

Non-Linear Analysis of Offshore Platforms - A Case Study of Two Platforms During Hurricane Andrew

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Abstract

This article presents a study of the ultimate strength capacity of two offshore platforms located in the Gulf of Mexico. The objective of the study was to validate existing non-linear finite element models for estimating the loads and strength of offshore platforms. From August 24 to 26 1992, hurricane Andrew moved through the Gulf of Mexico with sustained winds of 140 miles per hour. Thirty-Six major platforms suffered significant damage, of these, 10 were completely toppled and 26 were leaning significantly or had significant topside damage. Structures "H" and "K" were bridge-connected platforms, located in the ST151 field of the South Timbalier area of the Gulf of Mexico, platform "H" collapsed during Andrew, while "K" survived undamaged. They were both designed, fabricated, and installed in the early 1960's. A push-over analysis, using the program USFOS was used to estimate the ultimate strength of the two structures in three directions: end-on, diagonal and broadside. In the first series of analyses, all the primary members such as legs, vertical and horizontal braces, piles, soil, conductors and deck structure and secondary members such as conductors guides and barge bumpers were modelled with finite elements. The results of the pushover analysis indicate that the ultimate strength of structure K is larger than that of platform H. However, estimates of wave heights based on a post-Andrew survey show that the ultimate strength of both platforms is underestimated. In the second series of analyses, it was assumed that there was no horizontal or vertical movements at the level of the sea floor based on observations from post-hurricane survey. This assumption improved estimates of the ultimate strength significantly with minor modifications to the original model. A third series of analyses investigated the effects of increasing the stiffness and resistance of the soil to limit movements at the level of the sea floor and to improve estimates of the ultimate strength. The soil parameters of the first analyses had to be increased significantly to obtain results consistent with field observations of wave heights, soil conditions at the level of the sea floor, survival of platform K and the collapse mechanism of platform H.

Background

This paper describes results of a back-analysis for the structural analysis of two bridge-connected platforms (ST151H and ST151K) during hurricane Andrew in 1992. The platform ST151H collapsed while platform ST151K (Figure 1) remained intact with no apparent damage. The analyses are performed using a nonlinear structural analysis program UFOS using various modelling assumptions to obtain the best match between the observed and

predicted performance of the structures.

Literature review

Hellan et al (1991), used the program USFOS (Soreide et al, 1988) to perform nonlinear shakedown analyses of offshore platforms under repetitive wave loads. Case studies were done for two dimensional models of jacket structures for cyclic loads above first yielding and showed that offshore structures can be utilized beyond the conventional ultimate design limit defined as first member failure and still fulfil the basic regulatory requirements. Botelho et al. (1994) estimated the probability of failure of platform ST130A in the Gulf of Mexico during Hurricane Andrew using the program CAP (PMB Engineering Inc, 1992), and concluded that current analytical procedures gave consistent results with the observed performance of the platform. Petrauskas et al. (1994) analysed the behaviour of platforms ST151H and ST151K (the same structures analysed in this paper) during hurricane Andrew using the CAP program. The estimated probabilities of failure, were respectively 0.792 for ST151H, and 0.971 for ST151K which would imply that ST151K was more likely to fail than ST151H, when in fact ST151H failed while ST151K survived with no apparent damage. Vannan et al. (1994) estimated the ultimate strength of a platform that failed during hurricane Andrew with the program CAP. The failure mechanism was associated with foundation failure (pile yield or soil bearing); however, post-Andrew inspection of the collapsed platform did not conclusively reveal foundation failure. Therefore, it seems likely that the pile-foundation capacity was underestimated by the model. Bea et al. (1997) performed nonlinear push-over analyses using USFOS on eight platforms including ST151H and ST151K to validate a simplified methodology for the estimation of ultimate strength. They concluded that initial failure of platform ST151H occurred in the diagonal braces in the lowest bay of the structure and that ST151K survived due to its higher ultimate capacity. Bea and Young (1997) performed a nonlinear push-over analysis on four platforms in the path of hurricane Andrew. The performance of three of the four platforms was correctly predicted, while the fourth platform should have failed based on a static pile capacity analysis. They conclude that static and dynamic analyses provide respectively lower and upper bounds on ultimate pile capacities.

Properties of ST151H and ST151K

Both platforms have a main and a cellular deck which are supported by two rows of four columns. Columns have a spacing of 40' in the longitudinal