E+08 | -5.96E+08 |
| 260 | 130 | 3.714 | -52 | -6.17E+06 | 6.15E+06 | 6.20E+08 | -6.44E+08 |
| 260 | 130 | 3.714 | -65 | -7.55E+05 | 4.07E+06 | 6.30E+08 | -6.78E+08 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 260 | 65 | 5.253 | 18.57 | 8.34E+06 | -8.52E+06 |
| 260 | 65 | 5.253 | 20.43 | 9.41E+06 | -9.41E+06 |
| 260 | 65 | 5.253 | 22.29 | 1.03E+07 | -1.03E+07 |
| 260 | 65 | 5.253 | 24.14 | 1.10E+07 | -1.10E+07 |
| 260 | 65 | 5.253 | 26 | 1.14E+07 | -1.14E+07 |
| 260 | 65 | 5.253 | 27.86 | 1.19E+07 | -1.16E+07 |
| 260 | 78 | 4.795 | 18.57 | 9.04E+06 | -9.25E+06 |
| 260 | 78 | 4.795 | 20.43 | 1.02E+07 | -9.26E+06 |
| 260 | 78 | 4.795 | 22.29 | 1.12E+07 | -1.12E+07 |
| 260 | 78 | 4.795 | 24.14 | 1.19E+07 | -1.19E+07 |
| 260 | 78 | 4.795 | 26 | 1.24E+07 | -1.24E+07 |
| 260 | 78 | 4.795 | 27.86 | 1.29E+07 | -1.26E+07 |
| 260 | 91 | 4.439 | 18.57 | 9.67E+06 | -9.91E+06 |
| 260 | 91 | 4.439 | 20.43 | 1.09E+07 | -9.91E+06 |
| 260 | 91 | 4.439 | 22.29 | 1.20E+07 | -1.19E+07 |
| 260 | 91 | 4.439 | 24.14 | 1.27E+07 | -1.27E+07 |
| 260 | 91 | 4.439 | 26 | 1.32E+07 | -1.32E+07 |
| 260 | 91 | 4.439 | 27.86 | 1.38E+07 | -1.34E+07 |
| 260 | 104 | 4.153 | 18.57 | 1.02E+07 | -1.05E+07 |
| 260 | 104 | 4.153 | 20.43 | 1.16E+07 | -1.05E+07 |
| 260 | 104 | 4.153 | 22.29 | 1.27E+07 | -9.96E+06 |
| 260 | 104 | 4.153 | 24.14 | 1.35E+07 | -1.35E+07 |
| 260 | 104 | 4.153 | 26 | 1.40E+07 | -1.40E+07 |
| 260 | 104 | 4.153 | 27.86 | 1.46E+07 | -1.42E+07 |
| 260 | 117 | 3.915 | 18.57 | 1.08E+07 | -1.11E+07 |
| 260 | 117 | 3.915 | 20.43 | 1.22E+07 | -1.11E+07 |
| 260 | 117 | 3.915 | 22.29 | 1.33E+07 | -1.05E+07 |
| 260 | 117 | 3.915 | 24.14 | 1.42E+07 | -1.42E+07 |
| 260 | 117 | 3.915 | 26 | 1.47E+07 | -1.47E+07 |
| 260 | 117 | 3.915 | 27.86 | 1.53E+07 | -1.49E+07 |
| 260 | 130 | 3.714 | 18.57 | 1.13E+07 | -1.16E+07 |
| 260 | 130 | 3.714 | 20.43 | 1.27E+07 | -1.16E+07 |
| 260 | 130 | 3.714 | 22.29 | 1.39E+07 | -1.10E+07 |
| 260 | 130 | 3.714 | 24.14 | 1.48E+07 | -1.48E+07 |
| 260 | 130 | 3.714 | 26 | 1.54E+07 | -1.54E+07 |
| 260 | 130 | 3.714 | 27.86 | 1.60E+07 | -1.56E+07 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 280 | 70 | 5.657 | 0 | -1.86E+07 | 1.86E+07 | 2.37E+08 | -2.37E+08 |
| 280 | 70 | 5.657 | -21 | -1.73E+07 | 1.73E+07 | 2.21E+08 | -2.10E+08 |
| 280 | 70 | 5.657 | -42 | -1.41E+07 | 1.34E+07 | 2.18E+08 | -1.88E+08 |
| 280 | 70 | 5.657 | -63 | -1.08E+07 | 1.08E+07 | 2.15E+08 | -1.86E+08 |
| 280 | 70 | 5.657 | -84 | -8.67E+06 | 8.78E+06 | 2.00E+08 | -2.26E+08 |
| 280 | 70 | 5.657 | -105 | -9.17E+06 | 9.17E+06 | 2.05E+08 | -2.42E+08 |
| 280 | 84 | 5.164 | 0 | -1.89E+07 | 1.89E+07 | 3.41E+08 | -3.41E+08 |
| 280 | 84 | 5.164 | -19.6 | -1.77E+07 | 1.77E+07 | 3.26E+08 | -3.31E+08 |
| 280 | 84 | 5.164 | -39.2 | -1.46E+07 | 1.34E+07 | 3.23E+08 | -2.69E+08 |
| 280 | 84 | 5.164 | -58.8 | -1.11E+07 | 1.08E+07 | 3.18E+08 | -2.30E+08 |
| 280 | 84 | 5.164 | -78.4 | -8.67E+06 | 8.67E+06 | 3.14E+08 | -3.35E+08 |
| 280 | 84 | 5.164 | -98 | -8.39E+06 | 8.39E+06 | 2.85E+08 | -3.63E+08 |
| 280 | 98 | 4.781 | 0 | -1.86E+07 | 1.88E+07 | 4.50E+08 | -4.50E+08 |
| 280 | 98 | 4.781 | -18.2 | -1.82E+07 | 1.76E+07 | 4.42E+08 | -4.37E+08 |
| 280 | 98 | 4.781 | -36.4 | -1.47E+07 | 1.47E+07 | 4.39E+08 | -4.05E+08 |
| 280 | 98 | 4.781 | -54.6 | -1.12E+07 | 1.12E+07 | 4.33E+08 | -4.42E+08 |
| 280 | 98 | 4.781 | -72.8 | -8.43E+06 | 8.14E+06 | 4.27E+08 | -4.58E+08 |
| 280 | 98 | 4.781 | -91 | -7.48E+06 | 7.48E+06 | 4.23E+08 | -5.01E+08 |
| 280 | 112 | 4.472 | 0 | -1.84E+07 | 1.82E+07 | 5.51E+08 | -5.51E+08 |
| 280 | 112 | 4.472 | -16.8 | -1.80E+07 | 1.71E+07 | 5.62E+08 | -5.36E+08 |
| 280 | 112 | 4.472 | -33.6 | -1.50E+07 | 1.44E+07 | 5.57E+08 | -4.97E+08 |
| 280 | 112 | 4.472 | -50.4 | -1.11E+07 | 1.10E+07 | 5.71E+08 | -5.47E+08 |
| 280 | 112 | 4.472 | -67.2 | -8.09E+06 | 8.09E+06 | 6.05E+08 | -5.86E+08 |
| 280 | 112 | 4.472 | -84 | -6.56E+06 | 6.56E+06 | 5.37E+08 | -6.46E+08 |
| 280 | 126 | 4.216 | 0 | -1.79E+07 | 1.86E+07 | 6.75E+08 | -6.75E+08 |
| 280 | 126 | 4.216 | -15.4 | -1.70E+07 | 1.76E+07 | 6.75E+08 | -6.18E+08 |
| 280 | 126 | 4.216 | -30.8 | -1.48E+07 | 1.39E+07 | 6.70E+08 | -5.73E+08 |
| 280 | 126 | 4.216 | -46.2 | -1.11E+07 | 1.07E+07 | 6.95E+08 | -6.57E+08 |
| 280 | 126 | 4.216 | -61.6 | -7.56E+06 | 7.67E+06 | 7.39E+08 | -7.10E+08 |
| 280 | 126 | 4.216 | -77 | -5.68E+06 | 5.68E+06 | 7.73E+08 | -7.86E+08 |
| 280 | 140 | 4 | 0 | -1.71E+07 | 1.76E+07 | 7.73E+08 | -7.73E+08 |
| 280 | 140 | 4 | -14 | -1.49E+07 | 1.67E+07 | 7.72E+08 | -7.69E+08 |
| 280 | 140 | 4 | -28 | -1.29E+07 | 1.43E+07 | 7.68E+08 | -7.61E+08 |
| 280 | 140 | 4 | -42 | -1.08E+07 | 1.10E+07 | 8.07E+08 | -7.93E+08 |
| 280 | 140 | 4 | -56 | -7.54E+06 | 7.56E+06 | 8.60E+08 | -8.21E+08 |
| 280 | 140 | 4 | -70 | -4.74E+06 | 4.76E+06 | 9.05E+08 | -9.12E+08 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 280 | 70 | 5.657 | 20 | 1.05E+07 | -1.05E+07 |
| 280 | 70 | 5.657 | 22 | 1.16E+07 | -1.16E+07 |
| 280 | 70 | 5.657 | 24 | 1.25E+07 | -1.25E+07 |
| 280 | 70 | 5.657 | 26 | 1.30E+07 | -1.30E+07 |
| 280 | 70 | 5.657 | 28 | 1.37E+07 | -1.32E+07 |
| 280 | 70 | 5.657 | 30 | 1.47E+07 | -1.31E+07 |
| 280 | 84 | 5.164 | 20 | 1.13E+07 | -1.13E+07 |
| 280 | 84 | 5.164 | 22 | 1.26E+07 | -1.26E+07 |
| 280 | 84 | 5.164 | 24 | 1.35E+07 | -1.35E+07 |
| 280 | 84 | 5.164 | 26 | 1.41E+07 | -1.41E+07 |
| 280 | 84 | 5.164 | 28 | 1.49E+07 | -1.43E+07 |
| 280 | 84 | 5.164 | 30 | 1.59E+07 | -1.42E+07 |
| 280 | 98 | 4.781 | 20 | 1.21E+07 | -1.12E+07 |
| 280 | 98 | 4.781 | 22 | 1.35E+07 | -1.35E+07 |
| 280 | 98 | 4.781 | 24 | 1.45E+07 | -1.45E+07 |
| 280 | 98 | 4.781 | 26 | 1.51E+07 | -1.51E+07 |
| 280 | 98 | 4.781 | 28 | 1.59E+07 | -1.53E+07 |
| 280 | 98 | 4.781 | 30 | 1.70E+07 | -1.52E+07 |
| 280 | 112 | 4.472 | 20 | 1.28E+07 | -1.19E+07 |
| 280 | 112 | 4.472 | 22 | 1.43E+07 | -1.43E+07 |
| 280 | 112 | 4.472 | 24 | 1.53E+07 | -1.53E+07 |
| 280 | 112 | 4.472 | 26 | 1.60E+07 | -1.60E+07 |
| 280 | 112 | 4.472 | 28 | 1.68E+07 | -1.63E+07 |
| 280 | 112 | 4.472 | 30 | 1.80E+07 | -1.61E+07 |
| 280 | 126 | 4.216 | 20 | 1.35E+07 | -1.25E+07 |
| 280 | 126 | 4.216 | 22 | 1.50E+07 | -1.19E+07 |
| 280 | 126 | 4.216 | 24 | 1.61E+07 | -1.61E+07 |
| 280 | 126 | 4.216 | 26 | 1.68E+07 | -1.68E+07 |
| 280 | 126 | 4.216 | 28 | 1.77E+07 | -1.71E+07 |
| 280 | 126 | 4.216 | 30 | 1.90E+07 | -1.69E+07 |
| 280 | 140 | 4 | 20 | 1.41E+07 | -1.31E+07 |
| 280 | 140 | 4 | 22 | 1.57E+07 | -1.25E+07 |
| 280 | 140 | 4 | 24 | 1.69E+07 | -1.69E+07 |
| 280 | 140 | 4 | 26 | 1.76E+07 | -1.76E+07 |
| 280 | 140 | 4 | 28 | 1.85E+07 | -1.79E+07 |
| 280 | 140 | 4 | 30 | 1.98E+07 | -1.76E+07 |

| Lm (m) | Ls (m) | Bs (m) | Xs (m) | F_lg_sag (N) | F_lg_hog (N) | M_lg_pos (Nm) | M_lg_neg (Nm) |
|---|---|---|---|---|---|---|---|
| 300 | 75 | 6.061 | 0 | -2.15E+07 | 2.27E+07 | 3.02E+08 | -3.02E+08 |
| 300 | 75 | 6.061 | -22.5 | -2.10E+07 | 2.02E+07 | 2.93E+08 | -2.91E+08 |
| 300 | 75 | 6.061 | -45 | -1.68E+07 | 1.68E+07 | 2.82E+08 | -2.52E+08 |
| 300 | 75 | 6.061 | -67.5 | -1.31E+07 | 1.31E+07 | 2.83E+08 | -2.52E+08 |
| 300 | 75 | 6.061 | -90 | -1.08E+07 | 1.08E+07 | 2.56E+08 | -2.95E+08 |
| 300 | 75 | 6.061 | -112.5 | -1.07E+07 | 1.07E+07 | 2.69E+08 | -3.02E+08 |
| 300 | 90 | 5.533 | 0 | -2.32E+07 | 2.32E+07 | 4.30E+08 | -4.30E+08 |
| 300 | 90 | 5.533 | -21 | -2.16E+07 | 2.04E+07 | 4.30E+08 | -4.15E+08 |
| 300 | 90 | 5.533 | -42 | -1.71E+07 | 1.71E+07 | 4.14E+08 | -3.32E+08 |
| 300 | 90 | 5.533 | -63 | -1.33E+07 | 1.33E+07 | 4.20E+08 | -3.30E+08 |
| 300 | 90 | 5.533 | -84 | -1.06E+07 | 1.06E+07 | 3.85E+08 | -4.39E+08 |
| 300 | 90 | 5.533 | -105 | -9.90E+06 | 9.90E+06 | 3.84E+08 | -4.50E+08 |
| 300 | 105 | 5.122 | 0 | -2.27E+07 | 2.32E+07 | 5.86E+08 | -5.86E+08 |
| 300 | 105 | 5.122 | -19.5 | -2.17E+07 | 2.01E+07 | 5.79E+08 | -5.38E+08 |
| 300 | 105 | 5.122 | -39 | -1.79E+07 | 1.70E+07 | 5.55E+08 | -4.92E+08 |
| 300 | 105 | 5.122 | -58.5 | -1.32E+07 | 1.33E+07 | 5.75E+08 | -5.72E+08 |
| 300 | 105 | 5.122 | -78 | -1.02E+07 | 1.02E+07 | 5.91E+08 | -6.01E+08 |
| 300 | 105 | 5.122 | -97.5 | -8.90E+06 | 8.90E+06 | 5.10E+08 | -6.18E+08 |
| 300 | 120 | 4.792 | 0 | -2.24E+07 | 2.27E+07 | 7.37E+08 | -7.37E+08 |
| 300 | 120 | 4.792 | -18 | -2.11E+07 | 2.14E+07 | 7.28E+08 | -6.47E+08 |
| 300 | 120 | 4.792 | -36 | -1.78E+07 | 1.65E+07 | 7.10E+08 | -7.02E+08 |
| 300 | 120 | 4.792 | -54 | -1.33E+07 | 1.29E+07 | 7.37E+08 | -7.30E+08 |
| 300 | 120 | 4.792 | -72 | -9.40E+06 | 9.65E+06 | 7.60E+08 | -7.70E+08 |
| 300 | 120 | 4.792 | -90 | -7.79E+06 | 7.79E+06 | 7.73E+08 | -7.95E+08 |
| 300 | 135 | 4.518 | 0 | -2.18E+07 | 2.18E+07 | 8.74E+08 | -8.74E+08 |
| 300 | 135 | 4.518 | -16.5 | -2.06E+07 | 2.06E+07 | 8.65E+08 | -8.63E+08 |
| 300 | 135 | 4.518 | -33 | -1.74E+07 | 1.75E+07 | 8.63E+08 | -8.35E+08 |
| 300 | 135 | 4.518 | -49.5 | -1.32E+07 | 1.32E+07 | 8.94E+08 | -8.83E+08 |
| 300 | 135 | 4.518 | -66 | -9.20E+06 | 9.21E+06 | 9.25E+08 | -9.33E+08 |
| 300 | 135 | 4.518 | -82.5 | -6.52E+06 | 6.52E+06 | 9.46E+08 | -9.67E+08 |
| 300 | 150 | 4.286 | 0 | -1.69E+07 | 2.05E+07 | 9.87E+08 | -9.87E+08 |
| 300 | 150 | 4.286 | -15 | -1.61E+07 | 1.95E+07 | 9.78E+08 | -9.75E+08 |
| 300 | 150 | 4.286 | -30 | -1.59E+07 | 1.67E+07 | 9.99E+08 | -9.44E+08 |
| 300 | 150 | 4.286 | -45 | -1.22E+07 | 1.29E+07 | 1.04E+09 | -1.02E+09 |
| 300 | 150 | 4.286 | -60 | -8.82E+06 | 8.96E+06 | 1.07E+09 | -1.08E+09 |
| 300 | 150 | 4.286 | -75 | -5.86E+06 | 5.87E+06 | 1.10E+09 | -1.12E+09 |

| Lm (m) | Ls (m) | Bs (m) | Ys (m) | F_tr_sag (N) | F_tr_hog (N) |
|---|---|---|---|---|---|
| 300 | 75 | 6.061 | 21.43 | 1.27E+07 | -1.27E+07 |
| 300 | 75 | 6.061 | 23.57 | 1.39E+07 | -1.39E+07 |
| 300 | 75 | 6.061 | 25.71 | 1.47E+07 | -1.47E+07 |
| 300 | 75 | 6.061 | 27.86 | 1.55E+07 | -1.49E+07 |
| 300 | 75 | 6.061 | 30 | 1.67E+07 | -1.48E+07 |
| 300 | 75 | 6.061 | 32.14 | 1.77E+07 | -1.41E+07 |
| 300 | 90 | 5.533 | 21.43 | 1.38E+07 | -1.38E+07 |
| 300 | 90 | 5.533 | 23.57 | 1.51E+07 | -1.51E+07 |
| 300 | 90 | 5.533 | 25.71 | 1.59E+07 | -1.59E+07 |
| 300 | 90 | 5.533 | 27.86 | 1.68E+07 | -1.62E+07 |
| 300 | 90 | 5.533 | 30 | 1.81E+07 | -1.60E+07 |
| 300 | 90 | 5.533 | 32.14 | 1.92E+07 | -1.53E+07 |
| 300 | 105 | 5.122 | 21.43 | 1.48E+07 | -1.48E+07 |
| 300 | 105 | 5.122 | 23.57 | 1.61E+07 | -1.61E+07 |
| 300 | 105 | 5.122 | 25.71 | 1.70E+07 | -1.70E+07 |
| 300 | 105 | 5.122 | 27.86 | 1.79E+07 | -1.73E+07 |
| 300 | 105 | 5.122 | 30 | 1.94E+07 | -1.71E+07 |
| 300 | 105 | 5.122 | 32.14 | 2.05E+07 | -1.64E+07 |
| 300 | 120 | 4.792 | 21.43 | 1.56E+07 | -1.56E+07 |
| 300 | 120 | 4.792 | 23.57 | 1.71E+07 | -1.71E+07 |
| 300 | 120 | 4.792 | 25.71 | 1.80E+07 | -1.80E+07 |
| 300 | 120 | 4.792 | 27.86 | 1.90E+07 | -1.84E+07 |
| 300 | 120 | 4.792 | 30 | 2.05E+07 | -1.81E+07 |
| 300 | 120 | 4.792 | 32.14 | 2.17E+07 | -1.73E+07 |
| 300 | 135 | 4.518 | 21.43 | 1.65E+07 | -1.65E+07 |
| 300 | 135 | 4.518 | 23.57 | 1.80E+07 | -1.80E+07 |
| 300 | 135 | 4.518 | 25.71 | 1.89E+07 | -1.89E+07 |
| 300 | 135 | 4.518 | 27.86 | 2.00E+07 | -1.93E+07 |
| 300 | 135 | 4.518 | 30 | 2.16E+07 | -1.91E+07 |
| 300 | 135 | 4.518 | 32.14 | 2.28E+07 | -1.82E+07 |
| 300 | 150 | 4.286 | 21.43 | 1.72E+07 | -1.72E+07 |
| 300 | 150 | 4.286 | 23.57 | 1.88E+07 | -1.88E+07 |
| 300 | 150 | 4.286 | 25.71 | 1.98E+07 | -1.98E+07 |
| 300 | 150 | 4.286 | 27.86 | 2.09E+07 | -2.02E+07 |
| 300 | 150 | 4.286 | 30 | 2.25E+07 | -1.99E+07 |
| 300 | 150 | 4.286 | 32.14 | 2.39E+07 | -1.91E+07 |

# Appendix C. Wave Height Matching Reliability Index of Five

Where the required variables in this algorithm are contained in Appendix A

$$
\begin{aligned}
\text{design\_wave} := \; & \text{new}_{1,D} \leftarrow 0 \cdot m \\
& \text{for } q \in 1..D \\
& \quad \text{mean} \leftarrow 0 \\
& \quad \text{m2} \leftarrow 0 \\
& \quad \text{design} \leftarrow 0 \\
& \quad h \leftarrow 0 \\
& \quad \text{sum} \leftarrow \sum_{p=1}^{\text{pmax}_q} ss_{p,q} \\
& \quad \text{for } p \in 1..2B \\
& \quad\quad \text{if } ss_{p,q} \neq 0 \\
& \quad\quad\quad h \leftarrow h_{w_p} \\
& \quad\quad\quad \text{mean} \leftarrow \text{mean} + |h| \cdot \frac{ss_{p,q}}{\text{sum}} \\
& \quad\quad\quad \text{m2} \leftarrow \text{m2} + (h)^2 \cdot \frac{ss_{p,q}}{\text{sum}} \\
& \quad \text{design} \leftarrow \left[ \text{mean} + \beta \cdot \sqrt{\text{m2} - (\text{mean})^2} \right] \\
& \quad \text{new}_{1,q} \leftarrow \text{design} \\
& \text{new}
\end{aligned}
$$

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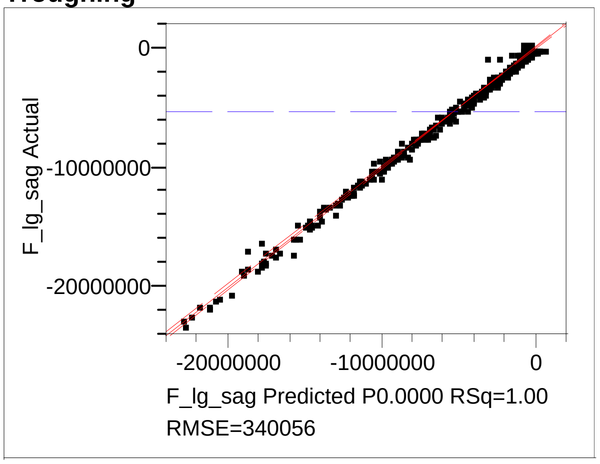
# Appendix D. Fit Parameters for Analytical Thesis Model

