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SCREENING METHODOLOGIES FOR USE IN PLATFORM ASSESSMENTS AND REQUALIFICATIONS

PROJECT PROGRESS REPORT #2

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1. Introduction

The present research work on the "Screening" project started in June 1993. Based on previous research on the requalification of platforms undertaken at University of California at Berkeley, the objective of this project is to further develop and verify qualitative and simplified quantitative screening methodologies for Level 1 and Level 2 platform assessments so that they can be used in practice. At the suggestion of the sponsors, this research is focusing on the simplified quantitative analyses of Level 2.

In the first stage the research focused on making improvements to the existing simplified quantitative limit equilibrium analysis procedures. The improvements included the P-Delta effects in decklegs, effect of local wave forces on diagonal brace capacities near the sea surface, inclusion of axial pile failure mode, and finally best estimate joint capacities depending on joint type.

In the second project phase, a PC-code has been developed to perform simplified limit state analysis for generic platforms (4-, 6-, 8- and 12-leg). Using the recently developed code, a verification case study has been performed. The performance of an 8-leg platform located in Gulf of Mexico has been studied and the results are compared to those available from a detailed non-linear push-over analysis. (AIM Platform Analysis Report)

This report briefly introduces the features of the developed code. The case study results are presented and briefly discussed.

2. Level 2 - Progress

2.1. Progress in Development of a PC-Code

A PC-Code is being developed to perform simplified Ultimate Limit State (ULS) analysis for platforms with generic geometries (4-, 6-, 8- and 12-leg platforms). The code utilizes the simplified procedures developed to estimate the ULS lateral load capacity of the three primary components of steel template-type platforms: the deck legs, the jacket and the foundation. The lateral loadings due to wind, wave and current are also computed.

The geometry of the platform is defined by the user. This includes the platform configuration, member sizes, effective deck areas and projected areas of appurtenances.

Soil parameters such as the effective internal angle of friction (for cohesionless soils), undrained shear strength (for cohesive soils) and the specific submerged weight of soil are specified by the user.

Oceanographic conditions are user defined and include the storm wind speed at a reference height, wave height and period, current and storm water depth. The wind drag coefficient for the exposed deck areas and the hydrodynamic drag coefficient must also be specified.

Wind forces, wave and current velocities and hydrodynamic forces are calculated using the simplified procedures described in [1],[2].

The deck leg shear capacity, the pile lateral and axial capacities in cohesive and cohesionless soils are estimated based on procedures described in Project Progress Report #1 [3].

To derive a realistic estimate of the jacket bay shear capacity, the ultimate strength of each diagonal brace at a bay is estimated first. The capacity of a given brace is taken as the minimum of the capacity of the brace or the capacity of either its joints (tension, compression). Next, the Most Likely to Fail (MLTF) member is determined. MLTF is defined as the member with the lowest capacity over stiffness ratio. The lateral load on a bay at failure of the first member can be estimated by combining the horizontal components of the load in other members at the moment of first member failure. A linear multi-spring model is used to relate the forces and displacements of diagonal braces at a given bay. The horizontal components of axial forces in the legs due to overturning moment are estimated and added to the brace forces.

2.2. Verification Case Study

2.2.1. Platform Description

Located in the main pass area of the Gulf of Mexico, the 8-leg template type platform is installed in a water depth of approximately 271 feet. Designed and installed in 1968-70, the platform has been exposed to high environmental loading developed by hurricanes passing through the Gulf. The typical leg diameter is 44 3/4 inches with 1/2 to 5/8 inches wall thickness. Major diagonal and horizontal brace sizes range from 14 to 30 inches with 3/8 to 1/2 inches wall thickness. The steel material used throughout the platform is A36. The structure foundation consists of eight 42-inch piles which penetrate to a depth of 270 ft into medium sands overlaying stiff clays. The piles are grouted to the jacket leg. The lower deck is located at an elevation of +46 ft and the upper deck is located at an elevation of +63 ft.

2.2.2. Detailed Non-Linear Push-Over Analysis

Oceanographic Conditions

The oceanographic conditions at the site consists of waves, currents, winds and tides. The H_{100} is 70 ft. A 9th order stream function was used to compute wave crest elevations. A wave steepness of 1/12 was used (wave period of 12.8 seconds for the 100-year wave). According to 1988 wave crest elevations, waves with return period greater than hundred years will result in deck inundation. Marine growth at the site was taken as 1 inch and considered for all members located between the waterline and -100 ft.