### Actual by Predicted Plot Longitudinal Troughing

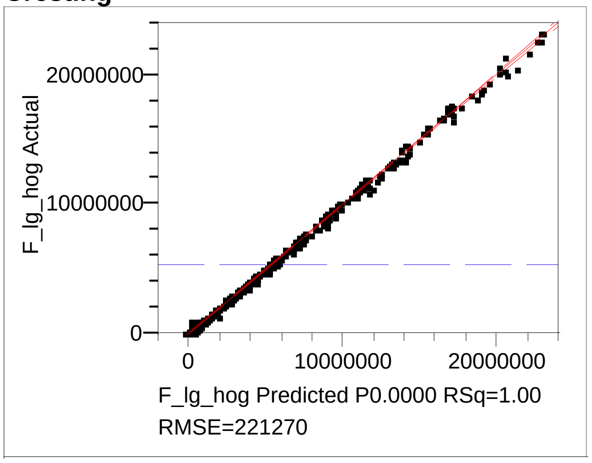



### Summary of Fit Longitudinal Troughing

| | |
|---|---|
| RSquare | 0.996193 |
| RSquare Adj | 0.995996 |
| Root Mean Square Error | 340056 |
| Mean of Response | -5293391 |
| Observations (or Sum Wgts) | 468 |

$$
\begin{aligned}
F_{trough} = {} & 3211000 + -61810 L_m + 2225000\frac{L_s}{L_m} - 10020000\frac{X_s}{L_m} - 273.9\left(L_m - 180\right)^2 \ldots \\
& + 76210\left(\frac{L_s}{L_m} - 0.375\right)\cdot\left(L_m - 180\right) - 136600\left(\frac{X_s}{L_m} + 0.3125\right)\cdot\left(L_m - 180\right) \ldots \\
& + -18420000\left(\frac{L_s}{L_m} - 0.375\right)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) - 2475000\left(\frac{X_s}{L_m} + 0.3125\right)^2 \ldots \\
& + -0.2781\cdot\left(L_m - 180\right)^3 + 408.3\cdot\left(L_m - 180\right)^2\cdot\left(\frac{L_s}{L_m} - 0.375\right) + 491600\left(\frac{L_s}{L_m} - 0.375\right)^2\cdot\left(L_m - 180\right) .. \\
& + -371.6\left(L_m - 180\right)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right) - 105500\left(L_m - 180\right)\cdot\left(\frac{L_s}{L_m} - 0.375\right)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) \ldots \\
& + 26770\left(\frac{X_s}{L_m} + 0.3125\right)^2\cdot\left(L_m - 180\right) + 170200000\left(\frac{L_s}{L_m} - 0.375\right)^3 \ldots \\
& + 21070000\left(\frac{X_s}{L_m} + 0.3125\right)^2\cdot\left(\frac{L_s}{L_m} - 0.375\right) + 37440000\left(\frac{X_s}{L_m} + 0.3125\right)^3 \ldots \\
& + 1225\left(L_m - 180\right)^2\cdot\left(\frac{L_s}{L_m} - 0.375\right)^2 + 483500\left(\frac{L_s}{L_m} - 0.375\right)^2\cdot\left(L_m - 180\right)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) \ldots \\
& + 416000\left(\frac{X_s}{L_m} + 0.3125\right)^3\cdot\left(L_m - 180\right) + 1911000000\left(\frac{L_s}{L_m} - 0.375\right)^4 \ldots \\
& + 285700000\left(\frac{L_s}{L_m} - 0.375\right)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right)^2 + 28010000\left(\frac{X_s}{L_m} + 0.3125\right)^4
\end{aligned}
$$

### Actual by Predicted Plot Longitudinal Cresting

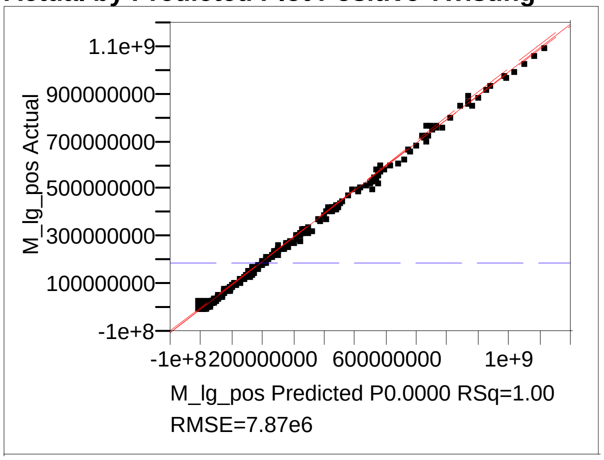



### Summary of Fit Longitudinal Cresting

| | |
|---|---|
| RSquare | 0.998383 |
| RSquare Adj | 0.998295 |
| Root Mean Square Error | 221269.5 |
| Mean of Response | 5328974 |
| Observations (or Sum Wgts) | 468 |

$$
\begin{aligned}
F_{crest} = {} & -2703000 + 58190 L_m + -3016000\frac{L_s}{L_m} + 9039000\frac{X_s}{L_m} + 269.00\left(L_m - 180\right)^2 \ldots \\
& + -50870\left(\frac{L_s}{L_m} - 0.375\right)\cdot\left(L_m - 180\right) + 118600\left(\frac{X_s}{L_m} + 0.3125\right)\cdot\left(L_m - 180\right) \ldots \\
& + 19850000\left(\frac{L_s}{L_m} - 0.375\right)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) + 0.3331\cdot\left(L_m - 180\right)^3 \ldots \\
& + -327.5\cdot\left(L_m - 180\right)^2\cdot\left(\frac{L_s}{L_m} - 0.375\right) + -255700\left(\frac{L_s}{L_m} - 0.375\right)^2\cdot\left(L_m - 180\right) \ldots \\
& + 451.3\cdot\left(L_m - 180\right)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right) + 157300\left(L_m - 180\right)\cdot\left(\frac{L_s}{L_m} - 0.375\right)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) \ldots \\
& + -11470000\left(\frac{X_s}{L_m} + 0.3125\right)^2\cdot\left(\frac{L_s}{L_m} - 0.375\right) + -36160000\left(\frac{X_s}{L_m} + 0.3125\right)^3 \ldots \\
& + -0.8241\cdot\left(L_m - 180\right)^3\cdot\left(\frac{L_s}{L_m} - 0.375\right) + -1240\cdot\left(L_m - 180\right)^2\cdot\left(\frac{L_s}{L_m} - 0.375\right)^2 \ldots \\
& + 0.5652\cdot\left(L_m - 180\right)^3\cdot\left(\frac{X_s}{L_m} + 0.3125\right) + 934.7\cdot\left(L_m - 180\right)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right)\cdot\left(\frac{L_s}{L_m} - 0.375\right) \ldots \\
& + 143.3\cdot\left(L_m - 180\right)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right)^2 + 364600\left(\frac{L_s}{L_m} - 0.375\right)^2\cdot\left(L_m - 180\right)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) \ldots \\
& + -122200\left(\frac{X_s}{L_m} + 0.3125\right)^2\cdot\left(L_m - 180\right)\cdot\left(\frac{L_s}{L_m} - 0.375\right) + -310300\left(\frac{X_s}{L_m} + 0.3125\right)^3\cdot\left(L_m - 180\right) .. \\
& + -640300000\left(\frac{L_s}{L_m} - 0.375\right)^4 + -157300000\left(\frac{X_s}{L_m} + 0.3125\right)^3\cdot\left(\frac{L_s}{L_m} - 0.375\right)
\end{aligned}
$$

**Actual by Predicted Plot Positive Twisting**

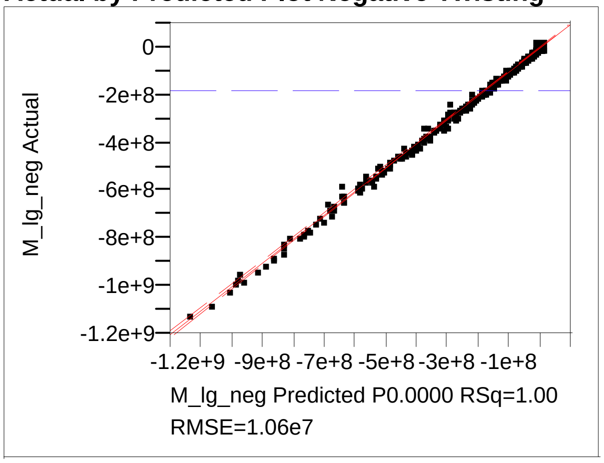



**Summary of Fit Positive Twisting**

| | |
|---|---|
| RSquare | 0.998925 |
| RSquare Adj | 0.998862 |
| Root Mean Square Error | 7872087 |
| Mean of Response | 1.8625e8 |
| Observations (or Sum Wgts) | 468 |

$$
\begin{aligned}
M_{pos} = {} & -454800000 + 1990000 L_m + 507700000 \frac{L_s}{L_m} + -13040000 \frac{X_s}{L_m} + 15350 \left(L_m - 180\right)^2 \ldots \\
& + 10620000 \left(\frac{L_s}{L_m} - 0.375\right)\cdot\left(L_m - 180\right) + -178900 \left(\frac{X_s}{L_m} + 0.3125\right)\cdot\left(L_m - 180\right) \ldots \\
& + -412500000 \left(\frac{L_s}{L_m} - 0.375\right)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) + 48.54 \left(L_m - 180\right)^3 \ldots \\
& + 76560 \left(L_m - 180\right)^2\cdot\left(\frac{L_s}{L_m} - 0.375\right) + 5028000 \left(\frac{L_s}{L_m} - 0.375\right)^2\cdot\left(L_m - 180\right) \ldots \\
& + -1562 \left(L_m - 180\right)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right) + -5227000 \left(L_m - 180\right)\cdot\left(\frac{L_s}{L_m} - 0.375\right)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) \ldots \\
& + 367400 \left(\frac{X_s}{L_m} + 0.3125\right)^2\cdot\left(L_m - 180\right) + -4038000000 \left(\frac{L_s}{L_m} - 0.375\right)^3 \ldots \\
& + -2110000000 \left(\frac{L_s}{L_m} - 0.375\right)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right) + 347900000 \left(\frac{X_s}{L_m} + 0.3125\right)^3 \ldots \\
& + 0.04053 \left(L_m - 180\right)^4 + 228.9 \left(L_m - 180\right)^3\cdot\left(\frac{L_s}{L_m} - 0.375\right) \ldots \\
& + 26720 \left(L_m - 180\right)^2\cdot\left(\frac{L_s}{L_m} - 0.375\right)^2 + -35500 \left(L_m - 180\right)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right)\cdot\left(\frac{L_s}{L_m} - 0.375\right) \ldots \\
& + -71960000 \left(\frac{L_s}{L_m} - 0.375\right)^3\cdot\left(L_m - 180\right) + -36190000 \left(\frac{L_s}{L_m} - 0.375\right)^2\cdot\left(L_m - 180\right)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) .. \\
& + 2871000 \left(\frac{X_s}{L_m} + 0.3125\right)^3\cdot\left(L_m - 180\right) + 3429000000 \left(\frac{L_s}{L_m} - 0.375\right)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right)^2 \ldots \\
& + 3328000000 \left(\frac{X_s}{L_m} + 0.3125\right)^3\cdot\left(\frac{L_s}{L_m} - 0.375\right) + -256800000 \left(\frac{X_s}{L_m} + 0.3125\right)^4
\end{aligned}
$$

**Actual by Predicted Plot Negative Twisting**




**Summary of Fit Negative Twisting**

| | |
|---|---|
| RSquare | 0.99804 |
| RSquare Adj | 0.99792 |
| Root Mean Square Error | 10575155 |
| Mean of Response | -1.849e8 |
| Observations (or Sum Wgts) | 468 |

$$M_{neg} = 470200000 + -1843000 L_m + -549900000\frac{L_s}{L_m} + 52640000\frac{X_s}{L_m} + -15260(L_m - 180)^2 \ldots$$

$$+ -10820000\left(\frac{L_s}{L_m} - 0.375\right)\cdot(L_m - 180) + 741500\left(\frac{X_s}{L_m} + 0.3125\right)\cdot(L_m - 180) \ldots$$

$$+ 842000000\left(\frac{L_s}{L_m} - 0.375\right)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) + -430100000\left(\frac{X_s}{L_m} + 0.3125\right)^2 + -47.46(L_m - 180)^3 \ldots$$

$$+ -78110(L_m - 180)^2\cdot\left(\frac{L_s}{L_m} - 0.375\right) + -5926000\left(\frac{L_s}{L_m} - 0.375\right)^2\cdot(L_m - 180) \ldots$$

$$+ 2805(L_m - 180)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right) + 7941000(L_m - 180)\cdot\left(\frac{L_s}{L_m} - 0.375\right)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) \ldots$$

$$+ -3490000\left(\frac{X_s}{L_m} + 0.3125\right)^2\cdot(L_m - 180) + 683300000\left(\frac{L_s}{L_m} - 0.375\right)^3 \ldots$$

$$+ -338275456\left(\frac{X_s}{L_m} + 0.3125\right)^3 + -224.6(L_m - 180)^3\cdot\left(\frac{L_s}{L_m} - 0.375\right) \ldots$$

$$+ 38050(L_m - 180)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right)\cdot\left(\frac{L_s}{L_m} - 0.375\right) + -14060(L_m - 180)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right)^2 \ldots$$

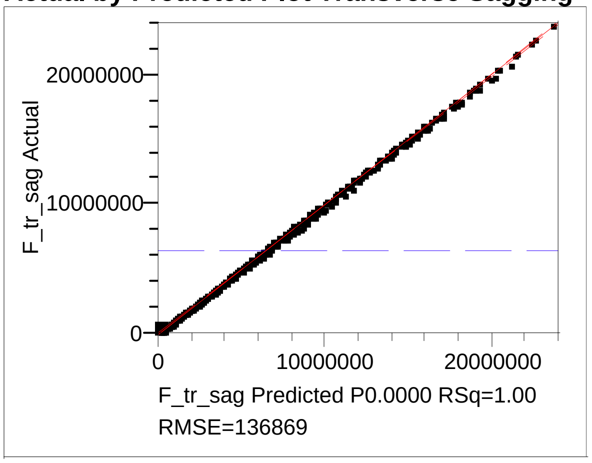
$$+ 79630000\left(\frac{L_s}{L_m} - 0.375\right)^3\cdot(L_m - 180) + 20870000\left(\frac{L_s}{L_m} - 0.375\right)^2\cdot(L_m - 180)\cdot\left(\frac{X_s}{L_m} + 0.3125\right) \ldots$$

$$+ -8802000\left(\frac{L_s}{L_m} - 0.375\right)\cdot(L_m - 180)\cdot\left(\frac{X_s}{L_m} + 0.3125\right)^2 + -2796000\left(\frac{X_s}{L_m} + 0.3125\right)^3\cdot(L_m - 180) \ldots$$

$$+ -37750000000\left(\frac{L_s}{L_m} - 0.375\right)^4 + 7867000000\left(\frac{L_s}{L_m} - 0.375\right)^2\cdot\left(\frac{X_s}{L_m} + 0.3125\right)^2 \ldots$$

$$+ -7595000000\left(\frac{X_s}{L_m} + 0.3125\right)^3\cdot\left(\frac{L_s}{L_m} - 0.375\right) + 2099000000\left(\frac{X_s}{L_m} + 0.3125\right)^4$$

**Actual by Predicted Plot Transverse Sagging**




**Summary of Fit Transverse Sagging**

| | |
|---|---|
| RSquare | 0.999459 |
| RSquare Adj | 0.999435 |
| Root Mean Square Error | 136868.7 |
| Mean of Response | 6480962 |
| Observations (or Sum Wgts) | 468 |

$$F_{tr\_sag} = -7051000 + 951100B_m + -17730000\frac{B_s}{B_m} + 3046000\frac{Y_s}{B_m} + 55500(B_m - 12.86)^2 \ldots$$
$$+ -3537000\left(\frac{B_s}{B_m} - 0.2357\right)\cdot(B_m - 12.86) + 60540000\left(\frac{B_s}{B_m} - 0.2357\right)^2 \ldots$$
$$+ 592100(B_m - 12.86)\cdot\left(\frac{Y_s}{B_m} - 1.25\right) + -10590000\left(\frac{B_s}{B_m} - 0.2357\right)\cdot\left(\frac{Y_s}{B_m} - 1.25\right) \ldots$$
$$+ 1055(B_m - 12.86)^3 + -216600(B_m - 12.86)^2\cdot\left(\frac{B_s}{B_m} - 0.2357\right) + 12750000\left(\frac{B_s}{B_m} - 0.2357\right)^2\cdot(B_m - 12.86) ..$$
$$+ 38890(B_m - 12.86)^2\cdot\left(\frac{Y_s}{B_m} - 1.25\right) + -2246000(B_m - 12.86)\cdot\left(\frac{B_s}{B_m} - 0.2357\right)\cdot\left(\frac{Y_s}{B_m} - 1.25\right) \ldots$$
$$+ -143000\left(\frac{Y_s}{B_m} - 1.25\right)^2\cdot(B_m - 12.86) + 35.06(B_m - 12.86)^4 \ldots$$
$$+ -3806(B_m - 12.86)^3\cdot\left(\frac{B_s}{B_m} - 0.2357\right) + 740600(B_m - 12.86)^2\cdot\left(\frac{B_s}{B_m} - 0.2357\right)^2 \ldots$$
$$+ -135100(B_m - 12.86)^2\cdot\left(\frac{B_s}{B_m} - 0.2357\right)\cdot\left(\frac{Y_s}{B_m} - 1.25\right) + 1063000\left(\frac{Y_s}{B_m} - 1.25\right)^3\cdot(B_m - 12.86) \ldots$$
$$+ -17961988\left(\frac{Y_s}{B_m} - 1.25\right)^4$$

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# Appendix E. Comparison of Results for Longitudinal Troughing

## Analytical Troughing

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.826 | 0.938 | 0.927 | 0.933 | 1.000 | 1.000 | 0.965 | 0.965 | 1.000 | 1.000 | 0.807 |
| 2 | 0.883 | 0.978 | 0.939 | 0.913 | 1.000 | 1.000 | 0.945 | 0.945 | 1.000 | 1.000 | 0.882 |
| 3 | 0.971 | 0.996 | 0.986 | 0.985 | 1.000 | 1.000 | 0.990 | 0.990 | 1.000 | 1.000 | 0.923 |
| 4 | 0.939 | 0.990 | 0.955 | 0.991 | 0.998 | 0.998 | 0.995 | 0.995 | 1.000 | 1.000 | 0.932 |
| 5 | 0.979 | 1.000 | 0.983 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.979 |
| 6 | 0.957 | 0.988 | 0.976 | 0.994 | 1.000 | 1.000 | 0.996 | 0.996 | 1.000 | 1.000 | 0.901 |
| 7 | 0.913 | 0.990 | 0.940 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.906 |

## MAESTRO Troughing

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.848 | 0.943 | 0.937 | 0.939 | 1.000 | 1.000 | 0.969 | 0.969 | 1.000 | 1.000 | 0.831 |
| 2 | 0.898 | 0.980 | 0.944 | 0.918 | 1.000 | 1.000 | 0.948 | 0.948 | 1.000 | 1.000 | 0.897 |
| 3 | 0.972 | 0.997 | 0.988 | 0.986 | 1.000 | 1.000 | 0.991 | 0.991 | 1.000 | 1.000 | 0.940 |
| 4 | 0.949 | 0.987 | 0.964 | 0.991 | 1.000 | 1.000 | 0.995 | 0.995 | 1.000 | 1.000 | 0.944 |
| 5 | 0.977 | 1.000 | 0.983 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.977 |
| 6 | 0.967 | 0.986 | 0.983 | 0.995 | 1.000 | 1.000 | 0.997 | 0.997 | 1.000 | 1.000 | 0.923 |
| 7 | 0.918 | 0.967 | 0.945 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.908 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
```

## Analytical Troughing

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.896 | 0.842 | 0.965 | 0.862 | 1.000 | 1.000 | 1.000 | 0.772 | 0.939 | 1.000 | 0.955 | 0.977 | 0.956 | 1.000 | 1.000 |
| 2 | 0.784 | 0.964 | 0.898 | 0.714 | 1.000 | 0.864 | 1.000 | 0.933 | 1.000 | 1.000 | 0.980 | 1.000 | 0.935 | 1.000 | 0.969 |
| 3 | 0.840 | 0.851 | 0.993 | 0.755 | 1.000 | 0.974 | 1.000 | 0.760 | 1.000 | 1.000 | 0.960 | 1.000 | 0.953 | 1.000 | 0.974 |
| 4 | 0.939 | 0.939 | 0.992 | 1.000 | 0.901 | 0.985 | 0.899 | 1.000 | 0.977 | 0.974 | 1.000 | 0.978 | 1.000 | 0.975 | 1.000 |
| 5 | 0.975 | 0.985 | 0.982 | 0.961 | 0.977 | 0.969 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.983 | 0.984 | 0.984 |
| 6 | 0.842 | 0.852 | 0.994 | 1.000 | 0.767 | 1.000 | 0.753 | 1.000 | 0.973 | 0.953 | 1.000 | 0.974 | 1.000 | 0.958 | 1.000 |
| 7 | 0.878 | 0.882 | 0.981 | 0.793 | 1.000 | 0.871 | 1.000 | 0.798 | 1.000 | 1.000 | 0.869 | 0.871 | 0.870 | 1.000 | 0.884 |

## MAESTRO Troughing

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.935 | 0.884 | 0.969 | 0.915 | 1.000 | 1.000 | 1.000 | 0.830 | 0.946 | 1.000 | 0.969 | 0.984 | 0.971 | 1.000 | 1.000 |
| 2 | 0.820 | 0.973 | 0.918 | 0.764 | 1.000 | 0.897 | 1.000 | 0.946 | 1.000 | 1.000 | 0.984 | 1.000 | 0.949 | 1.000 | 0.975 |
| 3 | 0.876 | 0.884 | 0.995 | 0.810 | 1.000 | 0.980 | 1.000 | 0.811 | 0.983 | 1.000 | 0.971 | 1.000 | 0.963 | 1.000 | 0.980 |
| 4 | 0.945 | 0.958 | 0.985 | 1.000 | 0.931 | 1.000 | 0.909 | 1.000 | 0.972 | 0.979 | 1.000 | 0.982 | 1.000 | 0.980 | 1.000 |
| 5 | 0.984 | 0.991 | 0.989 | 0.974 | 0.985 | 0.980 | 1.000 | 1.000 | 1.000 | 1.000 | 0.994 | 1.000 | 0.987 | 0.988 | 0.988 |
| 6 | 0.882 | 0.892 | 0.994 | 1.000 | 0.828 | 1.000 | 0.813 | 1.000 | 0.979 | 0.965 | 1.000 | 0.981 | 1.000 | 0.970 | 1.000 |
| 7 | 0.913 | 0.883 | 0.981 | 0.839 | 1.000 | 1.000 | 1.000 | 0.807 | 0.888 | 1.000 | 0.887 | 0.890 | 0.889 | 1.000 | 1.000 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Troughing

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.817 | 0.945 | 0.907 | 0.951 | 0.992 | 0.992 | 0.975 | 0.975 | 1.000 | 1.000 | 0.797 |
| 2 | 0.894 | 0.981 | 0.897 | 0.959 | 0.999 | 0.999 | 0.975 | 0.975 | 1.000 | 1.000 | 0.884 |
| 3 | 0.877 | 0.779 | 0.924 | 0.983 | 1.000 | 1.000 | 0.990 | 0.990 | 1.000 | 1.000 | 0.753 |
| 4 | 0.935 | 0.911 | 0.954 | 0.990 | 0.986 | 0.986 | 0.994 | 0.994 | 1.000 | 1.000 | 0.861 |
| 5 | 0.823 | 0.992 | 0.867 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.824 |
| 6 | 0.838 | 0.693 | 0.906 | 0.980 | 1.000 | 1.000 | 0.988 | 0.988 | 1.000 | 1.000 | 0.657 |
| 7 | 0.585 | 0.941 | 0.693 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.583 |

MAESTRO Troughing

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.843 | 0.941 | 0.929 | 0.956 | 0.994 | 0.994 | 0.977 | 0.977 | 1.000 | 1.000 | 0.823 |
| 2 | 0.911 | 0.983 | 0.919 | 0.958 | 1.000 | 1.000 | 0.974 | 0.974 | 1.000 | 1.000 | 0.903 |
| 3 | 0.903 | 0.825 | 0.941 | 0.987 | 1.000 | 1.000 | 0.992 | 0.992 | 1.000 | 1.000 | 0.803 |
| 4 | 0.947 | 0.930 | 0.962 | 0.992 | 0.989 | 0.989 | 0.995 | 0.995 | 1.000 | 1.000 | 0.891 |
| 5 | 0.873 | 0.972 | 0.907 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.873 |
| 6 | 0.870 | 0.752 | 0.926 | 0.985 | 1.000 | 1.000 | 0.991 | 0.991 | 1.000 | 1.000 | 0.719 |
| 7 | 0.658 | 0.963 | 0.750 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.657 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Troughing

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.964 | 0.982 | 0.985 | 0.963 | 1.000 | 0.989 | 1.000 | 0.971 | 1.000 | 0.995 | 0.988 | 0.992 | 0.977 | 0.989 | 0.983 |
| 2 | 0.932 | 0.932 | 0.997 | 0.897 | 1.000 | 1.000 | 0.985 | 0.886 | 0.937 | 1.000 | 0.981 | 0.992 | 0.925 | 0.937 | 0.931 |
| 3 | 0.890 | 0.900 | 0.994 | 0.829 | 0.986 | 0.937 | 1.000 | 0.843 | 1.000 | 0.945 | 0.933 | 0.939 | 0.972 | 1.000 | 0.984 |
| 4 | 0.988 | 0.976 | 0.986 | 0.975 | 0.976 | 0.976 | 0.984 | 0.967 | 0.980 | 0.976 | 0.976 | 0.976 | 1.000 | 1.000 | 1.000 |
| 5 | 0.962 | 0.987 | 0.981 | 0.961 | 0.971 | 0.968 | 0.942 | 0.899 | 0.924 | 0.986 | 0.985 | 0.986 | 0.878 | 0.891 | 0.884 |
| 6 | 0.888 | 0.896 | 0.993 | 0.982 | 0.833 | 0.938 | 0.829 | 1.000 | 0.984 | 0.918 | 0.929 | 0.923 | 1.000 | 0.976 | 1.000 |
| 7 | 0.892 | 0.918 | 0.974 | 0.820 | 1.000 | 0.896 | 0.853 | 0.787 | 0.819 | 0.929 | 0.897 | 0.923 | 0.830 | 0.840 | 0.835 |

MAESTRO Troughing

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.971 | 0.987 | 0.988 | 0.968 | 1.000 | 0.989 | 1.000 | 0.978 | 0.994 | 0.994 | 0.990 | 0.992 | 0.984 | 0.993 | 0.989 |
| 2 | 0.950 | 0.950 | 0.998 | 0.924 | 1.000 | 1.000 | 0.989 | 0.914 | 0.951 | 1.000 | 0.986 | 0.994 | 0.942 | 0.951 | 0.946 |
| 3 | 0.915 | 0.923 | 0.996 | 0.868 | 0.990 | 0.951 | 1.000 | 0.876 | 1.000 | 0.957 | 0.948 | 0.952 | 0.978 | 1.000 | 0.988 |
| 4 | 0.982 | 0.984 | 0.988 | 0.987 | 0.975 | 0.981 | 0.973 | 0.978 | 0.983 | 0.980 | 0.982 | 0.981 | 1.000 | 1.000 | 1.000 |
| 5 | 0.970 | 0.993 | 0.988 | 0.972 | 0.981 | 0.976 | 0.960 | 0.934 | 0.951 | 0.990 | 0.989 | 0.989 | 0.913 | 0.923 | 0.918 |
| 6 | 0.918 | 0.927 | 0.995 | 0.988 | 0.881 | 0.950 | 0.873 | 1.000 | 0.988 | 0.936 | 0.945 | 0.940 | 1.000 | 0.983 | 1.000 |
| 7 | 0.926 | 0.909 | 0.986 | 0.866 | 1.000 | 0.947 | 0.882 | 0.847 | 0.864 | 0.943 | 0.910 | 0.912 | 0.865 | 0.870 | 0.867 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Troughing

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.865 | 0.969 | 0.921 | 0.922 | 1.000 | 1.000 | 0.928 | 0.928 | 1.000 | 1.000 | 0.864 |
| 2 | 0.674 | 0.896 | 0.835 | 0.674 | 1.000 | 1.000 | 0.876 | 0.876 | 1.000 | 1.000 | 0.677 |
| 3 | 0.528 | 0.671 | 0.746 | 0.915 | 1.000 | 1.000 | 0.958 | 0.958 | 1.000 | 1.000 | 0.507 |
| 5 | 0.440 | 0.348 | 0.748 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.440 |
| 6 | 0.870 | 0.975 | 0.948 | 0.947 | 0.988 | 0.988 | 0.951 | 0.951 | 1.000 | 1.000 | 0.823 |

## MAESTRO Troughing

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.897 | 0.976 | 0.931 | 0.941 | 0.999 | 0.999 | 0.945 | 0.945 | 1.000 | 1.000 | 0.839 |
| 2 | 0.717 | 0.929 | 0.870 | 0.769 | 1.000 | 1.000 | 0.915 | 0.915 | 1.000 | 1.000 | 0.720 |
| 3 | 0.557 | 0.759 | 0.761 | 0.985 | 0.995 | 0.995 | 0.993 | 0.993 | 1.000 | 1.000 | 0.541 |
| 5 | 0.462 | 0.377 | 0.762 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.463 |
| 6 | 0.890 | 0.985 | 0.952 | 0.958 | 0.986 | 0.986 | 0.961 | 0.961 | 1.000 | 1.000 | 0.859 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Troughing

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.837 | 0.813 | 0.986 | 1.000 | 0.650 | 0.837 | 0.736 | 1.000 | 1.000 | 0.843 | 1.000 | 0.848 | 1.000 | 0.846 | 1.000 |
| 2 | 0.757 | 0.785 | 0.976 | 0.660 | 1.000 | 1.000 | 1.000 | 0.556 | 0.786 | 1.000 | 1.000 | 1.000 | 0.767 | 0.798 | 0.786 |
| 3 | 0.916 | 0.918 | 0.948 | 0.974 | 0.893 | 0.968 | 0.921 | 0.930 | 0.974 | 0.968 | 1.000 | 0.977 | 0.865 | 0.899 | 0.882 |
| 5 | 0.929 | 0.982 | 0.955 | 0.919 | 0.954 | 0.937 | 0.851 | 0.857 | 0.854 | 0.957 | 0.952 | 0.955 | 0.872 | 0.870 | 0.871 |
| 6 | 0.837 | 0.801 | 0.979 | 0.695 | 1.000 | 0.939 | 1.000 | 0.671 | 0.842 | 0.983 | 0.839 | 0.940 | 0.839 | 1.000 | 0.843 |

## MAESTRO Troughing

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.865 | 0.841 | 0.986 | 1.000 | 0.693 | 0.859 | 0.784 | 1.000 | 1.000 | 0.868 | 0.990 | 0.872 | 1.000 | 0.871 | 1.000 |
| 2 | 0.790 | 0.819 | 0.976 | 0.706 | 1.000 | 1.000 | 1.000 | 0.614 | 0.818 | 1.000 | 1.000 | 1.000 | 0.793 | 0.824 | 0.811 |
| 3 | 0.943 | 0.923 | 0.964 | 1.000 | 0.894 | 0.965 | 0.931 | 0.942 | 0.970 | 0.973 | 1.000 | 0.980 | 0.894 | 0.916 | 0.905 |
| 5 | 0.929 | 0.987 | 0.958 | 0.916 | 0.954 | 0.934 | 0.890 | 0.873 | 0.881 | 0.958 | 0.953 | 0.956 | 0.873 | 0.881 | 0.877 |
| 6 | 0.864 | 0.829 | 0.980 | 0.736 | 1.000 | 0.947 | 1.000 | 0.719 | 0.866 | 0.983 | 0.864 | 0.950 | 0.863 | 1.000 | 0.867 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Troughing

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.716 | 0.873 | 0.864 | 0.897 | 1.000 | 1.000 | 0.946 | 0.946 | 1.000 | 1.000 | 0.701 |
| 2 | 0.800 | 0.952 | 0.871 | 0.828 | 1.000 | 1.000 | 0.888 | 0.888 | 1.000 | 1.000 | 0.801 |
| 3 | 0.950 | 0.979 | 0.984 | 0.982 | 0.999 | 0.999 | 0.989 | 0.989 | 1.000 | 1.000 | 0.924 |
| 4 | 0.963 | 0.981 | 0.970 | 0.985 | 0.987 | 0.987 | 0.995 | 0.995 | 1.000 | 1.000 | 0.958 |
| 5 | 0.890 | 0.959 | 0.897 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.888 |
| 6 | 0.953 | 0.983 | 0.964 | 0.997 | 0.982 | 0.982 | 1.000 | 1.000 | 1.000 | 1.000 | 0.873 |
| 7 | 0.814 | 0.956 | 0.856 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.815 |

MAESTRO Troughing

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.743 | 0.880 | 0.874 | 0.921 | 1.000 | 1.000 | 0.959 | 0.959 | 1.000 | 1.000 | 0.730 |
| 2 | 0.832 | 0.960 | 0.907 | 0.875 | 1.000 | 1.000 | 0.921 | 0.921 | 1.000 | 1.000 | 0.833 |
| 3 | 0.964 | 0.998 | 0.981 | 0.992 | 0.990 | 0.990 | 0.995 | 0.995 | 1.000 | 1.000 | 0.922 |
| 4 | 0.971 | 1.000 | 0.968 | 1.000 | 0.982 | 0.982 | 1.000 | 1.000 | 1.000 | 1.000 | 0.961 |
| 5 | 0.903 | 0.946 | 0.905 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.902 |
| 6 | 0.965 | 1.000 | 0.964 | 0.998 | 0.978 | 0.978 | 1.000 | 1.000 | 1.000 | 1.000 | 0.888 |
| 7 | 0.822 | 0.948 | 0.864 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.823 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Troughing

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.950 | 0.981 | 0.968 | 0.941 | 0.989 | 0.965 | 0.969 | 0.944 | 0.957 | 0.987 | 0.980 | 0.983 | 0.962 | 0.978 | 0.972 |
| 2 | 0.871 | 0.883 | 0.986 | 0.825 | 1.000 | 1.000 | 1.000 | 0.799 | 0.966 | 1.000 | 0.972 | 0.987 | 0.942 | 1.000 | 0.972 |
| 3 | 0.835 | 0.842 | 0.994 | 0.777 | 1.000 | 0.978 | 1.000 | 0.774 | 0.976 | 1.000 | 0.956 | 0.985 | 0.939 | 1.000 | 0.974 |
| 4 | 0.879 | 0.919 | 0.971 | 1.000 | 0.639 | 1.000 | 0.624 | 1.000 | 0.652 | 0.652 | 1.000 | 0.653 | 1.000 | 0.653 | 0.961 |
| 5 | 0.972 | 0.977 | 0.975 | 0.957 | 0.964 | 0.961 | 0.973 | 0.953 | 0.964 | 0.990 | 0.990 | 0.990 | 0.932 | 0.938 | 0.935 |
| 6 | 0.828 | 0.832 | 0.994 | 1.000 | 0.762 | 0.975 | 0.765 | 1.000 | 0.978 | 0.940 | 1.000 | 0.975 | 1.000 | 0.949 | 1.000 |
| 7 | 0.918 | 0.918 | 0.946 | 0.854 | 1.000 | 0.911 | 0.969 | 0.860 | 0.932 | 0.967 | 0.907 | 0.911 | 0.911 | 1.000 | 0.942 |

MAESTRO Troughing

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.969 | 0.984 | 0.979 | 0.962 | 0.990 | 0.976 | 0.972 | 0.952 | 0.962 | 0.986 | 0.982 | 0.984 | 0.976 | 0.981 | 0.978 |
| 2 | 0.885 | 0.908 | 0.986 | 0.838 | 1.000 | 1.000 | 1.000 | 0.828 | 0.975 | 1.000 | 0.976 | 0.988 | 0.956 | 1.000 | 0.978 |
| 3 | 0.866 | 0.870 | 0.996 | 0.817 | 1.000 | 0.982 | 1.000 | 0.814 | 0.981 | 1.000 | 0.963 | 0.985 | 0.952 | 1.000 | 0.980 |
| 4 | 0.891 | 0.925 | 0.976 | 1.000 | 0.662 | 1.000 | 0.646 | 1.000 | 0.673 | 0.673 | 1.000 | 0.674 | 1.000 | 0.674 | 0.964 |
| 5 | 0.984 | 0.984 | 0.984 | 0.968 | 0.968 | 0.968 | 0.978 | 0.962 | 0.971 | 0.987 | 0.988 | 0.988 | 0.942 | 0.947 | 0.945 |
| 6 | 0.862 | 0.865 | 0.995 | 1.000 | 0.807 | 0.980 | 0.812 | 1.000 | 0.983 | 0.950 | 0.992 | 0.979 | 1.000 | 0.962 | 1.000 |
| 7 | 0.944 | 0.918 | 0.951 | 0.890 | 1.000 | 0.958 | 0.966 | 0.869 | 0.925 | 0.979 | 0.921 | 0.925 | 0.926 | 1.000 | 0.958 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Troughing

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.782 | 0.919 | 0.943 | 0.900 | 1.000 | 1.000 | 0.948 | 0.948 | 1.000 | 1.000 | 0.775 |
| 2 | 0.836 | 0.956 | 0.910 | 0.862 | 1.000 | 1.000 | 0.910 | 0.910 | 1.000 | 1.000 | 0.836 |
| 3 | 0.964 | 0.995 | 0.981 | 0.978 | 1.000 | 1.000 | 0.986 | 0.986 | 1.000 | 1.000 | 0.922 |
| 4 | 0.949 | 0.990 | 0.969 | 0.981 | 1.000 | 1.000 | 0.988 | 0.988 | 1.000 | 1.000 | 0.939 |
| 5 | 0.967 | 0.996 | 0.977 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.965 |
| 6 | 0.968 | 0.984 | 0.982 | 0.992 | 1.000 | 1.000 | 0.995 | 0.995 | 1.000 | 1.000 | 0.893 |
| 7 | 0.929 | 0.947 | 0.958 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.904 |

## MAESTRO Troughing

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.819 | 0.920 | 0.954 | 0.921 | 1.000 | 1.000 | 0.959 | 0.959 | 1.000 | 1.000 | 0.811 |
| 2 | 0.867 | 0.962 | 0.931 | 0.892 | 1.000 | 1.000 | 0.930 | 0.930 | 1.000 | 1.000 | 0.865 |
| 3 | 0.970 | 0.996 | 0.985 | 0.982 | 1.000 | 1.000 | 0.989 | 0.989 | 1.000 | 1.000 | 0.939 |
| 4 | 0.962 | 0.986 | 0.978 | 0.986 | 1.000 | 1.000 | 0.992 | 0.992 | 1.000 | 1.000 | 0.953 |
| 5 | 0.965 | 0.986 | 0.978 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.965 |
| 6 | 0.970 | 0.984 | 0.990 | 0.994 | 0.998 | 0.998 | 0.997 | 0.997 | 1.000 | 1.000 | 0.907 |
| 7 | 0.939 | 0.933 | 0.967 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.904 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Troughing

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.914 | 0.921 | 0.983 | 0.897 | 1.000 | 0.986 | 1.000 | 0.878 | 0.964 | 1.000 | 0.977 | 0.987 | 0.959 | 1.000 | 0.979 |
| 2 | 0.891 | 0.900 | 0.985 | 0.857 | 1.000 | 0.989 | 1.000 | 0.850 | 0.987 | 1.000 | 0.978 | 0.990 | 0.956 | 1.000 | 0.983 |
| 3 | 0.814 | 0.822 | 0.994 | 0.748 | 1.000 | 0.974 | 1.000 | 0.748 | 0.973 | 1.000 | 0.948 | 1.000 | 0.933 | 1.000 | 0.972 |
| 4 | 0.907 | 0.864 | 0.976 | 1.000 | 0.811 | 0.953 | 0.862 | 1.000 | 0.965 | 0.957 | 1.000 | 0.968 | 1.000 | 0.944 | 0.962 |
| 5 | 0.978 | 0.983 | 0.984 | 0.963 | 0.977 | 0.970 | 1.000 | 1.000 | 1.000 | 0.994 | 0.986 | 0.994 | 0.985 | 0.985 | 0.986 |
| 6 | 0.811 | 0.816 | 0.993 | 1.000 | 0.746 | 1.000 | 0.739 | 1.000 | 0.972 | 0.938 | 1.000 | 0.973 | 1.000 | 0.939 | 1.000 |
| 7 | 0.888 | 0.875 | 0.985 | 0.803 | 1.000 | 0.921 | 1.000 | 0.792 | 0.874 | 1.000 | 0.871 | 0.874 | 0.873 | 1.000 | 0.923 |

MAESTRO Troughing

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.946 | 0.940 | 0.980 | 0.937 | 1.000 | 0.992 | 1.000 | 0.908 | 0.963 | 0.993 | 0.982 | 0.989 | 0.973 | 1.000 | 0.985 |
| 2 | 0.911 | 0.921 | 0.986 | 0.885 | 1.000 | 0.989 | 1.000 | 0.878 | 0.991 | 1.000 | 0.983 | 0.992 | 0.963 | 1.000 | 0.985 |
| 3 | 0.856 | 0.860 | 0.996 | 0.804 | 1.000 | 0.980 | 1.000 | 0.800 | 0.979 | 1.000 | 0.960 | 1.000 | 0.948 | 1.000 | 0.978 |
| 4 | 0.916 | 0.891 | 0.979 | 1.000 | 0.848 | 0.965 | 0.876 | 1.000 | 0.960 | 0.963 | 1.000 | 0.975 | 1.000 | 0.954 | 0.968 |
| 5 | 0.986 | 0.988 | 0.989 | 0.975 | 0.985 | 0.980 | 1.000 | 1.000 | 1.000 | 0.995 | 0.989 | 0.995 | 0.989 | 0.990 | 0.989 |
| 6 | 0.856 | 0.861 | 0.993 | 1.000 | 0.806 | 1.000 | 0.799 | 1.000 | 0.979 | 0.954 | 1.000 | 0.980 | 1.000 | 0.955 | 1.000 |
| 7 | 0.919 | 0.873 | 0.973 | 0.844 | 1.000 | 1.000 | 1.000 | 0.798 | 0.885 | 1.000 | 0.886 | 0.889 | 0.889 | 1.000 | 0.944 |

POSITIVE NUMBER: CONSTRAINT SATISFIED. | THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED. | BETWEEN +1. AND -1.
1.000 : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
-2.000 : CONSTRAINT SUPPRESSED.
-- : STRAKE NOT EVALUATED.

# Appendix F. Comparison of Results for Longitudinal Cresting

## Analytical Cresting

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.858 | 0.934 | 0.944 | 0.943 | 1.000 | 1.000 | 0.971 | 0.971 | 1.000 | 1.000 | 0.841 |
| 2 | 0.917 | 0.982 | 0.951 | 0.926 | 1.000 | 1.000 | 0.953 | 0.953 | 1.000 | 1.000 | 0.915 |
| 3 | 0.974 | 0.997 | 0.988 | 0.987 | 1.000 | 1.000 | 0.992 | 0.992 | 1.000 | 1.000 | 0.972 |
| 4 | 0.953 | 0.983 | 0.970 | 0.986 | 1.000 | 1.000 | 0.992 | 0.992 | 1.000 | 1.000 | 0.936 |
| 5 | 0.950 | 0.931 | 0.983 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.950 |
| 6 | 0.967 | 0.982 | 0.980 | 0.992 | 1.000 | 1.000 | 0.995 | 0.995 | 1.000 | 1.000 | 0.952 |
| 7 | 0.928 | 0.950 | 0.961 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.922 |

## MAESTRO Cresting

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.834 | 0.970 | 0.925 | 0.947 | 1.000 | 1.000 | 0.973 | 0.973 | 1.000 | 1.000 | 0.825 |
| 2 | 0.902 | 0.979 | 0.945 | 0.916 | 1.000 | 1.000 | 0.947 | 0.947 | 1.000 | 1.000 | 0.901 |
| 3 | 0.969 | 0.986 | 0.980 | 0.986 | 1.000 | 1.000 | 0.991 | 0.991 | 1.000 | 1.000 | 0.961 |
| 4 | 0.942 | 0.998 | 0.958 | 0.991 | 0.999 | 0.999 | 0.995 | 0.995 | 1.000 | 1.000 | 0.942 |
| 5 | 0.966 | 0.968 | 0.987 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.966 |
| 6 | 0.957 | 0.999 | 0.969 | 0.997 | 1.000 | 1.000 | 0.998 | 0.998 | 1.000 | 1.000 | 0.949 |
| 7 | 0.913 | 0.988 | 0.937 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.913 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
```

Analytical Cresting

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.979 | 0.948 | 0.981 | 0.974 | 1.000 | 1.000 | 1.000 | 0.922 | 0.968 | 0.994 | 0.984 | 0.990 | 0.993 | 1.000 | 1.000 |
| 2 | 0.895 | 0.987 | 0.952 | 0.868 | 1.000 | 0.948 | 1.000 | 0.963 | 1.000 | 1.000 | 0.992 | 1.000 | 0.972 | 0.996 | 0.985 |
| 3 | 0.958 | 0.965 | 0.996 | 0.936 | 1.000 | 0.994 | 1.000 | 0.938 | 1.000 | 1.000 | 0.993 | 1.000 | 0.987 | 1.000 | 0.993 |
| 4 | 0.962 | 0.925 | 0.980 | 0.936 | 1.000 | 1.000 | 1.000 | 0.878 | 0.961 | 1.000 | 0.974 | 0.978 | 0.977 | 1.000 | 1.000 |
| 5 | 0.988 | 0.992 | 0.990 | 1.000 | 1.000 | 1.000 | 0.986 | 0.991 | 0.988 | 0.988 | 0.991 | 0.989 | 1.000 | 1.000 | 1.000 |
| 6 | 0.960 | 0.970 | 0.995 | 1.000 | 0.949 | 1.000 | 0.937 | 1.000 | 0.991 | 0.987 | 1.000 | 0.993 | 1.000 | 0.993 | 1.000 |
| 7 | 0.924 | 0.904 | 0.988 | 0.862 | 1.000 | 1.000 | 1.000 | 0.842 | 0.907 | 1.000 | 0.906 | 0.908 | 0.908 | 1.000 | 1.000 |

MAESTRO Cresting

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.812 | 0.860 | 0.972 | 0.742 | 1.000 | 0.953 | 1.000 | 0.802 | 1.000 | 1.000 | 0.955 | 0.972 | 0.956 | 1.000 | 0.987 |
| 2 | 0.871 | 0.970 | 0.947 | 0.837 | 1.000 | 0.944 | 1.000 | 0.937 | 1.000 | 1.000 | 0.988 | 1.000 | 0.966 | 1.000 | 0.983 |
| 3 | 0.956 | 0.962 | 0.994 | 0.928 | 1.000 | 0.990 | 1.000 | 0.939 | 1.000 | 1.000 | 0.988 | 0.993 | 0.990 | 1.000 | 0.996 |
| 4 | 0.932 | 0.868 | 0.930 | 0.902 | 0.791 | 0.884 | 1.000 | 0.951 | 1.000 | 0.975 | 0.980 | 1.000 | 0.975 | 0.964 | 0.973 |
| 5 | 0.950 | 0.971 | 0.960 | 0.921 | 0.947 | 0.934 | 1.000 | 1.000 | 1.000 | 0.989 | 0.976 | 0.976 | 0.976 | 0.997 | 0.979 |
| 6 | 0.931 | 0.909 | 0.988 | 1.000 | 0.857 | 0.979 | 0.886 | 1.000 | 1.000 | 0.984 | 1.000 | 0.994 | 1.000 | 0.973 | 0.985 |
| 7 | 0.903 | 0.805 | 0.873 | 0.865 | 0.721 | 0.806 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.916 | 0.908 | 0.913 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Cresting

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.899 | 0.952 | 0.957 | 0.971 | 0.996 | 0.996 | 0.985 | 0.985 | 1.000 | 1.000 | 0.884 |
| 2 | 0.950 | 0.991 | 0.960 | 0.969 | 1.000 | 1.000 | 0.981 | 0.981 | 1.000 | 1.000 | 0.947 |
| 3 | 0.947 | 0.897 | 0.970 | 0.994 | 1.000 | 1.000 | 0.997 | 0.997 | 1.000 | 1.000 | 0.887 |
| 4 | 0.962 | 0.965 | 0.973 | 0.999 | 0.992 | 0.992 | 0.999 | 0.999 | 1.000 | 1.000 | 0.945 |
| 5 | 0.928 | 0.956 | 0.947 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.929 |
| 6 | 0.924 | 0.846 | 0.955 | 0.989 | 1.000 | 1.000 | 0.993 | 0.993 | 1.000 | 1.000 | 0.819 |
| 7 | 0.934 | 0.931 | 0.963 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.926 |

MAESTRO Cresting

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.881 | 0.975 | 0.935 | 0.971 | 0.993 | 0.993 | 0.985 | 0.985 | 1.000 | 1.000 | 0.877 |
| 2 | 0.945 | 0.991 | 0.949 | 0.971 | 1.000 | 1.000 | 0.982 | 0.982 | 1.000 | 1.000 | 0.942 |
| 3 | 0.936 | 0.871 | 0.962 | 0.994 | 1.000 | 1.000 | 0.996 | 0.996 | 1.000 | 1.000 | 0.860 |
| 4 | 0.951 | 0.955 | 0.971 | 0.999 | 0.988 | 0.988 | 1.000 | 1.000 | 1.000 | 1.000 | 0.920 |
| 5 | 0.861 | 0.981 | 0.895 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.861 |
| 6 | 0.909 | 0.805 | 0.943 | 0.985 | 1.000 | 1.000 | 0.991 | 0.991 | 1.000 | 1.000 | 0.777 |
| 7 | 0.846 | 0.777 | 0.940 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.846 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Cresting