Environmental Forces

A three-dimensional platform computer model and a two-dimensional wave grid was used to compute the forces acting on the platform. The loading on each member throughout the platform is then summed to determine the platform's base shear. The process is repeated as the wave is moved through the structure in 24 increments to compute the maximum base shear. Wave forces are computed for two directions, end-on X and broadside Y.

The Morison (MJOS) equation was used to compute the local forces on members. The drag coefficient was taken as Cd = 0.7 and the inertia coefficient was taken as Cm = 1.5.

Wind forces were computed using the API RP2A formulation assuming a drag coefficient of Cs = 1.0 for clear decks, 1.5 for cluttered and 2.0 for blocked decks.

As mentioned before, the wave begins to impact the deck at the 100-year return period condition. The additional forces due to deck inundation were computed by hand calculations [1],[2]. The wave impact loads were computed using full impact area and a drag coefficient Cd = 2.0. The remaining deck area not covered by the wave is exposed to the wind. This wind forces were calculated and added to the wave forces.

ULS Capacity Determination

The ULS were determined for the platform's orthogonal directions -end-on (X) and broadside (Y) using the non-linear program SEASTAR. For each case, the platform was loaded to failure considering a wave acting below the deck and a wave acting on the deck. Two different wave profiles were used with the wave below the deck condition using a hundred-yr wave profile and the wave in the deck condition using a 200-year wave load profile. In the case of end-on loading, the wave in deck condition results in an ultimate capacity of 2607 kips. Most of the member failures are due to compressive buckling of braces. The analysis indicates a brittle strength behavior and little effective redundancy which is a typical result for K-braced platform systems. In the case of broadside loading with wave in the deck the ultimate capacity is 2935 kips.

2.2.3. Simplified Analysis

The same oceanographic conditions and hydrodynamic coefficients utilized in the detailed analysis were used to perform a simplified analysis. For 100 year return period conditions, water particle velocities and their decay based on depth stretched linear wave theory (deep water approximation) led to lateral forces which were 40% lower than those computed in detailed analysis. However, If the drag coefficient is increased to Cd=1.2, the total lateral forces are in good agreement.

In order to compare the total lateral forces acting on the platform, water particle velocities were also computed based on Stokes fifth order theory. The maximum lateral forces are computed (Cd= 0.7) and plotted versus the return period. This is done for both broadside and end-on directions. Compared to the results of detailed analysis, total lateral forces are over-predicted by up to 20% (Fig. 1, Fig. 2). Since in the simplified analysis the structure elements are modeled as equivalent vertical cylinders that are located at the wave crest, the difference in forces is reasonable.

The ultimate shear capacities have been checked against the non-linear results. The shear capacity and storm shear are plotted versus platform elevation (Fig.3, Fig.4). In case of broadside loading, the simplified analysis predicts a failure mode in the second jacket bay at a total base shear of about 2900 kips, which is in a very good agreement with the results from non linear analysis (Fig. 3). In case of end-on loading the simplified analysis indicates a failure due to buckling of compression braces in the upper jacket bay. This is confirmed by the results of the detailed analysis. However, the ultimate lateral capacity is over-predicted by 16% (Fig. 4).

2.3. Conclusions

Summarizing the results of the verification case study, we see that the simplified analysis tends to under-predict the lateral forces acting on the platform, if depth stretched linear wave theory is utilized to estimate the water kinematics with a drag coefficient Cd = 0.7. However, a calibrated Cd can be used, which leads to total lateral forces that are in good agreement with the results from detailed analysis. In the case that water particle velocities are based on Stokes Fifth Order Theory (Cd = 0.7), the simplified analysis tends to over-predict the lateral forces by 20%.

The simplified analysis was able to predict the failure mode and the ultimate lateral load capacity in case of broadside loading. In case of end-on loading, the failure mode was correctly predicted, however, the ultimate lateral capacity was over-predicted by 16%.

Further verification case studies will be performed to determine a bias factor for environmental loadings acting on the platforms. As a result of the verification case study, we are investigating the accuracy of wave force calculations based on the depth stretched linear wave theory versus Stokes Fifth Order Theory for different water depths.

3. Present focus and plans for next 6 months

Please refer to the attached research plan. With the development of the "generic" PC-code, the ground has been laid for further verification studies, which will enable us to verify and calibrate the results of the simplified analyses. This effort will be the major effort to be undertaken within the next months.

The code needs to be finalized, the input fully automated and documented before it can be delivered to the project sponsors.

Once the verification studies are completed and the code for analysis of "intact" platforms is finalized and documented, we will start the research on developing damaged and repaired element algorithms and their integration in the code.

Research Plan for the Next 6 Months

1. **Finalizing the "generic" code**
   - Inclusion of a procedure for defining joint parameters and geometry.
   - Inclusion of a procedure for calculating RSR based on axial failure mode in foundation.
   - Inclusion of an input option for marine growth on portions of structure.
   - Check the numerical stability of the code.

2. **Automating the input procedure used in the code**
   - Create subroutines and use dialog boxes to facilitate the input of all local and global parameters, material properties and environmental conditions.

3. **Verification case studies**

4. **Integration of verification case study results in the code**
   - The main objective of this task is to calibrate the forces and capacities as estimated in simplified analysis. The task will include the wrap-up of the results of case studies.

5. **Software documentation**
   - The objective is to provide the program user with a user-manual. The manual will include instructions on how to use the program and interpret the results.

6. **Developing non-linear models for jacket bays**
   - The objective is to develop a model which accounts for the post buckling behavior of the diagonal braces and the ultimate capacity of the horizontal braces. This work may be necessary to perform in the case of "intact" structures. It will be necessary to perform in the case of "damaged " structures.

7. **Developing damaged and repaired element algorithms**
   - The objective is to be able to predict the reduction in the ULS lateral capacity of the platform due to damaged elements. Different approaches need to be considered and evaluated; eliminating the damaged elements, or using existing research results and trying to integrate them in the simplified model.

	March	April	May	June	July	August
1. Finalize Work on Generic Code	■					
2. Automate Input Procedure		■				
3. Verification Case Studies		■	■	■		
4. Integrate the Results of the Verification Case Studies in the Code			■	■		
5. Document Software				■		
6. Develop Non-Linear Model for Jacket Bays					■	
7. Develop Damaged and Repaired Element Algorithms					■	■
	March	April	May	June	July	August

RESEARCH PLAN FOR THE NEXT SIX MONTHS

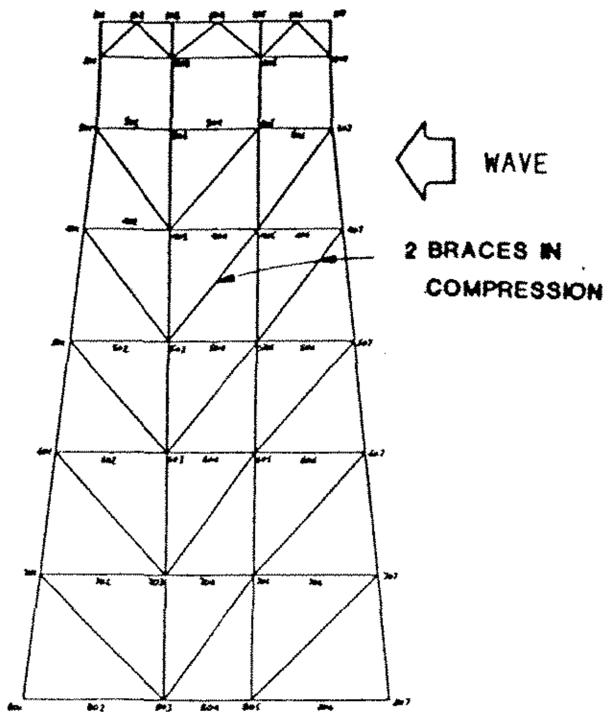
4. References

1. **Bea, R. G. , DesRoches, R. , 1993.** " *Development and Verification of a Simplified Procedure to Estimate the Ultimate Limit State Capacity of Template-Type Platforms.*" Fifth International Symposium, Integrity of Offshore Structures IOS '93, Glasgow, UK, 17-18 June 1993.