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.986 | 0.994 | 0.994 | 0.985 | 1.000 | 0.995 | 0.995 | 0.992 | 0.994 | 0.994 | 0.994 | 0.994 | 0.993 | 0.997 | 0.995 |
| 2 | 0.977 | 0.978 | 0.998 | 0.967 | 1.000 | 1.000 | 0.995 | 0.959 | 0.977 | 1.000 | 0.994 | 0.997 | 0.972 | 0.977 | 0.974 |
| 3 | 0.973 | 0.980 | 0.997 | 0.958 | 0.981 | 0.971 | 1.000 | 0.966 | 1.000 | 0.975 | 0.972 | 0.973 | 0.992 | 1.000 | 0.996 |
| 4 | 0.967 | 0.946 | 0.989 | 0.944 | 1.000 | 0.991 | 1.000 | 0.914 | 0.976 | 0.990 | 0.979 | 0.982 | 0.982 | 1.000 | 1.000 |
| 5 | 0.987 | 0.991 | 0.989 | 0.994 | 0.995 | 0.995 | 0.986 | 0.976 | 0.981 | 0.990 | 0.991 | 0.991 | 0.958 | 0.961 | 0.960 |
| 6 | 0.976 | 0.985 | 0.995 | 0.984 | 0.951 | 0.968 | 0.964 | 1.000 | 0.995 | 0.962 | 0.966 | 0.964 | 1.000 | 0.997 | 1.000 |
| 7 | 0.939 | 0.918 | 0.988 | 0.885 | 0.997 | 0.959 | 1.000 | 0.866 | 0.922 | 0.959 | 0.921 | 0.923 | 0.923 | 0.981 | 0.981 |

## MAESTRO Cresting

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.963 | 0.991 | 0.986 | 0.951 | 1.000 | 0.980 | 1.000 | 0.985 | 0.996 | 1.000 | 0.990 | 0.995 | 0.984 | 0.991 | 0.987 |
| 2 | 0.968 | 0.968 | 0.998 | 0.953 | 1.000 | 1.000 | 0.994 | 0.942 | 0.971 | 1.000 | 0.992 | 0.996 | 0.964 | 0.970 | 0.967 |
| 3 | 0.975 | 0.986 | 0.994 | 0.954 | 0.969 | 0.962 | 1.000 | 0.978 | 1.000 | 0.967 | 0.965 | 0.966 | 0.995 | 1.000 | 0.997 |
| 4 | 0.922 | 0.900 | 0.988 | 0.871 | 1.000 | 0.982 | 1.000 | 0.842 | 0.961 | 0.983 | 0.958 | 0.965 | 0.962 | 1.000 | 1.000 |
| 5 | 0.980 | 0.991 | 0.986 | 0.967 | 0.980 | 0.974 | 0.952 | 0.933 | 0.943 | 0.997 | 0.988 | 0.997 | 0.917 | 0.922 | 0.920 |
| 6 | 0.965 | 0.966 | 0.997 | 0.972 | 0.943 | 0.959 | 0.947 | 1.000 | 0.997 | 0.951 | 0.954 | 0.952 | 1.000 | 0.993 | 1.000 |
| 7 | 0.888 | 0.953 | 0.949 | 0.829 | 1.000 | 0.900 | 1.000 | 0.904 | 1.000 | 0.971 | 0.923 | 0.969 | 0.922 | 1.000 | 0.923 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Cresting

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.908 | 0.983 | 0.955 | 0.952 | 1.000 | 1.000 | 0.956 | 0.956 | 1.000 | 1.000 | 0.907 |
| 2 | 0.657 | 0.900 | 0.856 | 0.692 | 1.000 | 1.000 | 0.881 | 0.881 | 1.000 | 1.000 | 0.654 |
| 3 | 0.648 | 0.716 | 0.848 | 0.869 | 1.000 | 1.000 | 0.935 | 0.935 | 1.000 | 1.000 | 0.613 |
| 5 | 0.651 | 0.575 | 0.853 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.651 |
| 6 | 0.913 | 0.984 | 0.977 | 0.975 | 0.990 | 0.990 | 0.977 | 0.977 | 1.000 | 1.000 | 0.882 |

MAESTRO Cresting

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.866 | 0.976 | 0.941 | 0.937 | 1.000 | 1.000 | 0.942 | 0.942 | 1.000 | 1.000 | 0.863 |
| 2 | 0.503 | 0.855 | 0.775 | 0.585 | 1.000 | 1.000 | 0.817 | 0.817 | 1.000 | 1.000 | 0.500 |
| 3 | 0.514 | 0.627 | 0.840 | 0.772 | 1.000 | 1.000 | 0.883 | 0.883 | 1.000 | 1.000 | 0.471 |
| 5 | 0.676 | 0.594 | 0.857 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.676 |
| 6 | 0.893 | 0.972 | 0.973 | 0.970 | 0.992 | 0.992 | 0.973 | 0.973 | 1.000 | 1.000 | 0.850 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Cresting

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.904 | 0.890 | 0.992 | 1.000 | 0.790 | 0.906 | 0.835 | 1.000 | 1.000 | 0.907 | 1.000 | 0.911 | 1.000 | 0.909 | 0.994 |
| 2 | 0.853 | 0.881 | 0.978 | 0.787 | 1.000 | 1.000 | 1.000 | 0.736 | 0.880 | 1.000 | 1.000 | 1.000 | 0.874 | 0.885 | 0.882 |
| 3 | 0.913 | 0.963 | 0.948 | 0.947 | 0.957 | 0.988 | 0.948 | 0.952 | 0.984 | 0.979 | 0.990 | 0.985 | 0.886 | 0.923 | 0.904 |
| 5 | 0.950 | 0.988 | 0.974 | 0.964 | 0.978 | 0.971 | 0.847 | 0.901 | 0.875 | 0.978 | 0.975 | 0.977 | 0.923 | 0.903 | 0.913 |
| 6 | 0.902 | 0.886 | 0.991 | 0.814 | 1.000 | 0.967 | 1.000 | 0.801 | 0.908 | 0.989 | 0.905 | 0.908 | 0.906 | 1.000 | 1.000 |

## MAESTRO Cresting

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.893 | 0.882 | 0.992 | 1.000 | 0.782 | 0.901 | 0.812 | 1.000 | 0.988 | 0.899 | 1.000 | 0.903 | 0.988 | 0.901 | 0.984 |
| 2 | 0.839 | 0.871 | 0.977 | 0.767 | 1.000 | 1.000 | 1.000 | 0.715 | 0.869 | 1.000 | 0.872 | 1.000 | 0.869 | 0.961 | 0.874 |
| 3 | 0.878 | 0.970 | 0.926 | 0.911 | 0.974 | 0.974 | 0.942 | 0.946 | 0.974 | 0.974 | 0.986 | 0.980 | 0.854 | 0.906 | 0.880 |
| 5 | 0.913 | 0.985 | 0.956 | 0.972 | 0.981 | 0.978 | 0.790 | 0.875 | 0.834 | 0.982 | 0.979 | 0.980 | 0.899 | 0.874 | 0.888 |
| 6 | 0.893 | 0.882 | 0.994 | 0.806 | 1.000 | 0.966 | 1.000 | 0.788 | 0.902 | 0.990 | 0.899 | 0.903 | 0.901 | 1.000 | 1.000 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Cresting

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.773 | 0.869 | 0.940 | 0.907 | 1.000 | 1.000 | 0.952 | 0.952 | 1.000 | 1.000 | 0.756 |
| 2 | 0.801 | 0.959 | 0.878 | 0.839 | 1.000 | 1.000 | 0.894 | 0.894 | 1.000 | 1.000 | 0.795 |
| 3 | 0.957 | 0.995 | 0.981 | 0.978 | 1.000 | 1.000 | 0.986 | 0.986 | 1.000 | 1.000 | 0.954 |
| 4 | 0.936 | 0.990 | 0.971 | 0.961 | 1.000 | 1.000 | 0.986 | 0.986 | 1.000 | 1.000 | 0.938 |
| 5 | 0.934 | 0.898 | 0.946 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.934 |
| 6 | 0.960 | 0.980 | 0.975 | 0.992 | 0.991 | 0.991 | 0.995 | 0.995 | 1.000 | 1.000 | 0.925 |
| 7 | 0.910 | 0.923 | 0.926 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.911 |

## MAESTRO Cresting

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.718 | 0.870 | 0.915 | 0.876 | 1.000 | 1.000 | 0.935 | 0.935 | 1.000 | 1.000 | 0.696 |
| 2 | 0.703 | 0.941 | 0.830 | 0.778 | 1.000 | 1.000 | 0.853 | 0.853 | 1.000 | 1.000 | 0.695 |
| 3 | 0.930 | 0.990 | 0.969 | 0.960 | 1.000 | 1.000 | 0.975 | 0.975 | 1.000 | 1.000 | 0.928 |
| 4 | 0.898 | 0.982 | 0.953 | 0.934 | 1.000 | 1.000 | 0.977 | 0.977 | 1.000 | 1.000 | 0.900 |
| 5 | 0.930 | 0.924 | 0.942 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.921 |
| 6 | 0.942 | 0.973 | 0.967 | 0.985 | 0.996 | 0.996 | 0.991 | 0.991 | 1.000 | 1.000 | 0.919 |
| 7 | 0.906 | 0.924 | 0.939 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.906 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Cresting

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.979 | 0.977 | 0.978 | 0.975 | 0.973 | 0.974 | 0.981 | 0.967 | 0.974 | 0.984 | 0.982 | 0.983 | 0.985 | 0.984 | 0.985 |
| 2 | 0.921 | 0.945 | 0.987 | 0.904 | 1.000 | 1.000 | 1.000 | 0.875 | 0.969 | 1.000 | 0.986 | 1.000 | 0.964 | 0.987 | 0.975 |
| 3 | 0.947 | 0.952 | 0.995 | 0.932 | 1.000 | 0.994 | 1.000 | 0.922 | 0.990 | 1.000 | 0.990 | 1.000 | 0.974 | 1.000 | 0.987 |
| 4 | 0.934 | 0.955 | 0.980 | 1.000 | 0.773 | 1.000 | 0.769 | 0.945 | 0.785 | 0.785 | 0.991 | 0.785 | 0.990 | 0.785 | 0.983 |
| 5 | 0.988 | 0.997 | 0.994 | 0.984 | 0.980 | 0.983 | 0.980 | 0.966 | 0.973 | 0.979 | 0.984 | 0.982 | 0.955 | 0.958 | 0.957 |
| 6 | 0.945 | 0.949 | 0.997 | 1.000 | 0.923 | 0.993 | 0.925 | 1.000 | 0.993 | 0.979 | 0.995 | 0.991 | 1.000 | 0.987 | 1.000 |
| 7 | 0.954 | 0.951 | 0.973 | 0.915 | 1.000 | 0.949 | 0.979 | 0.918 | 0.979 | 0.959 | 0.946 | 0.948 | 0.949 | 1.000 | 0.968 |

MAESTRO Cresting

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.931 | 0.969 | 0.950 | 0.918 | 0.970 | 0.944 | 0.987 | 0.964 | 0.975 | 0.988 | 0.979 | 0.984 | 0.949 | 0.970 | 0.960 |
| 2 | 0.919 | 0.942 | 0.987 | 0.912 | 1.000 | 1.000 | 1.000 | 0.860 | 0.955 | 1.000 | 0.986 | 1.000 | 0.952 | 0.979 | 0.966 |
| 3 | 0.955 | 0.964 | 0.992 | 0.942 | 1.000 | 1.000 | 1.000 | 0.930 | 0.991 | 1.000 | 0.994 | 1.000 | 0.973 | 0.993 | 0.984 |
| 4 | 0.946 | 0.913 | 0.972 | 0.916 | 0.848 | 1.000 | 0.843 | 0.844 | 0.855 | 0.855 | 0.937 | 0.987 | 0.936 | 0.855 | 0.855 |
| 5 | 0.976 | 0.983 | 0.979 | 0.971 | 0.975 | 0.973 | 0.973 | 0.955 | 0.965 | 0.989 | 0.989 | 0.989 | 0.945 | 0.950 | 0.948 |
| 6 | 0.942 | 0.939 | 0.997 | 1.000 | 0.913 | 0.991 | 0.917 | 1.000 | 0.993 | 0.982 | 0.995 | 0.991 | 1.000 | 0.981 | 0.992 |
| 7 | 0.907 | 0.960 | 0.944 | 0.855 | 0.957 | 0.916 | 1.000 | 0.919 | 0.986 | 0.951 | 0.932 | 0.934 | 0.934 | 0.966 | 0.962 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Cresting

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.812 | 0.905 | 0.944 | 0.911 | 1.000 | 1.000 | 0.954 | 0.954 | 1.000 | 1.000 | 0.793 |
| 2 | 0.862 | 0.967 | 0.920 | 0.878 | 1.000 | 1.000 | 0.921 | 0.921 | 1.000 | 1.000 | 0.861 |
| 3 | 0.966 | 0.994 | 0.981 | 0.977 | 1.000 | 1.000 | 0.986 | 0.986 | 1.000 | 1.000 | 0.964 |
| 4 | 0.950 | 0.987 | 0.969 | 0.978 | 1.000 | 1.000 | 0.986 | 0.986 | 1.000 | 1.000 | 0.947 |
| 5 | 0.935 | 0.900 | 0.982 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.935 |
| 6 | 0.964 | 0.981 | 0.979 | 0.988 | 1.000 | 1.000 | 0.993 | 0.993 | 1.000 | 1.000 | 0.948 |
| 7 | 0.917 | 0.923 | 0.956 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.908 |

MAESTRO Cresting

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.756 | 0.927 | 0.911 | 0.884 | 1.000 | 1.000 | 0.939 | 0.939 | 1.000 | 1.000 | 0.737 |
| 2 | 0.812 | 0.957 | 0.891 | 0.838 | 1.000 | 1.000 | 0.894 | 0.894 | 1.000 | 1.000 | 0.811 |
| 3 | 0.955 | 0.989 | 0.973 | 0.963 | 1.000 | 1.000 | 0.977 | 0.977 | 1.000 | 1.000 | 0.953 |
| 4 | 0.926 | 0.992 | 0.948 | 0.967 | 1.000 | 1.000 | 0.978 | 0.978 | 1.000 | 1.000 | 0.924 |
| 5 | 0.931 | 0.925 | 0.962 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.931 |
| 6 | 0.949 | 0.993 | 0.966 | 0.983 | 1.000 | 1.000 | 0.989 | 0.989 | 1.000 | 1.000 | 0.942 |
| 7 | 0.893 | 0.948 | 0.930 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.894 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Cresting

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.989 | 0.971 | 0.987 | 0.989 | 0.995 | 0.992 | 0.993 | 0.954 | 0.976 | 0.991 | 0.986 | 0.989 | 0.992 | 0.994 | 0.993 |
| 2 | 0.946 | 0.949 | 0.991 | 0.936 | 1.000 | 1.000 | 1.000 | 0.915 | 0.983 | 1.000 | 0.992 | 0.996 | 0.972 | 1.000 | 0.986 |
| 3 | 0.949 | 0.955 | 0.996 | 0.931 | 1.000 | 1.000 | 1.000 | 0.926 | 0.992 | 1.000 | 0.990 | 1.000 | 0.980 | 1.000 | 0.991 |
| 4 | 0.981 | 0.946 | 0.980 | 0.970 | 1.000 | 1.000 | 1.000 | 0.907 | 0.960 | 1.000 | 0.982 | 0.984 | 0.984 | 0.997 | 0.995 |
| 5 | 0.986 | 0.992 | 0.991 | 0.998 | 0.995 | 0.997 | 0.984 | 0.990 | 0.988 | 0.984 | 0.988 | 0.986 | 1.000 | 1.000 | 1.000 |
| 6 | 0.950 | 0.957 | 0.995 | 1.000 | 0.934 | 1.000 | 0.925 | 1.000 | 0.991 | 0.984 | 1.000 | 0.992 | 1.000 | 0.987 | 1.000 |
| 7 | 0.932 | 0.913 | 0.989 | 0.872 | 1.000 | 1.000 | 1.000 | 0.857 | 0.916 | 1.000 | 0.913 | 0.916 | 0.916 | 1.000 | 1.000 |

## MAESTRO Cresting

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.835 | 0.938 | 0.936 | 0.784 | 1.000 | 0.926 | 1.000 | 0.909 | 1.000 | 1.000 | 0.970 | 0.982 | 0.933 | 1.000 | 0.964 |
| 2 | 0.928 | 0.921 | 0.994 | 0.911 | 1.000 | 1.000 | 1.000 | 0.875 | 0.970 | 1.000 | 0.985 | 0.993 | 0.964 | 1.000 | 0.984 |
| 3 | 0.948 | 0.952 | 0.995 | 0.926 | 1.000 | 0.992 | 1.000 | 0.933 | 0.993 | 1.000 | 0.985 | 0.993 | 0.984 | 1.000 | 0.992 |
| 4 | 0.971 | 0.828 | 0.912 | 0.959 | 0.761 | 0.874 | 0.969 | 1.000 | 1.000 | 0.970 | 1.000 | 1.000 | 0.971 | 0.941 | 0.961 |
| 5 | 0.953 | 0.973 | 0.963 | 0.923 | 0.947 | 0.935 | 1.000 | 1.000 | 1.000 | 0.981 | 0.977 | 0.977 | 0.975 | 0.981 | 0.978 |
| 6 | 0.923 | 0.900 | 0.988 | 1.000 | 0.857 | 0.980 | 0.884 | 1.000 | 1.000 | 0.979 | 1.000 | 0.991 | 1.000 | 0.965 | 0.985 |
| 7 | 0.926 | 0.810 | 0.881 | 0.892 | 0.724 | 0.811 | 1.000 | 1.000 | 1.000 | 0.914 | 0.975 | 1.000 | 0.917 | 0.907 | 0.913 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

# Appendix G. Comparison of Results for Longitudinal Positive Twisting

## Analytical Positive Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.888 | 0.943 | 0.966 | 0.954 | 1.000 | 1.000 | 0.976 | 0.976 | 1.000 | 1.000 | 0.875 |
| 2 | 0.923 | 0.986 | 0.960 | 0.942 | 1.000 | 1.000 | 0.964 | 0.964 | 1.000 | 1.000 | 0.921 |
| 3 | 0.974 | 0.998 | 0.987 | 0.990 | 1.000 | 1.000 | 0.994 | 0.994 | 1.000 | 1.000 | 0.954 |
| 4 | 0.968 | 0.988 | 0.979 | 0.994 | 1.000 | 1.000 | 0.996 | 0.996 | 1.000 | 1.000 | 0.966 |
| 5 | 0.978 | 0.991 | 0.995 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.978 |
| 6 | 0.969 | 0.982 | 0.985 | 0.994 | 1.000 | 1.000 | 0.996 | 0.996 | 1.000 | 1.000 | 0.925 |
| 7 | 0.962 | 0.974 | 0.976 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.938 |

## MAESTRO Positive Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.893 | 0.953 | 0.956 | 0.966 | 1.000 | 1.000 | 0.983 | 0.983 | 1.000 | 1.000 | 0.880 |
| 2 | 0.933 | 0.989 | 0.964 | 0.955 | 1.000 | 1.000 | 0.972 | 0.972 | 1.000 | 1.000 | 0.930 |
| 3 | 0.976 | 0.999 | 0.988 | 0.994 | 1.000 | 1.000 | 0.997 | 0.997 | 1.000 | 1.000 | 0.955 |
| 4 | 0.966 | 0.993 | 0.976 | 0.997 | 0.999 | 0.999 | 0.998 | 0.998 | 1.000 | 1.000 | 0.957 |
| 5 | 0.980 | 0.998 | 0.988 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.980 |
| 6 | 0.968 | 0.985 | 0.981 | 0.996 | 1.000 | 1.000 | 0.997 | 0.997 | 1.000 | 1.000 | 0.934 |
| 7 | 0.960 | 0.993 | 0.973 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.947 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Positive Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.934 | 0.891 | 0.972 | 0.912 | 1.000 | 1.000 | 1.000 | 0.843 | 0.953 | 1.000 | 0.968 | 0.984 | 0.971 | 1.000 | 1.000 |
| 2 | 0.836 | 0.973 | 0.925 | 0.782 | 1.000 | 0.902 | 1.000 | 0.954 | 1.000 | 1.000 | 0.987 | 1.000 | 0.950 | 1.000 | 0.977 |
| 3 | 0.894 | 0.905 | 0.994 | 0.842 | 1.000 | 0.984 | 1.000 | 0.848 | 1.000 | 1.000 | 0.972 | 1.000 | 0.963 | 1.000 | 0.983 |
| 4 | 0.983 | 0.978 | 0.986 | 1.000 | 0.992 | 1.000 | 0.976 | 0.962 | 0.976 | 0.994 | 0.994 | 0.996 | 1.000 | 0.996 | 1.000 |
| 5 | 0.991 | 0.993 | 0.993 | 0.983 | 0.990 | 0.987 | 1.000 | 1.000 | 1.000 | 0.992 | 0.992 | 0.992 | 0.996 | 0.995 | 0.996 |
| 6 | 0.898 | 0.908 | 0.994 | 1.000 | 0.856 | 1.000 | 0.842 | 1.000 | 0.983 | 0.965 | 1.000 | 0.984 | 1.000 | 0.972 | 1.000 |
| 7 | 0.896 | 0.881 | 0.987 | 0.818 | 1.000 | 1.000 | 1.000 | 0.803 | 0.882 | 1.000 | 0.880 | 0.883 | 0.881 | 1.000 | 1.000 |

## MAESTRO Positive Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.906 | 0.876 | 0.978 | 0.870 | 1.000 | 1.000 | 1.000 | 0.823 | 0.961 | 1.000 | 0.968 | 0.981 | 0.971 | 1.000 | 1.000 |
| 2 | 0.828 | 0.974 | 0.922 | 0.768 | 1.000 | 0.896 | 1.000 | 0.952 | 1.000 | 1.000 | 0.986 | 1.000 | 0.955 | 1.000 | 0.979 |
| 3 | 0.907 | 0.919 | 0.993 | 0.855 | 1.000 | 0.984 | 1.000 | 0.867 | 1.000 | 1.000 | 0.980 | 1.000 | 0.973 | 1.000 | 0.985 |
| 4 | 0.969 | 0.953 | 0.992 | 0.948 | 1.000 | 0.991 | 1.000 | 0.923 | 0.980 | 1.000 | 0.983 | 0.985 | 0.984 | 1.000 | 0.995 |
| 5 | 0.988 | 0.994 | 0.992 | 0.978 | 0.987 | 0.983 | 1.000 | 1.000 | 1.000 | 1.000 | 0.991 | 0.991 | 0.992 | 0.997 | 0.997 |
| 6 | 0.904 | 0.911 | 0.995 | 1.000 | 0.855 | 1.000 | 0.849 | 1.000 | 0.984 | 0.973 | 1.000 | 0.985 | 1.000 | 0.977 | 1.000 |
| 7 | 0.874 | 0.894 | 0.977 | 0.794 | 1.000 | 0.877 | 1.000 | 0.815 | 1.000 | 1.000 | 0.876 | 0.880 | 0.876 | 1.000 | 0.878 |

POSITIVE NUMBER: CONSTRAINT SATISFIED. | THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED. | BETWEEN +1. AND -1.
1.000 : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
-2.000 : CONSTRAINT SUPPRESSED.
-- : STRAKE NOT EVALUATED.