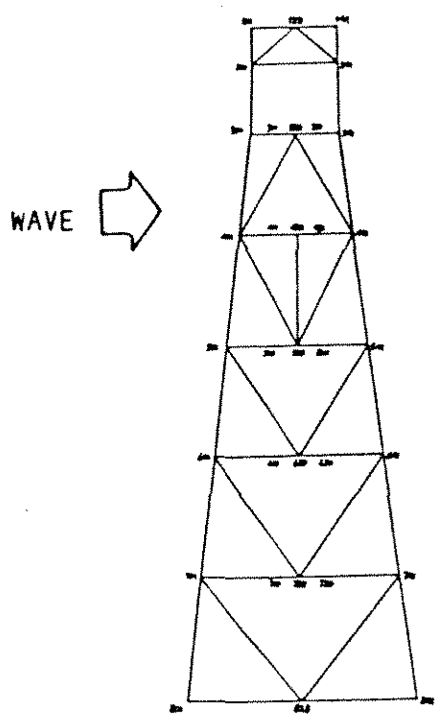
2. **Bea, R.G., DesRoches, R.,1992.** "*Platform Integrity Assessment, Unocal Thailand, Typhoon Contingency Plan Risk Assessment*".

3. **Bea, R.G., Mortazavi M.** *"Screening Methodologies for Use in Platform Assessments and Requalifications."* Project Progress Report #1, September 1993.