Analytical Positive Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.843 | 0.953 | 0.918 | 0.958 | 0.993 | 0.993 | 0.978 | 0.978 | 1.000 | 1.000 | 0.837 |
| 2 | 0.907 | 0.983 | 0.907 | 0.970 | 1.000 | 1.000 | 0.981 | 0.981 | 1.000 | 1.000 | 0.907 |
| 3 | 0.891 | 0.809 | 0.933 | 0.983 | 1.000 | 1.000 | 0.990 | 0.990 | 1.000 | 1.000 | 0.782 |
| 4 | 0.938 | 0.923 | 0.969 | 0.990 | 0.990 | 0.990 | 0.993 | 0.993 | 1.000 | 1.000 | 0.875 |
| 5 | 0.821 | 0.991 | 0.863 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.821 |
| 6 | 0.854 | 0.729 | 0.917 | 0.984 | 1.000 | 1.000 | 0.990 | 0.990 | 1.000 | 1.000 | 0.696 |
| 7 | 0.583 | 0.940 | 0.690 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.581 |

MAESTRO Positive Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.859 | 0.965 | 0.925 | 0.970 | 0.993 | 0.993 | 0.984 | 0.984 | 1.000 | 1.000 | 0.854 |
| 2 | 0.932 | 0.989 | 0.929 | 0.975 | 0.999 | 0.999 | 0.985 | 0.985 | 1.000 | 1.000 | 0.926 |
| 3 | 0.918 | 0.844 | 0.950 | 0.990 | 1.000 | 1.000 | 0.994 | 0.994 | 1.000 | 1.000 | 0.830 |
| 4 | 0.952 | 0.939 | 0.970 | 0.996 | 0.988 | 0.988 | 0.997 | 0.997 | 1.000 | 1.000 | 0.902 |
| 5 | 0.840 | 0.989 | 0.879 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.841 |
| 6 | 0.886 | 0.770 | 0.932 | 0.984 | 1.000 | 1.000 | 0.990 | 0.990 | 1.000 | 1.000 | 0.740 |
| 7 | 0.827 | 0.992 | 0.878 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.828 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Positive Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.964 | 0.986 | 0.985 | 0.969 | 1.000 | 0.992 | 1.000 | 0.974 | 0.993 | 0.996 | 0.992 | 0.994 | 0.972 | 0.985 | 0.978 |
| 2 | 0.947 | 0.947 | 0.998 | 0.917 | 1.000 | 1.000 | 0.992 | 0.906 | 0.948 | 1.000 | 0.985 | 0.993 | 0.937 | 0.948 | 0.943 |
| 3 | 0.915 | 0.923 | 0.995 | 0.868 | 0.993 | 0.946 | 1.000 | 0.877 | 1.000 | 0.954 | 0.942 | 0.948 | 0.978 | 1.000 | 0.988 |
| 4 | 0.988 | 0.979 | 0.986 | 0.990 | 0.965 | 0.978 | 0.987 | 0.968 | 0.979 | 0.977 | 0.980 | 0.979 | 1.000 | 1.000 | 1.000 |
| 5 | 0.961 | 0.991 | 0.985 | 0.980 | 0.986 | 0.985 | 0.938 | 0.893 | 0.918 | 0.998 | 0.987 | 0.988 | 0.869 | 0.882 | 0.876 |
| 6 | 0.918 | 0.929 | 0.994 | 0.989 | 0.883 | 0.945 | 0.874 | 1.000 | 0.988 | 0.928 | 0.939 | 0.934 | 1.000 | 0.985 | 1.000 |
| 7 | 0.916 | 0.893 | 0.981 | 0.847 | 1.000 | 0.947 | 0.842 | 0.807 | 0.824 | 0.925 | 0.895 | 0.898 | 0.828 | 0.834 | 0.831 |

## MAESTRO Positive Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.973 | 0.988 | 0.988 | 0.971 | 1.000 | 0.991 | 1.000 | 0.981 | 1.000 | 0.996 | 0.991 | 0.994 | 0.980 | 0.989 | 0.985 |
| 2 | 0.954 | 0.954 | 0.998 | 0.930 | 1.000 | 1.000 | 0.990 | 0.923 | 0.957 | 1.000 | 0.987 | 0.995 | 0.949 | 0.957 | 0.953 |
| 3 | 0.939 | 0.949 | 0.995 | 0.904 | 0.980 | 0.955 | 1.000 | 0.917 | 1.000 | 0.962 | 0.955 | 0.958 | 0.984 | 1.000 | 0.992 |
| 4 | 0.966 | 0.940 | 0.987 | 0.940 | 1.000 | 0.984 | 1.000 | 0.905 | 0.973 | 0.984 | 0.977 | 0.981 | 0.981 | 1.000 | 1.000 |
| 5 | 0.975 | 0.994 | 0.990 | 0.978 | 0.981 | 0.979 | 0.950 | 0.917 | 0.934 | 0.998 | 0.992 | 0.992 | 0.898 | 0.906 | 0.902 |
| 6 | 0.938 | 0.946 | 0.995 | 0.980 | 0.910 | 0.953 | 0.905 | 1.000 | 0.991 | 0.940 | 0.947 | 0.944 | 1.000 | 0.989 | 1.000 |
| 7 | 0.899 | 0.919 | 0.989 | 0.832 | 1.000 | 0.902 | 0.961 | 0.856 | 0.934 | 0.949 | 0.901 | 0.903 | 0.902 | 0.936 | 0.930 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Positive Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.910 | 0.981 | 0.951 | 0.948 | 1.000 | 1.000 | 0.952 | 0.952 | 1.000 | 1.000 | 0.909 |
| 2 | 0.726 | 0.922 | 0.881 | 0.750 | 1.000 | 1.000 | 0.906 | 0.906 | 1.000 | 1.000 | 0.727 |
| 3 | 0.702 | 0.750 | 0.849 | 0.903 | 1.000 | 1.000 | 0.952 | 0.952 | 1.000 | 1.000 | 0.680 |
| 5 | 0.632 | 0.547 | 0.847 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.633 |
| 6 | 0.920 | 0.982 | 0.971 | 0.968 | 0.996 | 0.996 | 0.971 | 0.971 | 1.000 | 1.000 | 0.885 |

MAESTRO Positive Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.911 | 0.981 | 0.949 | 0.947 | 1.000 | 1.000 | 0.951 | 0.951 | 1.000 | 1.000 | 0.910 |
| 2 | 0.751 | 0.926 | 0.880 | 0.761 | 1.000 | 1.000 | 0.910 | 0.910 | 1.000 | 1.000 | 0.753 |
| 3 | 0.682 | 0.749 | 0.837 | 0.913 | 1.000 | 1.000 | 0.957 | 0.957 | 1.000 | 1.000 | 0.661 |
| 5 | 0.619 | 0.531 | 0.841 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.619 |
| 6 | 0.926 | 0.978 | 0.970 | 0.968 | 0.990 | 0.990 | 0.970 | 0.970 | 1.000 | 1.000 | 0.891 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Positive Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.894 | 0.878 | 0.992 | 1.000 | 0.768 | 0.896 | 0.820 | 1.000 | 1.000 | 0.898 | 1.000 | 0.901 | 1.000 | 0.900 | 1.000 |
| 2 | 0.840 | 0.868 | 0.978 | 0.767 | 1.000 | 1.000 | 1.000 | 0.712 | 0.868 | 1.000 | 1.000 | 1.000 | 0.857 | 0.873 | 0.868 |
| 3 | 0.934 | 0.956 | 0.960 | 0.963 | 0.946 | 0.986 | 0.945 | 0.962 | 0.986 | 0.979 | 1.000 | 0.986 | 0.910 | 0.939 | 0.925 |
| 5 | 0.965 | 0.988 | 0.976 | 0.960 | 0.977 | 0.970 | 0.897 | 0.924 | 0.911 | 0.979 | 0.975 | 0.977 | 0.941 | 0.930 | 0.935 |
| 6 | 0.892 | 0.873 | 0.989 | 0.796 | 1.000 | 0.963 | 1.000 | 0.780 | 0.898 | 0.991 | 0.896 | 0.898 | 0.896 | 1.000 | 1.000 |

## MAESTRO Positive Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.857 | 0.841 | 0.991 | 1.000 | 0.706 | 0.864 | 0.758 | 1.000 | 1.000 | 0.865 | 1.000 | 0.869 | 1.000 | 0.867 | 1.000 |
| 2 | 0.805 | 0.835 | 0.977 | 0.714 | 1.000 | 1.000 | 1.000 | 0.654 | 0.838 | 1.000 | 1.000 | 1.000 | 0.824 | 0.843 | 0.837 |
| 3 | 0.932 | 0.951 | 0.961 | 0.961 | 0.938 | 0.985 | 0.938 | 0.955 | 0.984 | 0.978 | 1.000 | 0.985 | 0.908 | 0.940 | 0.924 |
| 5 | 0.964 | 0.983 | 0.973 | 0.960 | 0.976 | 0.968 | 0.891 | 0.911 | 0.901 | 0.980 | 0.977 | 0.979 | 0.937 | 0.929 | 0.933 |
| 6 | 0.855 | 0.834 | 0.988 | 0.733 | 1.000 | 0.950 | 1.000 | 0.717 | 0.865 | 0.989 | 0.862 | 0.865 | 0.863 | 1.000 | 1.000 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Positive Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.822 | 0.887 | 0.935 | 0.931 | 1.000 | 1.000 | 0.964 | 0.964 | 1.000 | 1.000 | 0.811 |
| 2 | 0.846 | 0.968 | 0.905 | 0.873 | 1.000 | 1.000 | 0.917 | 0.917 | 1.000 | 1.000 | 0.845 |
| 3 | 0.960 | 0.988 | 0.988 | 0.987 | 1.000 | 1.000 | 0.992 | 0.992 | 1.000 | 1.000 | 0.955 |
| 4 | 0.970 | 0.982 | 0.989 | 0.988 | 0.996 | 0.996 | 0.996 | 0.996 | 1.000 | 1.000 | 0.971 |
| 5 | 0.941 | 0.923 | 0.947 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.936 |
| 6 | 0.964 | 0.985 | 0.982 | 0.996 | 0.992 | 0.992 | 0.998 | 0.998 | 1.000 | 1.000 | 0.925 |
| 7 | 0.922 | 0.955 | 0.938 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.898 |

MAESTRO Positive Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.826 | 0.987 | 0.925 | 0.938 | 1.000 | 1.000 | 0.968 | 0.968 | 1.000 | 1.000 | 0.818 |
| 2 | 0.864 | 0.970 | 0.910 | 0.880 | 1.000 | 1.000 | 0.922 | 0.922 | 1.000 | 1.000 | 0.864 |
| 3 | 0.965 | 0.981 | 0.989 | 0.990 | 1.000 | 1.000 | 0.994 | 0.994 | 1.000 | 1.000 | 0.936 |
| 4 | 0.978 | 1.000 | 0.988 | 1.000 | 0.993 | 0.993 | 1.000 | 1.000 | 1.000 | 1.000 | 0.973 |
| 5 | 0.918 | 0.998 | 0.922 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.916 |
| 6 | 0.963 | 1.000 | 0.972 | 0.996 | 0.985 | 0.985 | 1.000 | 1.000 | 1.000 | 1.000 | 0.915 |
| 7 | 0.949 | 0.994 | 0.953 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.840 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Positive Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.966 | 0.988 | 0.978 | 0.955 | 0.986 | 0.971 | 0.994 | 0.971 | 0.982 | 0.988 | 0.981 | 0.985 | 0.979 | 0.992 | 0.986 |
| 2 | 0.908 | 0.930 | 0.987 | 0.877 | 1.000 | 1.000 | 1.000 | 0.863 | 0.975 | 1.000 | 0.984 | 1.000 | 0.962 | 0.993 | 0.980 |
| 3 | 0.914 | 0.922 | 0.994 | 0.885 | 1.000 | 0.989 | 1.000 | 0.883 | 0.988 | 1.000 | 0.981 | 0.993 | 0.967 | 1.000 | 0.986 |
| 4 | 0.943 | 0.946 | 0.973 | 0.969 | 0.877 | 1.000 | 0.857 | 0.908 | 0.874 | 0.877 | 0.968 | 0.878 | 0.969 | 0.878 | 0.996 |
| 5 | 0.990 | 0.991 | 0.991 | 0.975 | 0.976 | 0.976 | 0.986 | 0.975 | 0.981 | 0.985 | 0.985 | 0.985 | 0.966 | 0.969 | 0.968 |
| 6 | 0.908 | 0.912 | 0.997 | 1.000 | 0.873 | 0.987 | 0.873 | 1.000 | 0.988 | 0.968 | 0.995 | 0.987 | 1.000 | 0.975 | 1.000 |
| 7 | 0.915 | 0.942 | 0.978 | 0.855 | 1.000 | 0.918 | 1.000 | 0.893 | 0.969 | 0.952 | 0.920 | 0.922 | 0.922 | 1.000 | 0.937 |

## MAESTRO Positive Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.821 | 0.983 | 0.906 | 0.775 | 1.000 | 0.884 | 1.000 | 0.965 | 0.986 | 1.000 | 0.966 | 1.000 | 0.880 | 0.966 | 0.927 |
| 2 | 0.888 | 0.900 | 0.987 | 0.843 | 1.000 | 1.000 | 1.000 | 0.825 | 0.972 | 1.000 | 0.977 | 0.989 | 0.959 | 1.000 | 0.981 |
| 3 | 0.902 | 0.913 | 0.990 | 0.857 | 1.000 | 0.977 | 1.000 | 0.882 | 1.000 | 1.000 | 0.967 | 0.986 | 0.974 | 1.000 | 1.000 |
| 4 | 0.937 | 0.931 | 0.951 | 0.864 | 0.930 | 0.913 | 0.910 | 0.851 | 0.885 | 0.917 | 0.884 | 0.885 | 0.886 | 0.996 | 0.997 |
| 5 | 0.835 | 0.899 | 0.873 | 0.788 | 0.847 | 0.819 | 0.976 | 0.963 | 0.970 | 1.000 | 1.000 | 1.000 | 0.854 | 0.886 | 0.871 |
| 6 | 0.846 | 0.805 | 0.975 | 1.000 | 0.733 | 0.956 | 0.777 | 1.000 | 1.000 | 0.957 | 1.000 | 0.989 | 1.000 | 0.928 | 0.969 |
| 7 | 0.861 | 0.629 | 0.740 | 0.759 | 0.492 | 0.620 | 1.000 | 0.916 | 1.000 | 0.937 | 0.920 | 0.922 | 0.844 | 0.830 | 0.839 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Positive Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.856 | 0.916 | 0.968 | 0.934 | 1.000 | 1.000 | 0.966 | 0.966 | 1.000 | 1.000 | 0.846 |
| 2 | 0.898 | 0.977 | 0.938 | 0.906 | 1.000 | 1.000 | 0.939 | 0.939 | 1.000 | 1.000 | 0.897 |
| 3 | 0.970 | 0.997 | 0.986 | 0.986 | 1.000 | 1.000 | 0.992 | 0.992 | 1.000 | 1.000 | 0.953 |
| 4 | 0.972 | 0.992 | 0.987 | 0.989 | 1.000 | 1.000 | 0.993 | 0.993 | 1.000 | 1.000 | 0.970 |
| 5 | 0.955 | 0.937 | 0.986 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.955 |
| 6 | 0.972 | 0.984 | 0.989 | 0.993 | 1.000 | 1.000 | 0.996 | 0.996 | 1.000 | 1.000 | 0.929 |
| 7 | 0.961 | 0.951 | 0.987 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.930 |

MAESTRO Positive Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.851 | 0.974 | 0.952 | 0.949 | 1.000 | 1.000 | 0.974 | 0.974 | 1.000 | 1.000 | 0.846 |
| 2 | 0.893 | 0.973 | 0.947 | 0.917 | 1.000 | 1.000 | 0.946 | 0.946 | 1.000 | 1.000 | 0.891 |
| 3 | 0.967 | 0.979 | 0.987 | 0.994 | 1.000 | 1.000 | 0.996 | 0.996 | 1.000 | 1.000 | 0.929 |
| 4 | 0.975 | 0.999 | 0.972 | 0.996 | 0.995 | 0.995 | 0.998 | 0.998 | 1.000 | 1.000 | 0.974 |
| 5 | 0.977 | 0.992 | 0.969 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.975 |
| 6 | 0.976 | 1.000 | 0.980 | 0.999 | 0.994 | 0.994 | 1.000 | 1.000 | 1.000 | 1.000 | 0.934 |
| 7 | 0.950 | 0.991 | 0.952 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.950 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Positive Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.948 | 0.948 | 0.990 | 0.936 | 1.000 | 0.992 | 1.000 | 0.924 | 0.982 | 0.993 | 0.980 | 0.988 | 0.978 | 1.000 | 0.990 |
| 2 | 0.922 | 0.933 | 0.989 | 0.897 | 1.000 | 0.993 | 1.000 | 0.897 | 0.989 | 1.000 | 0.986 | 0.994 | 0.969 | 1.000 | 0.988 |
| 3 | 0.883 | 0.891 | 0.995 | 0.841 | 1.000 | 0.984 | 1.000 | 0.843 | 1.000 | 1.000 | 0.970 | 1.000 | 0.958 | 1.000 | 0.983 |
| 4 | 0.972 | 0.957 | 0.990 | 1.000 | 0.940 | 0.986 | 0.957 | 0.966 | 0.981 | 0.988 | 0.994 | 0.995 | 0.995 | 0.982 | 0.988 |
| 5 | 0.993 | 0.994 | 0.996 | 0.983 | 0.988 | 0.987 | 1.000 | 1.000 | 1.000 | 0.991 | 0.991 | 0.991 | 0.996 | 0.995 | 0.996 |
| 6 | 0.882 | 0.890 | 0.995 | 1.000 | 0.845 | 1.000 | 0.836 | 1.000 | 0.983 | 0.962 | 1.000 | 0.984 | 1.000 | 0.965 | 1.000 |
| 7 | 0.903 | 0.898 | 0.992 | 0.828 | 1.000 | 0.897 | 1.000 | 0.828 | 0.893 | 1.000 | 0.890 | 0.893 | 0.892 | 1.000 | 1.000 |

## MAESTRO Positive Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.785 | 0.899 | 0.935 | 0.702 | 1.000 | 0.900 | 1.000 | 0.860 | 1.000 | 1.000 | 0.958 | 0.981 | 0.957 | 1.000 | 0.973 |
| 2 | 0.912 | 0.916 | 0.994 | 0.870 | 1.000 | 0.992 | 1.000 | 0.854 | 0.980 | 1.000 | 0.978 | 0.989 | 0.970 | 1.000 | 0.989 |
| 3 | 0.891 | 0.901 | 0.994 | 0.839 | 1.000 | 0.982 | 1.000 | 0.850 | 1.000 | 1.000 | 0.970 | 0.983 | 0.963 | 1.000 | 0.985 |
| 4 | 0.935 | 0.699 | 0.866 | 0.990 | 0.543 | 0.770 | 0.863 | 1.000 | 1.000 | 0.901 | 1.000 | 1.000 | 0.991 | 0.884 | 0.900 |
| 5 | 0.912 | 0.936 | 0.928 | 0.865 | 0.893 | 0.884 | 1.000 | 1.000 | 1.000 | 1.000 | 0.963 | 0.984 | 0.962 | 0.967 | 0.962 |
| 6 | 0.864 | 0.827 | 0.978 | 1.000 | 0.735 | 0.961 | 0.780 | 1.000 | 0.983 | 0.962 | 1.000 | 0.983 | 1.000 | 0.947 | 0.971 |
| 7 | 0.893 | 0.683 | 0.809 | 0.824 | 0.553 | 0.696 | 1.000 | 0.920 | 1.000 | 1.000 | 0.930 | 1.000 | 0.835 | 0.825 | 0.832 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

# Appendix H. Comparison of Results for Longitudinal Negative Twisting

## Analytical Negative Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.771 | 0.923 | 0.899 | 0.917 | 1.000 | 1.000 | 0.957 | 0.957 | 1.000 | 1.000 | 0.750 |
| 2 | 0.867 | 0.972 | 0.924 | 0.890 | 1.000 | 1.000 | 0.930 | 0.930 | 1.000 | 1.000 | 0.862 |
| 3 | 0.969 | 0.995 | 0.984 | 0.980 | 1.000 | 1.000 | 0.987 | 0.987 | 1.000 | 1.000 | 0.946 |
| 4 | 0.919 | 0.983 | 0.943 | 0.983 | 0.998 | 0.998 | 0.990 | 0.990 | 1.000 | 1.000 | 0.915 |
| 5 | 0.955 | 0.972 | 0.971 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.954 |
| 6 | 0.954 | 0.988 | 0.969 | 0.991 | 1.000 | 1.000 | 0.994 | 0.994 | 1.000 | 1.000 | 0.923 |
| 7 | 0.875 | 0.961 | 0.918 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.874 |

## MAESTRO Negative Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.735 | 0.930 | 0.889 | 0.881 | 1.000 | 1.000 | 0.938 | 0.938 | 1.000 | 1.000 | 0.717 |
| 2 | 0.819 | 0.951 | 0.895 | 0.836 | 1.000 | 1.000 | 0.895 | 0.895 | 1.000 | 1.000 | 0.818 |
| 3 | 0.952 | 0.970 | 0.971 | 0.960 | 1.000 | 1.000 | 0.975 | 0.975 | 1.000 | 1.000 | 0.950 |
| 4 | 0.904 | 0.989 | 0.936 | 0.959 | 1.000 | 1.000 | 0.975 | 0.975 | 1.000 | 1.000 | 0.902 |
| 5 | 0.926 | 0.913 | 0.963 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.926 |
| 6 | 0.936 | 0.994 | 0.958 | 0.978 | 1.000 | 1.000 | 0.986 | 0.986 | 1.000 | 1.000 | 0.934 |
| 7 | 0.860 | 0.940 | 0.912 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.861 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Negative Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.940 | 0.894 | 0.972 | 0.923 | 1.000 | 1.000 | 1.000 | 0.843 | 0.949 | 1.000 | 0.972 | 0.984 | 0.979 | 1.000 | 1.000 |
| 2 | 0.836 | 0.976 | 0.926 | 0.792 | 1.000 | 0.916 | 1.000 | 0.940 | 1.000 | 1.000 | 0.984 | 1.000 | 0.957 | 0.994 | 0.977 |
| 3 | 0.892 | 0.901 | 0.995 | 0.834 | 1.000 | 0.983 | 1.000 | 0.835 | 1.000 | 1.000 | 0.976 | 1.000 | 0.968 | 1.000 | 0.982 |
| 4 | 0.967 | 0.963 | 0.984 | 0.967 | 0.970 | 1.000 | 0.943 | 0.940 | 0.972 | 0.988 | 0.987 | 0.990 | 0.990 | 0.990 | 1.000 |
| 5 | 0.988 | 0.997 | 0.994 | 0.979 | 0.987 | 0.984 | 1.000 | 1.000 | 1.000 | 0.988 | 0.987 | 0.988 | 1.000 | 1.000 | 1.000 |
| 6 | 0.895 | 0.905 | 0.995 | 1.000 | 0.847 | 1.000 | 0.833 | 1.000 | 0.982 | 0.972 | 1.000 | 0.984 | 1.000 | 0.975 | 1.000 |
| 7 | 0.905 | 0.896 | 0.984 | 0.833 | 1.000 | 0.903 | 1.000 | 0.824 | 0.893 | 1.000 | 0.891 | 0.893 | 0.892 | 1.000 | 0.931 |

MAESTRO Negative Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.823 | 0.886 | 0.964 | 0.757 | 1.000 | 0.945 | 1.000 | 0.837 | 0.982 | 1.000 | 0.961 | 0.978 | 0.933 | 1.000 | 0.972 |
| 2 | 0.900 | 0.973 | 0.957 | 0.897 | 1.000 | 0.978 | 1.000 | 0.934 | 1.000 | 1.000 | 0.988 | 0.996 | 0.966 | 0.996 | 0.982 |
| 3 | 0.975 | 0.979 | 0.996 | 0.958 | 1.000 | 0.989 | 1.000 | 0.969 | 0.997 | 0.996 | 0.986 | 0.992 | 0.994 | 1.000 | 0.997 |
| 4 | 0.957 | 0.859 | 0.918 | 0.933 | 0.774 | 0.873 | 1.000 | 0.948 | 1.000 | 0.973 | 0.986 | 1.000 | 0.980 | 0.957 | 0.971 |
| 5 | 0.949 | 0.964 | 0.960 | 0.919 | 0.946 | 0.933 | 1.000 | 0.988 | 1.000 | 0.986 | 0.973 | 0.973 | 0.973 | 0.981 | 0.979 |
| 6 | 0.944 | 0.911 | 0.982 | 1.000 | 0.880 | 0.978 | 0.916 | 1.000 | 0.995 | 0.986 | 1.000 | 0.996 | 1.000 | 0.967 | 0.986 |
| 7 | 0.931 | 0.735 | 0.844 | 0.870 | 0.650 | 0.771 | 1.000 | 0.957 | 1.000 | 0.884 | 0.961 | 1.000 | 0.874 | 0.846 | 0.864 |

POSITIVE NUMBER: CONSTRAINT SATISFIED. | THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED. | BETWEEN +1. AND -1.
1.000 : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
-2.000 : CONSTRAINT SUPPRESSED.
-- : STRAKE NOT EVALUATED.

Analytical Negative Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.822 | 0.945 | 0.910 | 0.964 | 0.995 | 0.995 | 0.981 | 0.981 | 1.000 | 1.000 | 0.808 |
| 2 | 0.919 | 0.989 | 0.953 | 0.956 | 0.999 | 0.999 | 0.973 | 0.973 | 1.000 | 1.000 | 0.914 |
| 3 | 0.934 | 0.868 | 0.961 | 0.995 | 1.000 | 1.000 | 0.997 | 0.997 | 1.000 | 1.000 | 0.857 |
| 4 | 0.924 | 1.000 | 0.945 | 1.000 | 0.987 | 0.987 | 1.000 | 1.000 | 1.000 | 1.000 | 0.906 |
| 5 | 0.946 | 0.948 | 0.962 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.943 |
| 6 | 0.910 | 0.810 | 0.943 | 0.985 | 1.000 | 1.000 | 0.991 | 0.991 | 1.000 | 1.000 | 0.781 |
| 7 | 0.897 | 0.844 | 0.929 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.895 |

MAESTRO Negative Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.835 | 0.986 | 0.918 | 0.957 | 0.994 | 0.994 | 0.978 | 0.978 | 1.000 | 1.000 | 0.826 |
| 2 | 0.919 | 0.986 | 0.960 | 0.942 | 1.000 | 1.000 | 0.964 | 0.964 | 1.000 | 1.000 | 0.917 |
| 3 | 0.933 | 0.861 | 0.959 | 0.992 | 1.000 | 1.000 | 0.995 | 0.995 | 1.000 | 1.000 | 0.852 |
| 4 | 0.935 | 1.000 | 0.954 | 0.997 | 0.988 | 0.988 | 1.000 | 1.000 | 1.000 | 1.000 | 0.910 |
| 5 | 0.902 | 0.987 | 0.927 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.914 | 0.917 | 0.902 |
| 6 | 0.914 | 0.816 | 0.946 | 0.985 | 0.998 | 0.998 | 0.991 | 0.991 | 1.000 | 1.000 | 0.781 |
| 7 | 0.728 | 0.666 | 0.869 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.851 | 0.864 | 0.728 |

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POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Negative Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.987 | 0.990 | 0.995 | 0.978 | 0.997 | 0.988 | 1.000 | 0.986 | 1.000 | 0.995 | 0.990 | 0.992 | 1.000 | 1.000 | 1.000 |
| 2 | 0.962 | 0.963 | 0.998 | 0.947 | 1.000 | 1.000 | 0.988 | 0.932 | 0.967 | 1.000 | 0.991 | 0.996 | 0.961 | 0.966 | 0.964 |
| 3 | 0.948 | 0.957 | 0.996 | 0.918 | 0.972 | 0.962 | 1.000 | 0.931 | 1.000 | 0.967 | 0.964 | 0.965 | 0.987 | 1.000 | 0.993 |
| 4 | 0.960 | 0.940 | 0.989 | 0.928 | 1.000 | 0.982 | 1.000 | 0.907 | 0.976 | 0.986 | 0.974 | 0.978 | 0.978 | 1.000 | 1.000 |
| 5 | 0.992 | 0.998 | 0.996 | 0.975 | 0.980 | 0.978 | 1.000 | 0.992 | 1.000 | 0.991 | 0.990 | 0.991 | 0.981 | 0.983 | 0.982 |
| 6 | 0.946 | 0.951 | 0.997 | 0.976 | 0.919 | 0.960 | 0.917 | 1.000 | 0.992 | 0.953 | 0.957 | 0.955 | 1.000 | 0.989 | 1.000 |
| 7 | 0.913 | 0.942 | 0.981 | 0.856 | 1.000 | 0.919 | 1.000 | 0.893 | 1.000 | 0.982 | 0.921 | 0.960 | 0.921 | 1.000 | 0.923 |

## MAESTRO Negative Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.812 | 0.991 | 0.904 | 0.756 | 1.000 | 0.869 | 1.000 | 0.966 | 1.000 | 1.000 | 0.966 | 1.000 | 0.933 | 0.996 | 0.958 |
| 2 | 0.970 | 0.967 | 0.997 | 0.964 | 1.000 | 1.000 | 0.994 | 0.932 | 0.976 | 1.000 | 0.994 | 1.000 | 0.971 | 0.975 | 0.973 |
| 3 | 0.988 | 0.997 | 0.995 | 0.959 | 0.958 | 0.958 | 1.000 | 1.000 | 1.000 | 0.962 | 0.962 | 0.962 | 1.000 | 1.000 | 1.000 |
| 4 | 0.928 | 0.952 | 0.961 | 0.877 | 0.906 | 0.921 | 1.000 | 0.932 | 1.000 | 0.980 | 0.970 | 0.976 | 0.976 | 1.000 | 1.000 |
| 5 | 0.805 | 0.883 | 0.844 | 0.726 | 0.815 | 0.770 | 0.964 | 0.938 | 0.952 | 1.000 | 1.000 | 1.000 | 0.886 | 0.898 | 0.893 |
| 6 | 0.940 | 0.881 | 0.968 | 0.959 | 0.826 | 0.954 | 0.893 | 1.000 | 1.000 | 0.959 | 0.958 | 0.958 | 0.988 | 0.959 | 0.976 |
| 7 | 0.903 | 0.502 | 0.704 | 0.711 | 0.336 | 0.541 | 1.000 | 0.926 | 1.000 | 0.922 | 0.909 | 0.916 | 0.714 | 0.697 | 0.710 |

POSITIVE NUMBER: CONSTRAINT SATISFIED. | THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED. | BETWEEN +1. AND -1.
1.000 : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
-2.000 : CONSTRAINT SUPPRESSED.
-- : STRAKE NOT EVALUATED.

Analytical Negative Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.856 | 0.969 | 0.922 | 0.922 | 1.000 | 1.000 | 0.927 | 0.927 | 1.000 | 1.000 | 0.856 |
| 2 | 0.607 | 0.868 | 0.809 | 0.604 | 1.000 | 1.000 | 0.845 | 0.845 | 1.000 | 1.000 | 0.607 |
| 3 | 0.510 | 0.622 | 0.730 | 0.878 | 1.000 | 1.000 | 0.939 | 0.939 | 1.000 | 1.000 | 0.488 |
| 5 | 0.427 | 0.340 | 0.738 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.427 |
| 6 | 0.855 | 0.976 | 0.951 | 0.951 | 0.980 | 0.980 | 0.955 | 0.955 | 1.000 | 1.000 | 0.810 |

MAESTRO Negative Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.823 | 0.968 | 0.927 | 0.922 | 1.000 | 1.000 | 0.928 | 0.928 | 1.000 | 1.000 | 0.817 |
| 2 | 0.357 | 0.793 | 0.701 | 0.457 | 1.000 | 1.000 | 0.757 | 0.757 | 1.000 | 1.000 | 0.351 |
| 3 | 0.382 | 0.537 | 0.795 | 0.699 | 1.000 | 1.000 | 0.842 | 0.842 | 1.000 | 1.000 | 0.338 |
| 5 | 0.611 | 0.530 | 0.821 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.612 |
| 6 | 0.858 | 0.969 | 0.967 | 0.965 | 0.989 | 0.989 | 0.968 | 0.968 | 1.000 | 1.000 | 0.798 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Negative Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.837 | 0.814 | 0.986 | 1.000 | 0.652 | 0.838 | 0.737 | 1.000 | 1.000 | 0.843 | 1.000 | 0.849 | 1.000 | 0.847 | 1.000 |
| 2 | 0.756 | 0.785 | 0.976 | 0.662 | 1.000 | 1.000 | 1.000 | 0.553 | 0.785 | 1.000 | 1.000 | 1.000 | 0.769 | 0.798 | 0.787 |
| 3 | 0.890 | 0.919 | 0.933 | 0.960 | 0.896 | 0.970 | 0.920 | 0.914 | 0.971 | 0.965 | 1.000 | 0.976 | 0.831 | 0.876 | 0.853 |
| 5 | 0.931 | 0.982 | 0.956 | 0.919 | 0.952 | 0.936 | 0.795 | 0.830 | 0.812 | 0.953 | 0.947 | 0.950 | 0.855 | 0.840 | 0.847 |
| 6 | 0.837 | 0.802 | 0.979 | 0.696 | 1.000 | 0.939 | 1.000 | 0.673 | 0.843 | 0.980 | 0.840 | 0.941 | 0.840 | 1.000 | 0.844 |

MAESTRO Negative Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.915 | 0.902 | 0.990 | 1.000 | 0.815 | 0.918 | 0.851 | 1.000 | 0.986 | 0.917 | 1.000 | 0.921 | 0.980 | 0.920 | 0.978 |
| 2 | 0.846 | 0.879 | 0.977 | 0.789 | 1.000 | 1.000 | 1.000 | 0.719 | 0.872 | 1.000 | 0.877 | 0.881 | 0.879 | 0.939 | 0.910 |
| 3 | 0.833 | 0.965 | 0.897 | 0.879 | 0.976 | 0.965 | 0.938 | 0.927 | 0.969 | 0.967 | 0.980 | 0.974 | 0.799 | 0.867 | 0.833 |
| 5 | 0.870 | 0.987 | 0.935 | 0.960 | 0.977 | 0.970 | 0.701 | 0.821 | 0.764 | 0.973 | 0.970 | 0.972 | 0.851 | 0.817 | 0.836 |
| 6 | 0.914 | 0.901 | 0.993 | 0.842 | 1.000 | 0.973 | 1.000 | 0.822 | 0.919 | 0.985 | 0.917 | 0.920 | 0.919 | 1.000 | 1.000 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Negative Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.675 | 0.849 | 0.862 | 0.866 | 1.000 | 1.000 | 0.930 | 0.930 | 1.000 | 1.000 | 0.667 |
| 2 | 0.757 | 0.935 | 0.839 | 0.785 | 1.000 | 1.000 | 0.859 | 0.859 | 1.000 | 1.000 | 0.758 |
| 3 | 0.946 | 0.970 | 0.975 | 0.971 | 1.000 | 1.000 | 0.982 | 0.982 | 1.000 | 1.000 | 0.937 |
| 4 | 0.921 | 0.988 | 0.965 | 0.955 | 0.989 | 0.989 | 0.984 | 0.984 | 1.000 | 1.000 | 0.926 |
| 5 | 0.879 | 0.957 | 0.888 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.877 |
| 6 | 0.940 | 0.977 | 0.954 | 0.996 | 0.978 | 0.978 | 0.997 | 0.997 | 1.000 | 1.000 | 0.861 |
| 7 | 0.786 | 0.932 | 0.832 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.785 |

MAESTRO Negative Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.612 | 0.812 | 0.883 | 0.814 | 1.000 | 1.000 | 0.901 | 0.901 | 1.000 | 1.000 | 0.583 |
| 2 | 0.596 | 0.915 | 0.762 | 0.695 | 1.000 | 1.000 | 0.795 | 0.795 | 1.000 | 1.000 | 0.585 |
| 3 | 0.903 | 0.985 | 0.953 | 0.939 | 1.000 | 1.000 | 0.961 | 0.961 | 1.000 | 1.000 | 0.902 |
| 4 | 0.851 | 0.970 | 0.933 | 0.889 | 1.000 | 1.000 | 0.960 | 0.960 | 1.000 | 1.000 | 0.853 |
| 5 | 0.900 | 0.857 | 0.924 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.897 |
| 6 | 0.922 | 0.970 | 0.953 | 0.972 | 0.996 | 0.996 | 0.982 | 0.982 | 1.000 | 1.000 | 0.905 |
| 7 | 0.880 | 0.874 | 0.901 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.880 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Negative Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.963 | 0.973 | 0.968 | 0.963 | 0.976 | 0.969 | 0.950 | 0.935 | 0.943 | 0.982 | 0.980 | 0.981 | 0.966 | 0.970 | 0.968 |
| 2 | 0.879 | 0.900 | 0.986 | 0.846 | 1.000 | 1.000 | 1.000 | 0.801 | 0.959 | 1.000 | 0.973 | 0.986 | 0.941 | 0.989 | 0.966 |
| 3 | 0.855 | 0.859 | 0.996 | 0.808 | 1.000 | 0.985 | 1.000 | 0.793 | 0.977 | 1.000 | 0.965 | 0.986 | 0.942 | 1.000 | 0.975 |
| 4 | 0.856 | 0.871 | 0.978 | 1.000 | 0.516 | 1.000 | 0.516 | 1.000 | 0.541 | 0.541 | 1.000 | 0.541 | 1.000 | 0.541 | 0.849 |
| 5 | 0.977 | 0.982 | 0.987 | 0.973 | 0.969 | 0.975 | 0.965 | 0.939 | 0.953 | 0.987 | 0.988 | 0.988 | 0.914 | 0.921 | 0.917 |
| 6 | 0.852 | 0.856 | 0.994 | 1.000 | 0.794 | 0.979 | 0.799 | 1.000 | 0.981 | 0.947 | 0.990 | 0.978 | 1.000 | 0.958 | 1.000 |
| 7 | 0.931 | 0.919 | 0.936 | 0.918 | 1.000 | 1.000 | 0.907 | 0.874 | 0.930 | 0.937 | 0.932 | 0.935 | 0.943 | 0.972 | 0.976 |

## MAESTRO Negative Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.950 | 0.944 | 0.947 | 0.949 | 0.941 | 0.945 | 0.961 | 0.952 | 0.956 | 0.978 | 0.976 | 0.977 | 0.955 | 0.952 | 0.954 |
| 2 | 0.928 | 0.954 | 0.986 | 0.953 | 1.000 | 1.000 | 0.977 | 0.855 | 0.932 | 1.000 | 0.990 | 1.000 | 0.935 | 0.952 | 0.943 |
| 3 | 0.964 | 0.969 | 0.995 | 0.958 | 1.000 | 1.000 | 1.000 | 0.933 | 0.982 | 1.000 | 0.995 | 1.000 | 0.971 | 0.985 | 0.978 |
| 4 | 0.917 | 0.906 | 0.984 | 1.000 | 0.648 | 0.674 | 0.663 | 0.938 | 0.882 | 0.675 | 1.000 | 1.000 | 0.967 | 0.675 | 0.675 |
| 5 | 0.980 | 0.994 | 0.991 | 0.980 | 0.975 | 0.978 | 0.960 | 0.936 | 0.948 | 0.980 | 0.982 | 0.981 | 0.923 | 0.929 | 0.926 |
| 6 | 0.970 | 0.970 | 0.997 | 1.000 | 0.956 | 0.996 | 0.959 | 1.000 | 0.994 | 0.986 | 0.993 | 0.990 | 1.000 | 0.992 | 1.000 |
| 7 | 0.946 | 0.971 | 0.966 | 0.960 | 0.965 | 0.978 | 0.931 | 0.973 | 0.957 | 0.970 | 0.972 | 0.971 | 0.988 | 0.977 | 0.986 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Negative Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.727 | 0.906 | 0.902 | 0.869 | 1.000 | 1.000 | 0.931 | 0.931 | 1.000 | 1.000 | 0.712 |
| 2 | 0.800 | 0.942 | 0.886 | 0.826 | 1.000 | 1.000 | 0.886 | 0.886 | 1.000 | 1.000 | 0.799 |
| 3 | 0.958 | 0.992 | 0.974 | 0.967 | 1.000 | 1.000 | 0.980 | 0.980 | 1.000 | 1.000 | 0.942 |
| 4 | 0.917 | 0.984 | 0.947 | 0.967 | 1.000 | 1.000 | 0.979 | 0.979 | 1.000 | 1.000 | 0.916 |
| 5 | 0.950 | 0.974 | 0.969 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.950 |
| 6 | 0.953 | 0.979 | 0.972 | 0.987 | 1.000 | 1.000 | 0.992 | 0.992 | 1.000 | 1.000 | 0.900 |
| 7 | 0.870 | 0.909 | 0.920 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.862 |

MAESTRO Negative Twist

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.653 | 0.878 | 0.881 | 0.818 | 1.000 | 1.000 | 0.903 | 0.903 | 1.000 | 1.000 | 0.631 |
| 2 | 0.704 | 0.933 | 0.827 | 0.748 | 1.000 | 1.000 | 0.832 | 0.832 | 1.000 | 1.000 | 0.702 |
| 3 | 0.929 | 0.984 | 0.953 | 0.936 | 1.000 | 1.000 | 0.961 | 0.961 | 1.000 | 1.000 | 0.927 |
| 4 | 0.892 | 0.984 | 0.932 | 0.938 | 1.000 | 1.000 | 0.960 | 0.960 | 1.000 | 1.000 | 0.889 |
| 5 | 0.910 | 0.854 | 0.965 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.910 |
| 6 | 0.926 | 0.979 | 0.954 | 0.966 | 1.000 | 1.000 | 0.979 | 0.979 | 1.000 | 1.000 | 0.922 |
| 7 | 0.852 | 0.883 | 0.913 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.853 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Negative Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.955 | 0.942 | 0.977 | 0.952 | 1.000 | 0.988 | 1.000 | 0.903 | 0.952 | 0.994 | 0.983 | 0.989 | 0.973 | 0.989 | 0.981 |
| 2 | 0.911 | 0.913 | 0.986 | 0.890 | 1.000 | 1.000 | 1.000 | 0.862 | 0.981 | 1.000 | 0.982 | 0.992 | 0.957 | 1.000 | 0.981 |
| 3 | 0.869 | 0.875 | 0.995 | 0.809 | 1.000 | 1.000 | 1.000 | 0.799 | 0.979 | 1.000 | 0.966 | 1.000 | 0.951 | 1.000 | 0.978 |
| 4 | 0.922 | 0.905 | 0.974 | 1.000 | 0.870 | 0.970 | 0.867 | 1.000 | 0.947 | 0.966 | 1.000 | 0.968 | 1.000 | 0.958 | 0.972 |
| 5 | 0.989 | 0.993 | 0.992 | 0.979 | 0.988 | 0.985 | 0.991 | 1.000 | 1.000 | 0.989 | 0.988 | 0.989 | 0.991 | 0.990 | 0.991 |
| 6 | 0.868 | 0.873 | 0.993 | 1.000 | 0.819 | 1.000 | 0.807 | 1.000 | 0.978 | 0.958 | 1.000 | 0.980 | 1.000 | 0.959 | 1.000 |
| 7 | 0.915 | 0.875 | 0.972 | 0.843 | 1.000 | 0.948 | 1.000 | 0.799 | 0.886 | 1.000 | 0.887 | 0.891 | 0.890 | 1.000 | 0.948 |

## MAESTRO Negative Twist

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.961 | 0.946 | 0.953 | 0.959 | 0.947 | 0.956 | 1.000 | 0.946 | 0.977 | 0.991 | 0.984 | 0.988 | 0.969 | 0.964 | 0.966 |
| 2 | 0.932 | 0.914 | 0.990 | 0.932 | 1.000 | 1.000 | 0.984 | 0.852 | 0.950 | 1.000 | 0.989 | 0.995 | 0.951 | 0.990 | 0.971 |
| 3 | 0.973 | 0.977 | 0.996 | 0.970 | 1.000 | 1.000 | 1.000 | 0.954 | 0.987 | 1.000 | 0.997 | 1.000 | 0.984 | 0.995 | 0.990 |
| 4 | 0.970 | 0.940 | 0.964 | 0.960 | 0.925 | 0.958 | 0.995 | 0.941 | 0.979 | 1.000 | 0.988 | 1.000 | 0.984 | 0.971 | 0.978 |
| 5 | 0.983 | 0.996 | 0.990 | 0.988 | 0.996 | 0.990 | 0.971 | 0.984 | 0.979 | 0.983 | 0.987 | 0.984 | 1.000 | 0.985 | 1.000 |
| 6 | 0.968 | 0.967 | 0.997 | 1.000 | 0.955 | 1.000 | 0.951 | 1.000 | 0.992 | 0.991 | 1.000 | 0.995 | 1.000 | 0.988 | 0.995 |
| 7 | 0.945 | 0.967 | 0.978 | 0.912 | 0.979 | 0.951 | 1.000 | 0.933 | 1.000 | 1.000 | 0.952 | 0.953 | 0.953 | 0.990 | 0.989 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

# Appendix I. Comparison of Results for Transverse Hogging

## Analytical Transverse Hogging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.605 | 0.743 | 0.856 | 0.810 | 1.000 | 1.000 | 0.899 | 0.899 | 1.000 | 1.000 | 0.556 |
| 2 | 0.716 | 0.903 | 0.835 | 0.744 | 1.000 | 1.000 | 0.833 | 0.833 | 1.000 | 1.000 | 0.714 |
| 3 | 0.932 | 0.985 | 0.956 | 0.940 | 1.000 | 1.000 | 0.962 | 0.962 | 1.000 | 1.000 | 0.930 |
| 4 | 0.870 | 0.952 | 0.918 | 0.942 | 1.000 | 1.000 | 0.964 | 0.964 | 1.000 | 1.000 | 0.860 |
| 5 | 0.934 | 0.933 | 0.964 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.922 |
| 6 | 0.920 | 0.979 | 0.948 | 0.971 | 1.000 | 1.000 | 0.982 | 0.982 | 1.000 | 1.000 | 0.889 |
| 7 | 0.844 | 0.924 | 0.897 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.845 |

## MAESTRO Transverse Hogging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.480 | 0.735 | 0.796 | 0.723 | 1.000 | 1.000 | 0.849 | 0.849 | 1.000 | 1.000 | 0.437 |
| 2 | 0.583 | 0.855 | 0.752 | 0.625 | 1.000 | 1.000 | 0.749 | 0.749 | 1.000 | 1.000 | 0.582 |
| 3 | 0.890 | 0.976 | 0.930 | 0.905 | 1.000 | 1.000 | 0.940 | 0.940 | 1.000 | 1.000 | 0.885 |
| 4 | 0.818 | 0.947 | 0.887 | 0.902 | 1.000 | 1.000 | 0.939 | 0.939 | 1.000 | 1.000 | 0.808 |
| 5 | 0.870 | 0.837 | 0.940 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.870 |
| 6 | 0.875 | 0.965 | 0.919 | 0.951 | 1.000 | 1.000 | 0.969 | 0.969 | 1.000 | 1.000 | 0.871 |
| 7 | 0.785 | 0.849 | 0.875 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.786 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Transverse Hogging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.927 | 0.794 | 0.907 | 0.907 | 1.000 | 1.000 | 1.000 | 0.693 | 0.839 | 0.980 | 0.922 | 0.960 | 0.948 | 1.000 | 1.000 |
| 2 | 0.747 | 0.794 | 0.966 | 0.695 | 1.000 | 1.000 | 1.000 | 0.667 | 0.948 | 1.000 | 0.939 | 0.975 | 0.899 | 1.000 | 0.967 |
| 3 | 0.871 | 0.885 | 0.991 | 0.806 | 1.000 | 0.980 | 1.000 | 0.806 | 1.000 | 1.000 | 0.968 | 1.000 | 0.958 | 1.000 | 0.979 |
| 4 | 0.978 | 0.935 | 0.975 | 0.965 | 1.000 | 1.000 | 0.959 | 0.894 | 0.953 | 0.984 | 0.976 | 0.982 | 0.986 | 1.000 | 1.000 |
| 5 | 0.945 | 0.974 | 0.964 | 0.921 | 0.955 | 0.940 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.957 | 0.959 | 0.958 |
| 6 | 0.869 | 0.877 | 0.995 | 1.000 | 0.807 | 1.000 | 0.791 | 1.000 | 0.977 | 0.957 | 1.000 | 0.979 | 1.000 | 0.961 | 1.000 |
| 7 | 0.862 | 0.900 | 0.954 | 0.783 | 1.000 | 0.874 | 1.000 | 0.816 | 1.000 | 1.000 | 0.875 | 1.000 | 0.874 | 1.000 | 0.876 |