5. Appendix : Verification Case Study Results



END-ON



BROADSIDE

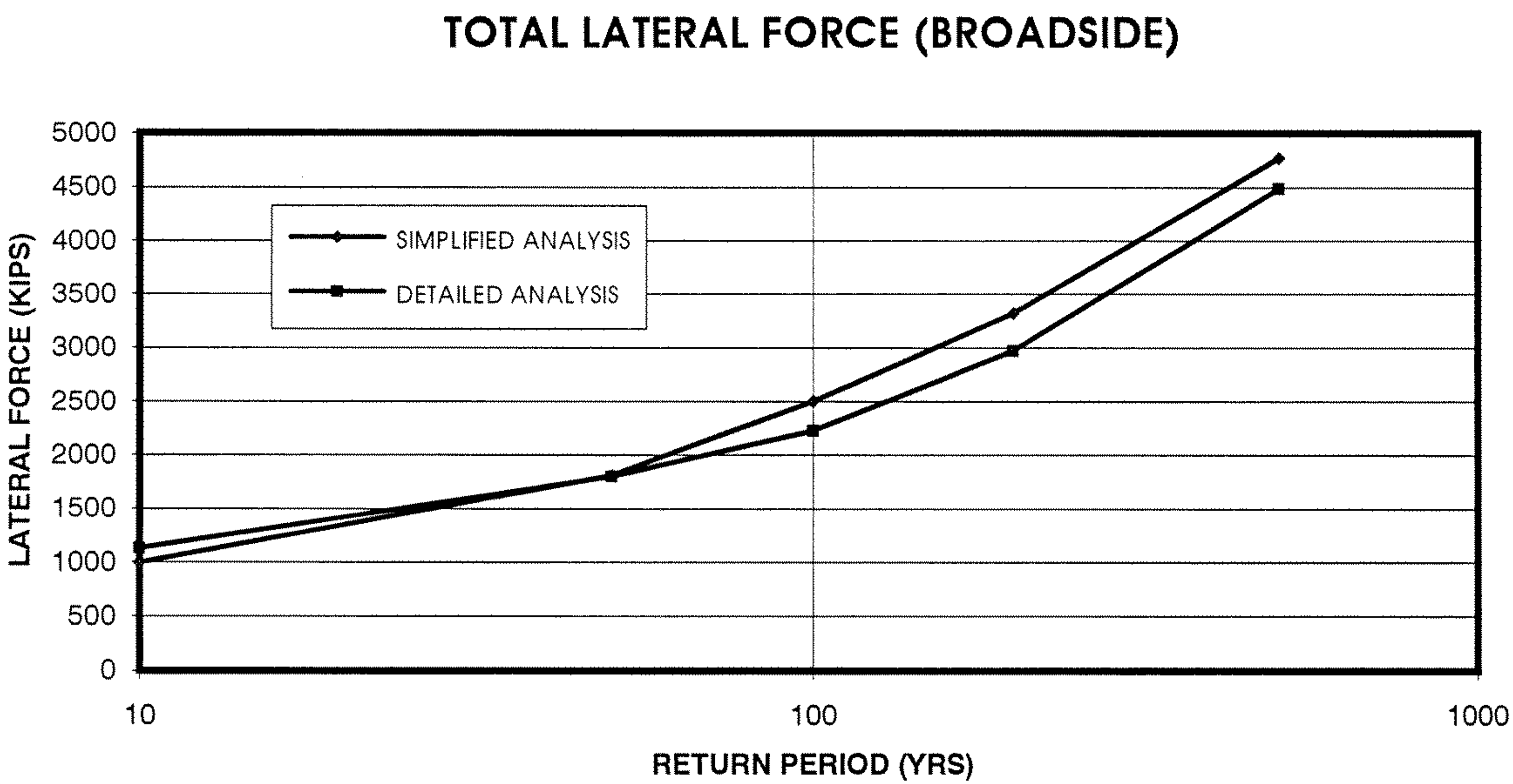


FIG. 1: TOTAL LATERAL FORCES (BROADSIDE)- COMPARISON SIMPLIFIED VS. DETAILED ANALYSIS