## MAESTRO Transverse Hogging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.919 | 0.867 | 0.950 | 0.906 | 1.000 | 1.000 | 0.976 | 0.783 | 0.887 | 0.982 | 0.947 | 0.965 | 0.941 | 1.000 | 0.981 |
| 2 | 0.832 | 0.848 | 0.977 | 0.824 | 1.000 | 1.000 | 1.000 | 0.730 | 0.918 | 1.000 | 0.955 | 0.980 | 0.905 | 1.000 | 0.958 |
| 3 | 0.933 | 0.952 | 0.990 | 0.912 | 1.000 | 0.989 | 1.000 | 0.925 | 0.991 | 1.000 | 0.988 | 1.000 | 0.974 | 1.000 | 0.989 |
| 4 | 0.919 | 0.884 | 0.979 | 0.882 | 1.000 | 1.000 | 1.000 | 0.818 | 0.948 | 1.000 | 0.956 | 0.964 | 0.958 | 1.000 | 1.000 |
| 5 | 0.944 | 0.978 | 0.966 | 0.921 | 0.952 | 0.940 | 0.988 | 1.000 | 1.000 | 0.987 | 0.952 | 0.988 | 0.951 | 0.980 | 0.952 |
| 6 | 0.930 | 0.939 | 0.993 | 1.000 | 0.912 | 1.000 | 0.902 | 1.000 | 0.985 | 0.977 | 0.993 | 0.988 | 1.000 | 0.981 | 1.000 |
| 7 | 0.863 | 0.883 | 0.965 | 0.783 | 1.000 | 0.868 | 1.000 | 0.794 | 0.874 | 1.000 | 0.866 | 0.868 | 0.866 | 1.000 | 0.895 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Transverse Hogging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.686 | 0.872 | 0.855 | 0.877 | 0.985 | 0.985 | 0.935 | 0.935 | 1.000 | 1.000 | 0.651 |
| 2 | 0.806 | 0.951 | 0.846 | 0.861 | 1.000 | 1.000 | 0.912 | 0.912 | 1.000 | 1.000 | 0.801 |
| 3 | 0.833 | 0.655 | 0.890 | 0.969 | 1.000 | 1.000 | 0.981 | 0.981 | 1.000 | 1.000 | 0.628 |
| 4 | 0.879 | 0.862 | 0.919 | 0.985 | 0.981 | 0.981 | 0.991 | 0.991 | 1.000 | 1.000 | 0.802 |
| 5 | 0.760 | 0.981 | 0.819 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.761 |
| 6 | 0.731 | 0.503 | 0.834 | 0.960 | 1.000 | 1.000 | 0.976 | 0.976 | 1.000 | 1.000 | 0.433 |
| 7 | 0.527 | 0.918 | 0.646 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.528 |

MAESTRO Transverse Hogging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.604 | 0.860 | 0.814 | 0.823 | 0.978 | 0.978 | 0.905 | 0.905 | 1.000 | 1.000 | 0.570 |
| 2 | 0.739 | 0.927 | 0.816 | 0.787 | 1.000 | 1.000 | 0.863 | 0.863 | 1.000 | 1.000 | 0.740 |
| 3 | 0.807 | 0.590 | 0.870 | 0.956 | 1.000 | 1.000 | 0.971 | 0.971 | 1.000 | 1.000 | 0.561 |
| 4 | 0.850 | 0.835 | 0.902 | 0.964 | 0.973 | 0.973 | 0.979 | 0.979 | 1.000 | 1.000 | 0.773 |
| 5 | 0.692 | 0.955 | 0.763 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.693 |
| 6 | 0.669 | 0.397 | 0.788 | 0.945 | 1.000 | 1.000 | 0.966 | 0.966 | 1.000 | 1.000 | 0.308 |
| 7 | 0.658 | 0.894 | 0.744 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.659 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Transverse Hogging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.946 | 0.986 | 0.978 | 0.950 | 1.000 | 0.988 | 1.000 | 0.961 | 0.992 | 0.993 | 0.983 | 0.988 | 0.960 | 0.979 | 0.970 |
| 2 | 0.933 | 0.935 | 0.997 | 0.917 | 1.000 | 1.000 | 0.977 | 0.862 | 0.918 | 1.000 | 0.982 | 0.992 | 0.904 | 0.919 | 0.912 |
| 3 | 0.900 | 0.912 | 0.993 | 0.845 | 0.954 | 0.899 | 1.000 | 0.860 | 1.000 | 0.909 | 0.895 | 0.902 | 0.977 | 1.000 | 1.000 |
| 4 | 0.978 | 0.947 | 0.984 | 0.952 | 0.969 | 0.963 | 1.000 | 0.919 | 0.974 | 0.959 | 0.958 | 0.958 | 0.984 | 1.000 | 1.000 |
| 5 | 0.948 | 0.984 | 0.982 | 0.952 | 0.962 | 0.959 | 0.918 | 0.859 | 0.891 | 0.995 | 0.980 | 0.980 | 0.827 | 0.845 | 0.836 |
| 6 | 0.897 | 0.905 | 0.991 | 0.941 | 0.835 | 0.886 | 0.842 | 1.000 | 0.985 | 0.860 | 0.874 | 0.867 | 1.000 | 0.979 | 1.000 |
| 7 | 0.880 | 0.918 | 0.976 | 0.806 | 1.000 | 0.888 | 0.839 | 0.723 | 0.779 | 0.899 | 0.881 | 0.890 | 0.773 | 0.789 | 0.781 |

## MAESTRO Transverse Hogging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.934 | 0.985 | 0.974 | 0.946 | 1.000 | 0.984 | 1.000 | 0.943 | 0.986 | 0.991 | 0.980 | 0.986 | 0.943 | 0.968 | 0.956 |
| 2 | 0.942 | 0.945 | 0.997 | 0.944 | 1.000 | 1.000 | 0.974 | 0.855 | 0.913 | 1.000 | 0.986 | 0.994 | 0.900 | 0.915 | 0.907 |
| 3 | 0.942 | 0.958 | 0.991 | 0.836 | 0.917 | 0.875 | 1.000 | 0.929 | 1.000 | 0.888 | 0.877 | 0.882 | 0.987 | 1.000 | 0.993 |
| 4 | 0.926 | 0.893 | 0.982 | 0.870 | 1.000 | 0.958 | 1.000 | 0.832 | 0.954 | 0.951 | 0.940 | 0.945 | 0.960 | 1.000 | 1.000 |
| 5 | 0.943 | 0.987 | 0.978 | 0.953 | 0.958 | 0.956 | 0.891 | 0.822 | 0.857 | 0.993 | 0.979 | 0.993 | 0.782 | 0.799 | 0.790 |
| 6 | 0.940 | 0.955 | 0.990 | 0.900 | 0.804 | 0.851 | 0.913 | 1.000 | 0.988 | 0.824 | 0.836 | 0.830 | 1.000 | 0.989 | 1.000 |
| 7 | 0.871 | 0.886 | 0.983 | 0.776 | 1.000 | 0.871 | 0.910 | 0.760 | 0.839 | 0.880 | 0.860 | 0.871 | 0.804 | 0.827 | 0.815 |

POSITIVE NUMBER: CONSTRAINT SATISFIED. | THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED. | BETWEEN +1. AND -1.
1.000 : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
-2.000 : CONSTRAINT SUPPRESSED.
-- : STRAKE NOT EVALUATED.

## Analytical Transverse Hogging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.750 | 0.949 | 0.884 | 0.874 | 1.000 | 1.000 | 0.883 | 0.883 | 1.000 | 1.000 | 0.749 |
| 2 | 0.240 | 0.729 | 0.635 | 0.325 | 1.000 | 1.000 | 0.693 | 0.693 | 1.000 | 1.000 | 0.237 |
| 3 | 0.266 | 0.387 | 0.677 | 0.638 | 1.000 | 1.000 | 0.807 | 0.807 | 1.000 | 1.000 | 0.210 |
| 5 | 0.376 | 0.276 | 0.697 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.376 |
| 6 | 0.786 | 0.946 | 0.937 | 0.930 | 0.983 | 0.983 | 0.935 | 0.935 | 1.000 | 1.000 | 0.703 |

## MAESTRO Transverse Hogging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.664 | 0.937 | 0.853 | 0.846 | 1.000 | 1.000 | 0.857 | 0.857 | 1.000 | 1.000 | 0.655 |
| 2 | -0.007 | 0.575 | 0.451 | 0.120 | 1.000 | 1.000 | 0.543 | 0.543 | 1.000 | 1.000 | -0.010 |
| 3 | 0.017 | 0.226 | 0.625 | 0.444 | 1.000 | 1.000 | 0.686 | 0.686 | 1.000 | 1.000 | -0.024 |
| 5 | 0.381 | 0.277 | 0.681 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.381 |
| 6 | 0.733 | 0.928 | 0.934 | 0.930 | 0.979 | 0.979 | 0.935 | 0.935 | 1.000 | 1.000 | 0.630 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Transverse Hogging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.812 | 0.791 | 0.987 | 1.000 | 0.621 | 0.821 | 0.690 | 1.000 | 0.986 | 0.822 | 1.000 | 0.828 | 0.990 | 0.825 | 0.981 |
| 2 | 0.721 | 0.751 | 0.975 | 0.623 | 1.000 | 1.000 | 1.000 | 0.488 | 0.748 | 1.000 | 0.770 | 1.000 | 0.754 | 0.902 | 0.767 |
| 3 | 0.778 | 0.921 | 0.863 | 0.853 | 0.918 | 0.964 | 0.902 | 0.879 | 0.968 | 0.948 | 0.974 | 0.962 | 0.721 | 0.811 | 0.765 |
| 5 | 0.846 | 0.975 | 0.918 | 0.931 | 0.954 | 0.943 | 0.616 | 0.751 | 0.683 | 0.951 | 0.946 | 0.949 | 0.807 | 0.757 | 0.783 |
| 6 | 0.812 | 0.779 | 0.980 | 0.663 | 1.000 | 0.934 | 1.000 | 0.627 | 0.820 | 0.976 | 0.817 | 0.822 | 0.819 | 1.000 | 1.000 |

MAESTRO Transverse Hogging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.820 | 0.803 | 0.979 | 1.000 | 0.649 | 0.833 | 0.694 | 1.000 | 0.965 | 0.830 | 1.000 | 0.836 | 0.954 | 0.834 | 0.950 |
| 2 | 0.718 | 0.760 | 0.967 | 0.626 | 1.000 | 1.000 | 1.000 | 0.494 | 0.752 | 1.000 | 0.763 | 0.772 | 0.771 | 0.874 | 0.824 |
| 3 | 0.672 | 0.935 | 0.794 | 0.748 | 0.966 | 0.921 | 0.890 | 0.849 | 0.938 | 0.934 | 0.957 | 0.945 | 0.621 | 0.748 | 0.682 |
| 5 | 0.725 | 0.971 | 0.854 | 0.946 | 0.956 | 0.954 | 0.448 | 0.650 | 0.551 | 0.955 | 0.951 | 0.953 | 0.702 | 0.647 | 0.680 |
| 6 | 0.819 | 0.795 | 0.986 | 0.685 | 1.000 | 0.972 | 1.000 | 0.644 | 0.830 | 0.969 | 0.826 | 0.832 | 0.831 | 1.000 | 1.000 |

Analytical Transverse Hogging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.488 | 0.747 | 0.839 | 0.745 | 1.000 | 1.000 | 0.862 | 0.862 | 1.000 | 1.000 | 0.469 |
| 2 | 0.510 | 0.885 | 0.692 | 0.603 | 1.000 | 1.000 | 0.729 | 0.729 | 1.000 | 1.000 | 0.499 |
| 3 | 0.875 | 0.981 | 0.941 | 0.924 | 1.000 | 1.000 | 0.951 | 0.951 | 1.000 | 1.000 | 0.874 |
| 4 | 0.841 | 0.966 | 0.930 | 0.874 | 1.000 | 1.000 | 0.954 | 0.954 | 1.000 | 1.000 | 0.844 |
| 5 | 0.845 | 0.847 | 0.870 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.832 |
| 6 | 0.895 | 0.969 | 0.945 | 0.970 | 0.987 | 0.987 | 0.981 | 0.981 | 1.000 | 1.000 | 0.829 |
| 7 | 0.776 | 0.868 | 0.816 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.777 |

MAESTRO Transverse Hogging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.325 | 0.648 | 0.775 | 0.637 | 1.000 | 1.000 | 0.797 | 0.797 | 1.000 | 1.000 | 0.290 |
| 2 | 0.299 | 0.821 | 0.555 | 0.448 | 1.000 | 1.000 | 0.611 | 0.611 | 1.000 | 1.000 | 0.285 |
| 3 | 0.807 | 0.969 | 0.905 | 0.876 | 1.000 | 1.000 | 0.919 | 0.919 | 1.000 | 1.000 | 0.807 |
| 4 | 0.725 | 0.936 | 0.874 | 0.783 | 1.000 | 1.000 | 0.919 | 0.919 | 1.000 | 1.000 | 0.730 |
| 5 | 0.795 | 0.725 | 0.850 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.795 |
| 6 | 0.848 | 0.934 | 0.911 | 0.943 | 0.994 | 0.994 | 0.963 | 0.963 | 1.000 | 1.000 | 0.809 |
| 7 | 0.790 | 0.767 | 0.816 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.790 |

POSITIVE NUMBER: CONSTRAINT SATISFIED. | THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED. | BETWEEN +1. AND -1.
1.000 : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
-2.000 : CONSTRAINT SUPPRESSED.
-- : STRAKE NOT EVALUATED.

## Analytical Transverse Hogging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.923 | 0.930 | 0.927 | 0.921 | 0.930 | 0.925 | 0.935 | 0.918 | 0.927 | 0.970 | 0.965 | 0.967 | 0.932 | 0.936 | 0.934 |
| 2 | 0.871 | 0.888 | 0.983 | 0.880 | 1.000 | 1.000 | 1.000 | 0.751 | 0.906 | 1.000 | 0.977 | 1.000 | 0.894 | 0.949 | 0.921 |
| 3 | 0.860 | 0.868 | 0.994 | 0.827 | 1.000 | 1.000 | 1.000 | 0.793 | 0.972 | 1.000 | 0.977 | 1.000 | 0.932 | 1.000 | 0.967 |
| 4 | 0.839 | 0.840 | 0.974 | 1.000 | 0.450 | 0.483 | 0.461 | 1.000 | 0.757 | 0.483 | 1.000 | 1.000 | 1.000 | 0.483 | 0.483 |
| 5 | 0.968 | 0.980 | 0.985 | 0.962 | 0.960 | 0.963 | 0.943 | 0.906 | 0.925 | 0.975 | 0.976 | 0.975 | 0.882 | 0.891 | 0.886 |
| 6 | 0.856 | 0.855 | 0.993 | 1.000 | 0.798 | 0.979 | 0.800 | 1.000 | 0.981 | 0.953 | 0.989 | 0.978 | 1.000 | 0.954 | 1.000 |
| 7 | 0.924 | 0.939 | 0.932 | 0.901 | 0.976 | 0.943 | 0.914 | 0.917 | 0.927 | 0.944 | 0.940 | 0.943 | 0.948 | 0.974 | 0.978 |

## MAESTRO Transverse Hogging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.896 | 0.881 | 0.888 | 0.896 | 0.876 | 0.886 | 0.919 | 0.907 | 0.913 | 0.956 | 0.951 | 0.954 | 0.904 | 0.895 | 0.900 |
| 2 | 0.880 | 0.919 | 0.979 | 0.951 | 1.000 | 1.000 | 0.940 | 0.736 | 0.855 | 1.000 | 0.984 | 1.000 | 0.861 | 0.893 | 0.877 |
| 3 | 0.928 | 0.936 | 0.991 | 0.917 | 1.000 | 1.000 | 1.000 | 0.864 | 0.964 | 1.000 | 1.000 | 1.000 | 0.943 | 0.970 | 0.956 |
| 4 | 0.838 | 0.802 | 0.962 | 1.000 | 0.399 | 0.440 | 0.425 | 0.892 | 0.918 | 0.441 | 1.000 | 1.000 | 0.939 | 0.441 | 0.442 |
| 5 | 0.961 | 0.986 | 0.982 | 0.961 | 0.951 | 0.956 | 0.919 | 0.873 | 0.896 | 0.960 | 0.962 | 0.961 | 0.851 | 0.862 | 0.857 |
| 6 | 0.944 | 0.942 | 0.993 | 1.000 | 0.919 | 0.991 | 0.919 | 1.000 | 0.987 | 0.969 | 0.985 | 0.977 | 1.000 | 0.981 | 0.992 |
| 7 | 0.908 | 0.943 | 0.936 | 0.923 | 0.929 | 0.958 | 0.885 | 0.946 | 0.922 | 0.953 | 0.955 | 0.955 | 0.972 | 0.964 | 0.969 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Transverse Hogging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.530 | 0.824 | 0.855 | 0.745 | 1.000 | 1.000 | 0.862 | 0.862 | 1.000 | 1.000 | 0.514 |
| 2 | 0.619 | 0.893 | 0.765 | 0.657 | 1.000 | 1.000 | 0.768 | 0.768 | 1.000 | 1.000 | 0.619 |
| 3 | 0.904 | 0.980 | 0.940 | 0.919 | 1.000 | 1.000 | 0.949 | 0.949 | 1.000 | 1.000 | 0.902 |
| 4 | 0.865 | 0.979 | 0.917 | 0.919 | 1.000 | 1.000 | 0.949 | 0.949 | 1.000 | 1.000 | 0.861 |
| 5 | 0.879 | 0.847 | 0.952 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.879 |
| 6 | 0.913 | 0.973 | 0.946 | 0.961 | 1.000 | 1.000 | 0.976 | 0.976 | 1.000 | 1.000 | 0.884 |
| 7 | 0.830 | 0.844 | 0.907 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.830 |

## MAESTRO Transverse Hogging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.373 | 0.764 | 0.773 | 0.637 | 1.000 | 1.000 | 0.797 | 0.797 | 1.000 | 1.000 | 0.348 |
| 2 | 0.444 | 0.845 | 0.653 | 0.516 | 1.000 | 1.000 | 0.663 | 0.663 | 1.000 | 1.000 | 0.442 |
| 3 | 0.851 | 0.967 | 0.904 | 0.870 | 1.000 | 1.000 | 0.918 | 0.918 | 1.000 | 1.000 | 0.848 |
| 4 | 0.800 | 0.964 | 0.875 | 0.869 | 1.000 | 1.000 | 0.916 | 0.916 | 1.000 | 1.000 | 0.794 |
| 5 | 0.808 | 0.722 | 0.932 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.808 |
| 6 | 0.856 | 0.958 | 0.911 | 0.932 | 1.000 | 1.000 | 0.958 | 0.958 | 1.000 | 1.000 | 0.847 |
| 7 | 0.756 | 0.768 | 0.870 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.757 |

POSITIVE NUMBER: CONSTRAINT SATISFIED. | THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED. | BETWEEN +1. AND -1.
1.000 : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
-2.000 : CONSTRAINT SUPPRESSED.
-- : STRAKE NOT EVALUATED.

Analytical Transverse Hogging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.929 | 0.925 | 0.934 | 0.922 | 0.932 | 0.944 | 1.000 | 0.882 | 0.947 | 0.987 | 0.972 | 0.980 | 0.950 | 0.944 | 0.947 |
| 2 | 0.870 | 0.840 | 0.983 | 0.859 | 1.000 | 1.000 | 1.000 | 0.741 | 0.928 | 1.000 | 0.976 | 0.989 | 0.916 | 0.985 | 0.955 |
| 3 | 0.845 | 0.850 | 0.994 | 0.795 | 1.000 | 1.000 | 1.000 | 0.780 | 0.976 | 1.000 | 0.963 | 1.000 | 0.938 | 1.000 | 0.974 |
| 4 | 0.909 | 0.819 | 0.949 | 1.000 | 0.759 | 0.928 | 0.852 | 1.000 | 0.954 | 0.954 | 1.000 | 1.000 | 1.000 | 0.919 | 0.947 |
| 5 | 0.973 | 0.986 | 0.984 | 0.954 | 0.969 | 0.966 | 0.964 | 1.000 | 0.972 | 0.972 | 0.974 | 0.975 | 1.000 | 0.969 | 0.971 |
| 6 | 0.841 | 0.841 | 0.994 | 1.000 | 0.782 | 1.000 | 0.776 | 1.000 | 0.976 | 0.952 | 1.000 | 0.978 | 1.000 | 0.945 | 0.977 |
| 7 | 0.906 | 0.899 | 0.978 | 0.840 | 1.000 | 0.971 | 1.000 | 0.826 | 0.898 | 1.000 | 0.896 | 0.899 | 0.899 | 0.978 | 0.975 |

MAESTRO Transverse Hogging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.927 | 0.825 | 0.889 | 0.933 | 0.813 | 0.900 | 0.992 | 0.904 | 0.950 | 0.981 | 0.970 | 0.976 | 0.937 | 0.895 | 0.916 |
| 2 | 0.872 | 0.812 | 0.965 | 0.890 | 1.000 | 1.000 | 0.939 | 0.682 | 0.876 | 1.000 | 0.979 | 0.990 | 0.888 | 0.972 | 0.930 |
| 3 | 0.938 | 0.940 | 0.993 | 0.930 | 1.000 | 1.000 | 1.000 | 0.898 | 0.972 | 1.000 | 0.991 | 1.000 | 0.963 | 0.991 | 0.979 |
| 4 | 0.961 | 0.815 | 0.921 | 0.995 | 0.763 | 0.906 | 0.913 | 0.938 | 0.965 | 1.000 | 1.000 | 1.000 | 0.960 | 0.913 | 0.940 |
| 5 | 0.960 | 0.995 | 0.981 | 0.960 | 0.991 | 0.970 | 0.924 | 0.953 | 0.944 | 0.951 | 0.969 | 0.953 | 1.000 | 0.952 | 1.000 |
| 6 | 0.937 | 0.937 | 0.993 | 1.000 | 0.916 | 1.000 | 0.905 | 1.000 | 0.983 | 0.982 | 0.994 | 0.989 | 1.000 | 0.975 | 0.990 |
| 7 | 0.934 | 0.918 | 0.984 | 0.886 | 0.967 | 1.000 | 0.963 | 0.855 | 0.918 | 0.939 | 0.917 | 0.920 | 0.921 | 0.972 | 0.976 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

# Appendix J. Comparison of Results for Transverse Sagging

## Analytical Transverse Sagging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.655 | 0.859 | 0.864 | 0.824 | 1.000 | 1.000 | 0.906 | 0.906 | 1.000 | 1.000 | 0.624 |
| 2 | 0.719 | 0.915 | 0.843 | 0.758 | 1.000 | 1.000 | 0.842 | 0.842 | 1.000 | 1.000 | 0.718 |
| 3 | 0.932 | 0.986 | 0.957 | 0.943 | 1.000 | 1.000 | 0.964 | 0.964 | 1.000 | 1.000 | 0.929 |
| 4 | 0.879 | 0.975 | 0.924 | 0.937 | 1.000 | 1.000 | 0.962 | 0.962 | 1.000 | 1.000 | 0.874 |
| 5 | 0.862 | 0.791 | 0.954 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.862 |
| 6 | 0.913 | 0.974 | 0.946 | 0.968 | 1.000 | 1.000 | 0.980 | 0.980 | 1.000 | 1.000 | 0.908 |
| 7 | 0.835 | 0.877 | 0.908 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.835 |

## MAESTRO Transverse Sagging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.458 | 0.819 | 0.773 | 0.707 | 1.000 | 1.000 | 0.839 | 0.839 | 1.000 | 1.000 | 0.435 |
| 2 | 0.541 | 0.842 | 0.730 | 0.594 | 1.000 | 1.000 | 0.727 | 0.727 | 1.000 | 1.000 | 0.540 |
| 3 | 0.879 | 0.970 | 0.924 | 0.897 | 1.000 | 1.000 | 0.934 | 0.934 | 1.000 | 1.000 | 0.872 |
| 4 | 0.808 | 0.949 | 0.882 | 0.891 | 1.000 | 1.000 | 0.933 | 0.933 | 1.000 | 1.000 | 0.798 |
| 5 | 0.859 | 0.835 | 0.923 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.859 |
| 6 | 0.861 | 0.962 | 0.910 | 0.945 | 1.000 | 1.000 | 0.965 | 0.965 | 1.000 | 1.000 | 0.855 |
| 7 | 0.781 | 0.828 | 0.877 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.782 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.   |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.    |  BETWEEN +1. AND -1.
      1.000     : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000     : CONSTRAINT SUPPRESSED.
```

Analytical Transverse Sagging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.986 | 0.976 | 0.989 | 0.990 | 0.985 | 1.000 | 0.959 | 0.980 | 0.976 | 0.981 | 0.987 | 0.984 | 0.988 | 0.995 | 0.992 |
| 2 | 0.965 | 0.978 | 0.983 | 1.000 | 1.000 | 1.000 | 0.898 | 0.931 | 0.936 | 0.984 | 0.991 | 0.990 | 0.970 | 0.983 | 0.976 |
| 3 | 0.956 | 0.950 | 0.995 | 1.000 | 0.928 | 0.994 | 0.918 | 1.000 | 0.991 | 0.989 | 1.000 | 1.000 | 1.000 | 0.984 | 0.992 |
| 4 | 0.896 | 0.878 | 0.989 | 0.852 | 1.000 | 1.000 | 1.000 | 0.813 | 0.954 | 1.000 | 0.951 | 0.960 | 0.950 | 1.000 | 0.963 |
| 5 | 0.971 | 0.981 | 0.977 | 1.000 | 1.000 | 1.000 | 0.960 | 0.972 | 0.967 | 0.977 | 0.979 | 0.979 | 1.000 | 1.000 | 1.000 |
| 6 | 0.957 | 0.950 | 0.996 | 0.929 | 1.000 | 1.000 | 1.000 | 0.918 | 0.990 | 1.000 | 0.981 | 0.989 | 0.989 | 1.000 | 1.000 |
| 7 | 0.929 | 0.930 | 0.996 | 0.883 | 1.000 | 0.934 | 1.000 | 0.879 | 0.927 | 1.000 | 0.925 | 0.927 | 0.926 | 1.000 | 1.000 |

MAESTRO Transverse Sagging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.847 | 0.946 | 0.931 | 0.828 | 1.000 | 0.944 | 1.000 | 0.890 | 1.000 | 0.991 | 0.967 | 0.981 | 0.920 | 1.000 | 0.960 |
| 2 | 0.927 | 0.923 | 0.986 | 0.961 | 1.000 | 1.000 | 0.885 | 0.826 | 0.886 | 0.983 | 0.977 | 0.983 | 0.932 | 0.983 | 0.957 |
| 3 | 0.935 | 0.924 | 0.991 | 1.000 | 0.892 | 0.990 | 0.881 | 1.000 | 0.987 | 0.981 | 1.000 | 0.989 | 1.000 | 0.981 | 0.991 |
| 4 | 0.833 | 0.825 | 0.993 | 0.768 | 1.000 | 0.955 | 1.000 | 0.744 | 0.939 | 1.000 | 0.925 | 0.940 | 0.922 | 1.000 | 0.943 |
| 5 | 0.891 | 0.952 | 0.922 | 0.851 | 0.913 | 0.884 | 1.000 | 1.000 | 1.000 | 1.000 | 0.978 | 1.000 | 0.927 | 0.930 | 0.929 |
| 6 | 0.941 | 0.935 | 0.994 | 0.910 | 1.000 | 1.000 | 1.000 | 0.891 | 0.986 | 1.000 | 0.977 | 0.986 | 0.985 | 1.000 | 1.000 |
| 7 | 0.864 | 0.901 | 0.965 | 0.795 | 1.000 | 0.878 | 1.000 | 0.820 | 1.000 | 1.000 | 0.877 | 0.879 | 0.878 | 1.000 | 0.897 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Transverse Sagging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.773 | 0.915 | 0.910 | 0.903 | 0.989 | 0.989 | 0.949 | 0.949 | 1.000 | 1.000 | 0.748 |
| 2 | 0.857 | 0.962 | 0.920 | 0.872 | 1.000 | 1.000 | 0.919 | 0.919 | 1.000 | 1.000 | 0.856 |
| 3 | 0.904 | 0.798 | 0.939 | 0.979 | 1.000 | 1.000 | 0.986 | 0.986 | 1.000 | 1.000 | 0.780 |
| 4 | 0.914 | 0.934 | 0.945 | 0.978 | 0.985 | 0.985 | 0.988 | 0.988 | 1.000 | 1.000 | 0.889 |
| 5 | 0.882 | 0.887 | 0.912 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.882 |
| 6 | 0.829 | 0.670 | 0.894 | 0.971 | 1.000 | 1.000 | 0.983 | 0.983 | 1.000 | 1.000 | 0.598 |
| 7 | 0.749 | 0.659 | 0.877 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.749 |

## MAESTRO Transverse Sagging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.618 | 0.925 | 0.789 | 0.817 | 0.973 | 0.973 | 0.902 | 0.902 | 1.000 | 1.000 | 0.596 |
| 2 | 0.740 | 0.927 | 0.826 | 0.768 | 1.000 | 1.000 | 0.850 | 0.850 | 1.000 | 1.000 | 0.741 |
| 3 | 0.811 | 0.607 | 0.875 | 0.954 | 1.000 | 1.000 | 0.970 | 0.970 | 1.000 | 1.000 | 0.582 |
| 4 | 0.852 | 0.844 | 0.911 | 0.955 | 0.965 | 0.965 | 0.974 | 0.974 | 1.000 | 1.000 | 0.759 |
| 5 | 0.605 | 0.940 | 0.689 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.606 |
| 6 | 0.670 | 0.391 | 0.783 | 0.938 | 1.000 | 1.000 | 0.962 | 0.962 | 1.000 | 1.000 | 0.296 |
| 7 | 0.442 | 0.288 | 0.712 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.443 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Transverse Sagging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.976 | 0.993 | 0.991 | 0.980 | 1.000 | 0.996 | 0.991 | 0.978 | 0.993 | 0.991 | 0.990 | 0.991 | 0.980 | 0.989 | 0.985 |
| 2 | 0.983 | 0.987 | 0.998 | 0.995 | 1.000 | 1.000 | 0.984 | 0.953 | 0.972 | 1.000 | 0.999 | 0.999 | 0.968 | 0.973 | 0.970 |
| 3 | 0.977 | 0.968 | 0.995 | 0.946 | 0.941 | 0.943 | 0.959 | 1.000 | 1.000 | 0.948 | 0.949 | 0.949 | 1.000 | 0.991 | 0.996 |
| 4 | 0.908 | 0.887 | 0.987 | 0.854 | 1.000 | 0.968 | 1.000 | 0.819 | 0.954 | 0.978 | 0.952 | 0.959 | 0.955 | 1.000 | 1.000 |
| 5 | 0.978 | 0.985 | 0.982 | 0.996 | 0.993 | 0.994 | 0.965 | 0.955 | 0.960 | 0.982 | 0.984 | 0.983 | 0.926 | 0.928 | 0.927 |
| 6 | 0.976 | 0.967 | 0.995 | 0.940 | 0.909 | 0.925 | 1.000 | 0.951 | 0.992 | 0.917 | 0.921 | 0.919 | 0.996 | 1.000 | 1.000 |
| 7 | 0.922 | 0.912 | 0.968 | 0.857 | 0.955 | 0.912 | 1.000 | 0.854 | 0.912 | 0.979 | 0.910 | 0.912 | 0.910 | 1.000 | 0.912 |

## MAESTRO Transverse Sagging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 1

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.923 | 0.986 | 0.963 | 0.906 | 1.000 | 0.955 | 1.000 | 0.927 | 0.979 | 1.000 | 0.977 | 0.985 | 0.927 | 0.953 | 0.940 |
| 2 | 0.957 | 0.961 | 0.998 | 0.976 | 1.000 | 1.000 | 0.975 | 0.881 | 0.927 | 1.000 | 0.994 | 0.997 | 0.918 | 0.929 | 0.923 |
| 3 | 0.980 | 0.965 | 0.990 | 0.877 | 0.879 | 0.878 | 0.964 | 1.000 | 1.000 | 0.891 | 0.890 | 0.891 | 1.000 | 0.994 | 0.997 |
| 4 | 0.851 | 0.830 | 0.986 | 0.748 | 1.000 | 0.929 | 1.000 | 0.742 | 0.927 | 0.945 | 0.915 | 0.927 | 0.923 | 1.000 | 1.000 |
| 5 | 0.948 | 0.960 | 0.954 | 0.913 | 0.927 | 0.920 | 0.828 | 0.767 | 0.797 | 1.000 | 0.986 | 0.986 | 0.728 | 0.743 | 0.736 |
| 6 | 0.977 | 0.970 | 0.991 | 0.864 | 0.827 | 0.845 | 0.975 | 0.957 | 0.987 | 0.822 | 0.827 | 0.825 | 1.000 | 1.000 | 1.000 |
| 7 | 0.835 | 0.885 | 0.971 | 0.710 | 1.000 | 0.833 | 1.000 | 0.798 | 1.000 | 0.890 | 0.851 | 0.867 | 0.846 | 1.000 | 0.851 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Transverse Sagging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.780 | 0.966 | 0.910 | 0.912 | 1.000 | 1.000 | 0.919 | 0.919 | 1.000 | 1.000 | 0.772 |
| 2 | 0.213 | 0.721 | 0.600 | 0.340 | 1.000 | 1.000 | 0.678 | 0.678 | 1.000 | 1.000 | 0.206 |
| 3 | 0.217 | 0.435 | 0.767 | 0.592 | 1.000 | 1.000 | 0.779 | 0.779 | 1.000 | 1.000 | 0.187 |
| 5 | 0.651 | 0.566 | 0.828 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.651 |
| 6 | 0.834 | 0.965 | 0.964 | 0.968 | 0.986 | 0.986 | 0.970 | 0.970 | 1.000 | 1.000 | 0.770 |

MAESTRO Transverse Sagging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.644 | 0.937 | 0.849 | 0.849 | 1.000 | 1.000 | 0.861 | 0.861 | 1.000 | 1.000 | 0.632 |
| 2 | -0.067 | 0.526 | 0.395 | 0.078 | 1.000 | 1.000 | 0.500 | 0.500 | 1.000 | 1.000 | -0.069 |
| 3 | -0.055 | 0.207 | 0.627 | 0.385 | 1.000 | 1.000 | 0.646 | 0.646 | 1.000 | 1.000 | -0.083 |
| 5 | 0.474 | 0.370 | 0.718 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.474 |
| 6 | 0.739 | 0.926 | 0.937 | 0.942 | 0.979 | 0.979 | 0.947 | 0.947 | 1.000 | 1.000 | 0.639 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Transverse Sagging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.903 | 0.896 | 0.986 | 1.000 | 0.814 | 0.913 | 0.822 | 0.983 | 0.966 | 0.910 | 1.000 | 0.913 | 0.960 | 0.912 | 0.960 |
| 2 | 0.851 | 0.880 | 0.977 | 0.795 | 1.000 | 1.000 | 1.000 | 0.724 | 0.874 | 0.883 | 0.867 | 0.877 | 0.864 | 0.925 | 0.894 |
| 3 | 0.775 | 0.958 | 0.862 | 0.820 | 1.000 | 0.940 | 0.938 | 0.908 | 0.952 | 0.960 | 0.968 | 0.964 | 0.746 | 0.840 | 0.792 |
| 5 | 0.803 | 0.982 | 0.899 | 0.976 | 0.974 | 0.979 | 0.602 | 0.759 | 0.686 | 0.978 | 0.977 | 0.978 | 0.786 | 0.755 | 0.776 |
| 6 | 0.900 | 0.894 | 0.992 | 0.825 | 0.997 | 0.998 | 1.000 | 0.802 | 0.910 | 0.971 | 0.907 | 0.911 | 0.910 | 1.000 | 1.000 |

## MAESTRO Transverse Sagging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 1 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.859 | 0.848 | 0.977 | 1.000 | 0.731 | 0.872 | 0.747 | 0.960 | 0.949 | 0.868 | 0.977 | 0.873 | 0.932 | 0.871 | 0.933 |
| 2 | 0.767 | 0.811 | 0.968 | 0.693 | 1.000 | 1.000 | 1.000 | 0.579 | 0.799 | 0.815 | 0.790 | 0.806 | 0.781 | 0.867 | 0.823 |
| 3 | 0.646 | 0.923 | 0.773 | 0.713 | 1.000 | 0.896 | 0.901 | 0.858 | 0.924 | 0.933 | 0.946 | 0.940 | 0.604 | 0.739 | 0.669 |
| 5 | 0.681 | 0.973 | 0.833 | 0.958 | 0.961 | 0.966 | 0.404 | 0.621 | 0.519 | 0.965 | 0.962 | 0.964 | 0.657 | 0.612 | 0.642 |
| 6 | 0.857 | 0.845 | 0.985 | 0.755 | 0.989 | 0.996 | 0.997 | 0.716 | 0.868 | 0.956 | 0.864 | 0.870 | 0.870 | 1.000 | 1.000 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Transverse Sagging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.512 | 0.739 | 0.839 | 0.757 | 1.000 | 1.000 | 0.869 | 0.869 | 1.000 | 1.000 | 0.471 |
| 2 | 0.484 | 0.886 | 0.691 | 0.616 | 1.000 | 1.000 | 0.737 | 0.737 | 1.000 | 1.000 | 0.469 |
| 3 | 0.873 | 0.979 | 0.937 | 0.917 | 1.000 | 1.000 | 0.947 | 0.947 | 1.000 | 1.000 | 0.873 |
| 4 | 0.793 | 0.956 | 0.906 | 0.846 | 1.000 | 1.000 | 0.943 | 0.943 | 1.000 | 1.000 | 0.798 |
| 5 | 0.838 | 0.733 | 0.918 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.838 |
| 6 | 0.897 | 0.962 | 0.935 | 0.960 | 0.999 | 0.999 | 0.974 | 0.974 | 1.000 | 1.000 | 0.886 |
| 7 | 0.821 | 0.810 | 0.905 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.822 |

## MAESTRO Transverse Sagging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.292 | 0.663 | 0.740 | 0.613 | 1.000 | 1.000 | 0.782 | 0.782 | 1.000 | 1.000 | 0.255 |
| 2 | 0.243 | 0.802 | 0.520 | 0.413 | 1.000 | 1.000 | 0.583 | 0.583 | 1.000 | 1.000 | 0.228 |
| 3 | 0.789 | 0.964 | 0.896 | 0.860 | 1.000 | 1.000 | 0.910 | 0.910 | 1.000 | 1.000 | 0.789 |
| 4 | 0.692 | 0.926 | 0.856 | 0.760 | 1.000 | 1.000 | 0.909 | 0.909 | 1.000 | 1.000 | 0.697 |
| 5 | 0.821 | 0.760 | 0.849 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.796 |
| 6 | 0.832 | 0.935 | 0.893 | 0.933 | 0.999 | 0.999 | 0.957 | 0.957 | 1.000 | 1.000 | 0.811 |
| 7 | 0.753 | 0.753 | 0.861 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.754 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

Analytical Transverse Sagging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.954 | 0.919 | 0.936 | 0.955 | 0.907 | 0.931 | 0.954 | 0.949 | 0.951 | 0.967 | 0.967 | 0.967 | 0.957 | 0.937 | 0.947 |
| 2 | 0.933 | 0.962 | 0.984 | 0.983 | 1.000 | 1.000 | 0.915 | 0.850 | 0.908 | 1.000 | 0.992 | 1.000 | 0.921 | 0.924 | 0.923 |
| 3 | 0.972 | 0.968 | 0.994 | 0.983 | 0.983 | 1.000 | 0.934 | 0.938 | 0.975 | 1.000 | 1.000 | 1.000 | 0.979 | 0.963 | 0.971 |
| 4 | 0.922 | 0.890 | 0.981 | 0.941 | 0.624 | 0.657 | 0.651 | 0.859 | 0.937 | 0.659 | 1.000 | 1.000 | 0.953 | 0.659 | 0.659 |
| 5 | 0.959 | 0.995 | 0.977 | 0.979 | 0.961 | 0.976 | 0.945 | 0.922 | 0.936 | 0.947 | 0.958 | 0.953 | 0.911 | 0.918 | 0.914 |
| 6 | 0.973 | 0.973 | 0.997 | 0.961 | 0.984 | 0.996 | 0.989 | 0.961 | 0.993 | 0.987 | 0.988 | 0.988 | 0.992 | 1.000 | 0.996 |
| 7 | 0.946 | 0.966 | 0.971 | 0.959 | 0.950 | 0.972 | 0.929 | 0.984 | 0.959 | 0.967 | 0.970 | 0.969 | 1.000 | 0.973 | 0.979 |

MAESTRO Transverse Sagging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 2 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.827 | 0.864 | 0.846 | 0.814 | 0.864 | 0.839 | 0.942 | 0.915 | 0.928 | 0.968 | 0.948 | 0.958 | 0.855 | 0.876 | 0.865 |
| 2 | 0.908 | 0.946 | 0.979 | 1.000 | 1.000 | 1.000 | 0.867 | 0.766 | 0.838 | 1.000 | 0.990 | 1.000 | 0.860 | 0.871 | 0.866 |
| 3 | 0.946 | 0.932 | 0.987 | 0.987 | 0.946 | 1.000 | 0.882 | 0.914 | 0.962 | 1.000 | 1.000 | 1.000 | 0.969 | 0.936 | 0.952 |
| 4 | 0.869 | 0.842 | 0.943 | 0.797 | 0.576 | 0.612 | 0.605 | 0.715 | 0.854 | 0.614 | 0.868 | 1.000 | 0.862 | 0.613 | 0.614 |
| 5 | 0.949 | 0.963 | 0.956 | 0.922 | 0.925 | 0.925 | 0.910 | 0.862 | 0.886 | 0.973 | 0.973 | 0.973 | 0.846 | 0.857 | 0.851 |
| 6 | 0.953 | 0.957 | 0.994 | 0.935 | 0.979 | 0.994 | 0.990 | 0.936 | 0.991 | 0.978 | 0.981 | 0.980 | 0.984 | 1.000 | 0.993 |
| 7 | 0.900 | 0.922 | 0.932 | 0.855 | 0.897 | 0.896 | 0.937 | 1.000 | 0.964 | 0.960 | 0.957 | 0.959 | 0.965 | 0.969 | 0.974 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Transverse Sagging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.556 | 0.807 | 0.841 | 0.758 | 1.000 | 1.000 | 0.869 | 0.869 | 1.000 | 1.000 | 0.524 |
| 2 | 0.610 | 0.908 | 0.769 | 0.674 | 1.000 | 1.000 | 0.779 | 0.779 | 1.000 | 1.000 | 0.605 |
| 3 | 0.906 | 0.979 | 0.937 | 0.915 | 1.000 | 1.000 | 0.947 | 0.947 | 1.000 | 1.000 | 0.904 |
| 4 | 0.859 | 0.977 | 0.911 | 0.915 | 1.000 | 1.000 | 0.945 | 0.945 | 1.000 | 1.000 | 0.854 |
| 5 | 0.836 | 0.732 | 0.953 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.837 |
| 6 | 0.895 | 0.968 | 0.937 | 0.954 | 1.000 | 1.000 | 0.971 | 0.971 | 1.000 | 1.000 | 0.888 |
| 7 | 0.815 | 0.823 | 0.902 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.815 |

## MAESTRO Transverse Sagging

INITIAL PANEL ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | PCSF | PCCB | PCMY | PCSB | PYTF | PYTP | PYCF | PYCP | PSPBT | PSPBL | PFLB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.335 | 0.780 | 0.735 | 0.613 | 1.000 | 1.000 | 0.782 | 0.782 | 1.000 | 1.000 | 0.308 |
| 2 | 0.398 | 0.833 | 0.622 | 0.482 | 1.000 | 1.000 | 0.636 | 0.636 | 1.000 | 1.000 | 0.394 |
| 3 | 0.837 | 0.963 | 0.896 | 0.857 | 1.000 | 1.000 | 0.910 | 0.910 | 1.000 | 1.000 | 0.834 |
| 4 | 0.779 | 0.959 | 0.853 | 0.853 | 1.000 | 1.000 | 0.906 | 0.906 | 1.000 | 1.000 | 0.773 |
| 5 | 0.818 | 0.729 | 0.916 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.818 |
| 6 | 0.831 | 0.959 | 0.895 | 0.923 | 1.000 | 1.000 | 0.952 | 0.952 | 1.000 | 1.000 | 0.821 |
| 7 | 0.734 | 0.751 | 0.860 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.734 |

```
POSITIVE NUMBER: CONSTRAINT SATISFIED.  |  THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED.   |  BETWEEN +1. AND -1.
      1.000    : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
     -2.000    : CONSTRAINT SUPPRESSED.
        --     : STRAKE NOT EVALUATED.
```

## Analytical Transverse Sagging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.982 | 0.865 | 0.938 | 1.000 | 0.842 | 0.937 | 0.955 | 0.982 | 0.970 | 0.978 | 0.980 | 0.979 | 0.979 | 0.935 | 0.957 |
| 2 | 0.945 | 0.906 | 0.979 | 0.969 | 1.000 | 1.000 | 0.923 | 0.825 | 0.923 | 0.997 | 0.994 | 0.996 | 0.937 | 0.977 | 0.957 |
| 3 | 0.953 | 0.951 | 0.996 | 1.000 | 0.935 | 1.000 | 0.917 | 1.000 | 0.982 | 0.991 | 1.000 | 1.000 | 0.994 | 0.974 | 0.986 |
| 4 | 0.921 | 0.892 | 0.969 | 0.883 | 1.000 | 0.971 | 1.000 | 0.811 | 0.937 | 1.000 | 0.955 | 1.000 | 0.954 | 0.980 | 0.958 |
| 5 | 0.954 | 0.982 | 0.968 | 1.000 | 1.000 | 1.000 | 0.937 | 0.965 | 0.953 | 0.954 | 0.964 | 0.959 | 1.000 | 1.000 | 1.000 |
| 6 | 0.953 | 0.950 | 0.996 | 0.933 | 1.000 | 1.000 | 1.000 | 0.920 | 0.989 | 1.000 | 0.982 | 0.990 | 0.983 | 1.000 | 0.993 |
| 7 | 0.958 | 0.962 | 0.990 | 0.928 | 0.986 | 0.957 | 0.980 | 0.931 | 0.958 | 0.957 | 0.953 | 0.956 | 1.000 | 0.989 | 0.990 |

## MAESTRO Transverse Sagging

INITIAL FRAME ADEQUACY PARAMETER VALUES - MODULE 3 OF SUBSTR. 2

| STRAKE | FCPH1 | FCPH2 | FCPH3 | FYCF1 | FYCF2 | FYCF3 | FYTF1 | FYTF2 | FYTF3 | FYCP1 | FYCP2 | FYCP3 | FYTP1 | FYTP2 | FYTP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.840 | 0.796 | 0.846 | 0.811 | 0.784 | 0.850 | 1.000 | 0.914 | 1.000 | 0.988 | 0.967 | 0.979 | 0.910 | 0.878 | 0.893 |
| 2 | 0.896 | 0.814 | 0.954 | 0.933 | 1.000 | 1.000 | 0.884 | 0.678 | 0.853 | 0.997 | 0.982 | 0.990 | 0.885 | 0.963 | 0.924 |
| 3 | 0.937 | 0.937 | 0.995 | 1.000 | 0.921 | 1.000 | 0.882 | 1.000 | 0.969 | 0.985 | 1.000 | 1.000 | 0.991 | 0.965 | 0.981 |
| 4 | 0.918 | 0.783 | 0.868 | 0.895 | 0.722 | 0.836 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.952 | 0.905 | 0.929 |
| 5 | 0.949 | 0.975 | 0.966 | 0.925 | 0.950 | 0.943 | 0.924 | 1.000 | 0.943 | 0.950 | 0.961 | 0.962 | 1.000 | 0.945 | 0.949 |
| 6 | 0.936 | 0.932 | 0.996 | 0.906 | 1.000 | 1.000 | 1.000 | 0.886 | 0.984 | 1.000 | 0.977 | 0.987 | 0.974 | 1.000 | 0.989 |
| 7 | 0.932 | 0.948 | 0.977 | 0.972 | 0.914 | 0.979 | 0.889 | 0.953 | 0.938 | 0.939 | 0.980 | 0.981 | 1.000 | 0.937 | 0.940 |

POSITIVE NUMBER: CONSTRAINT SATISFIED. | THESE VALUES ARE NORMALIZED
NEGATIVE NUMBER: CONSTRAINT VIOLATED. | BETWEEN +1. AND -1.
1.000 : CONSTRAINT NOT RELEVANT OR NULLIFIED BY USER.
-2.000 : CONSTRAINT SUPPRESSED.
-- : STRAKE NOT EVALUATED.