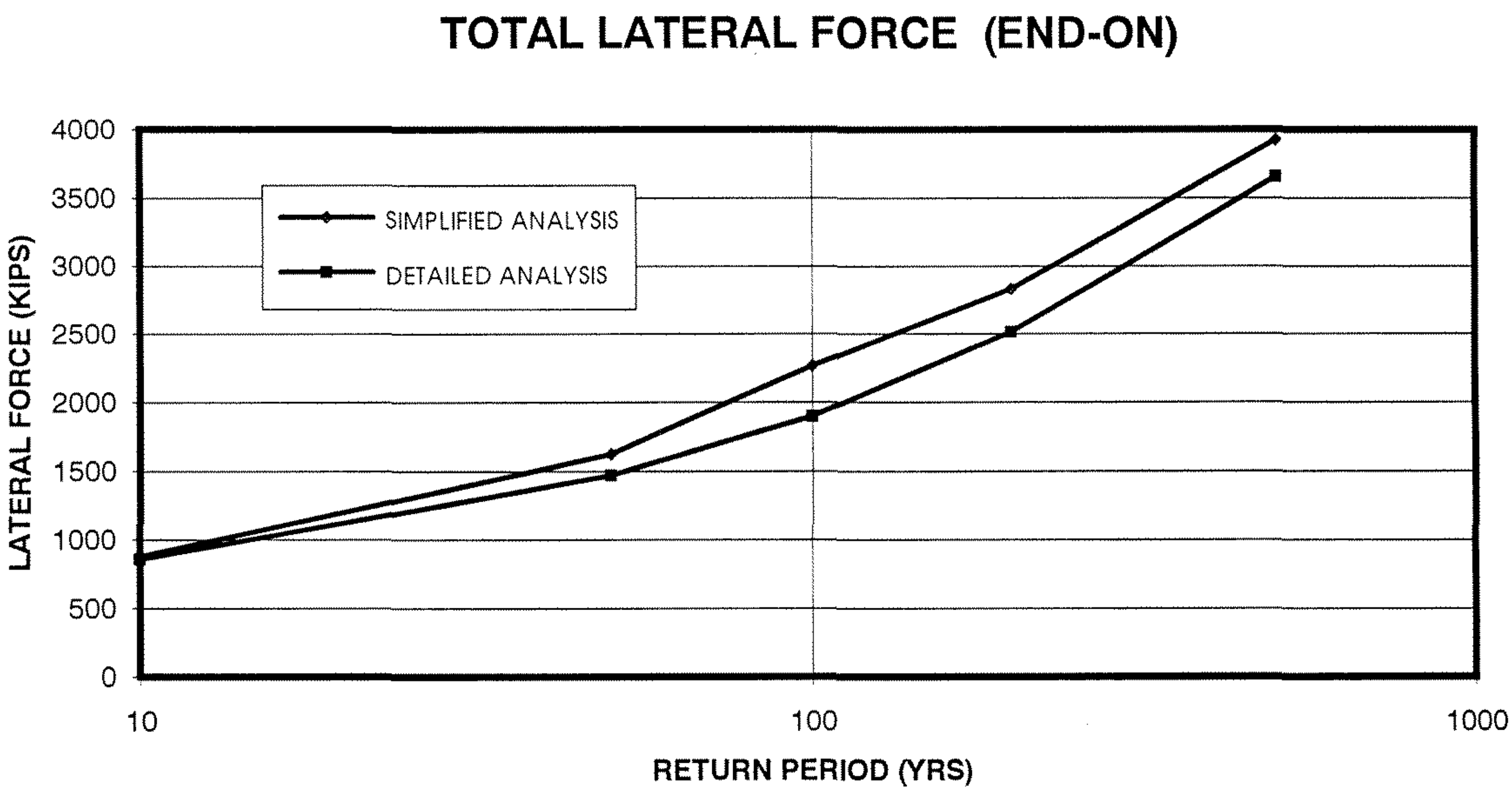


FIG. 2: TOTAL LATERAL FORCES (END-ON)- COMPARISON SIMPLIFIED VS. DETAILED ANALYSIS

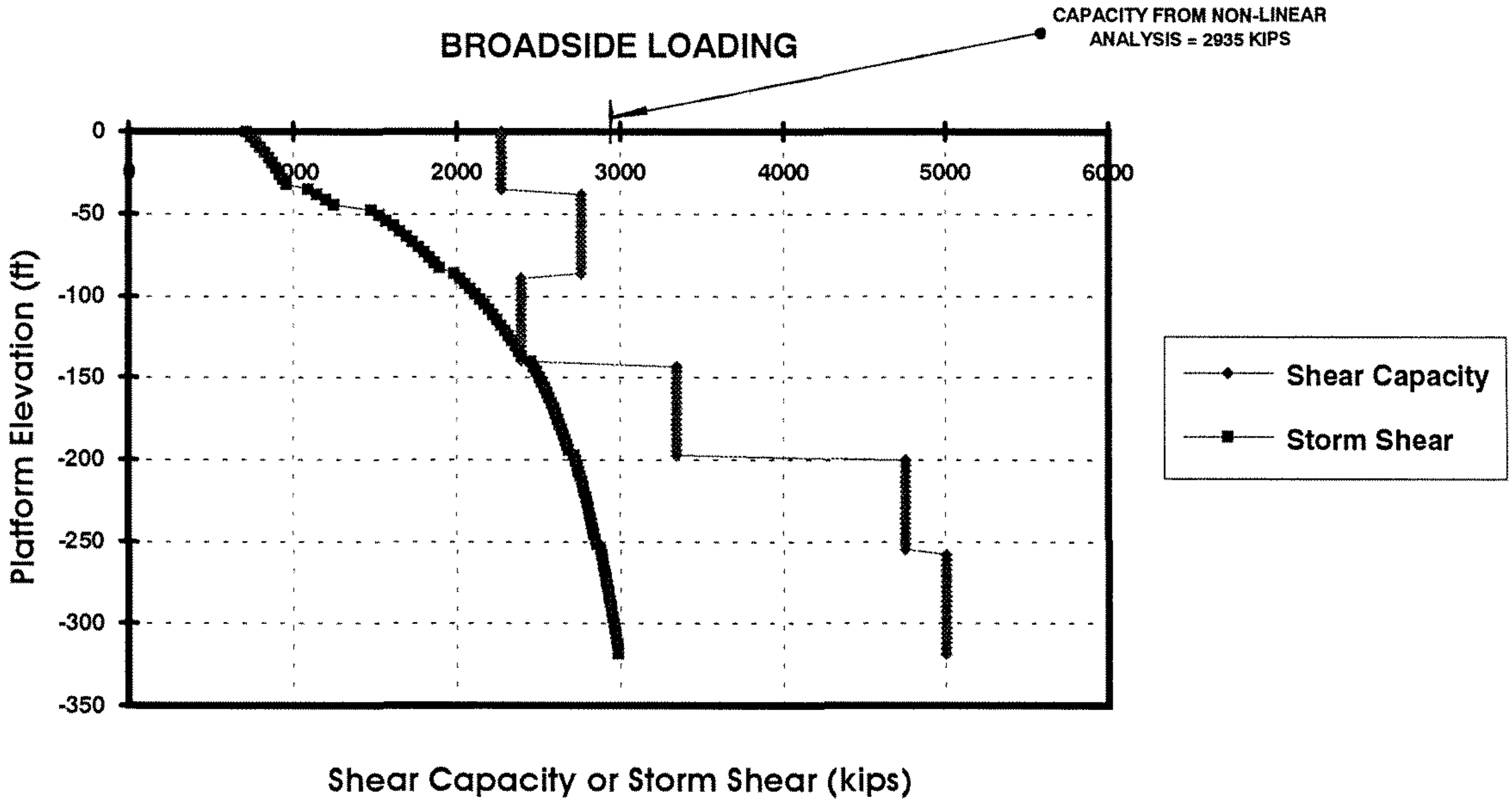


FIG. 3: LOADING VS. CAPACITY PROFILE (END-ON)

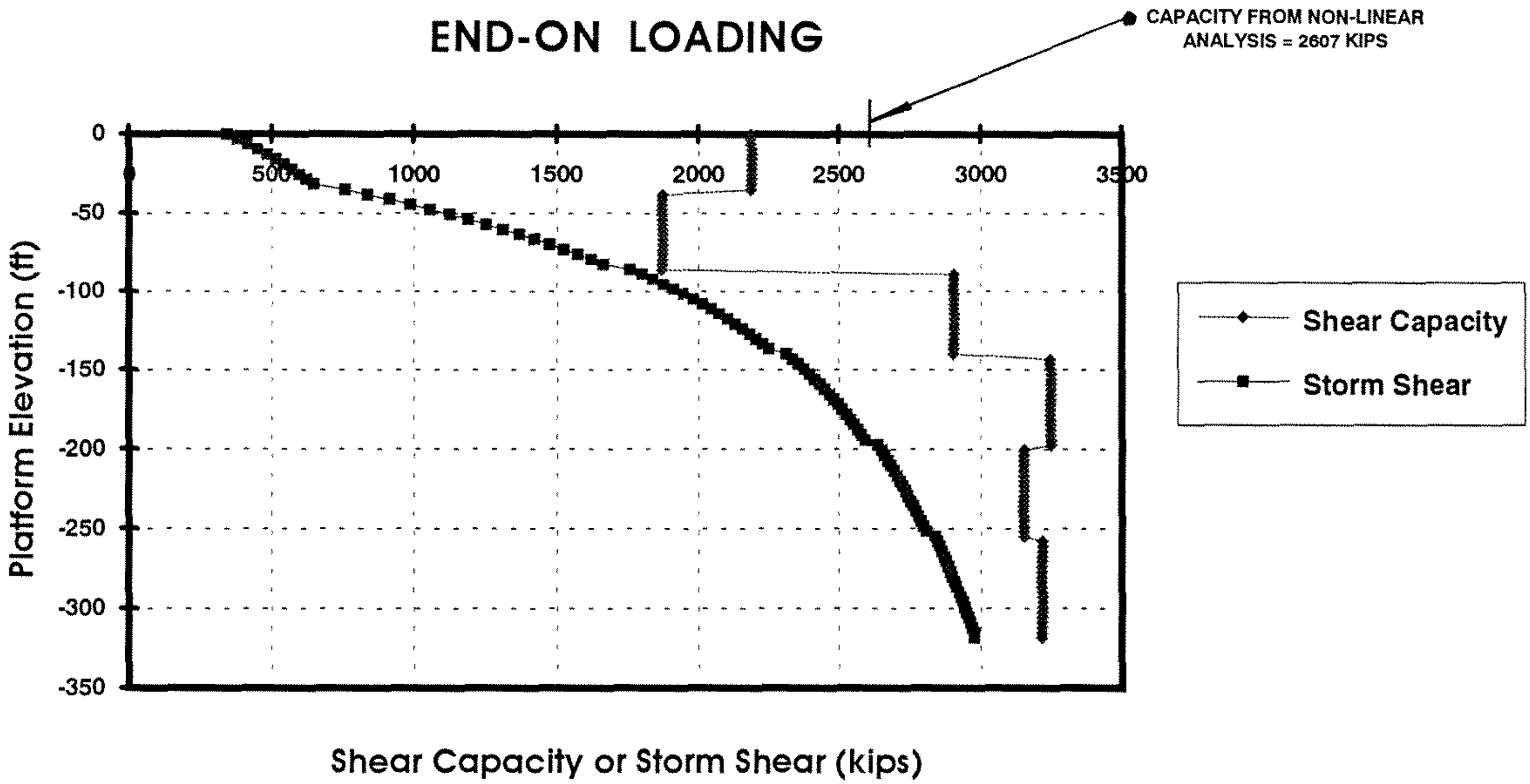


FIG. 4: LOADING VS. CAPACITY PROFILE (BROADSIDE)