VALIDATION OF 3650 DWT SEMI CONTAINER SHIP FINITE ELEMENT MODEL BY FULL SCALE MEASUREMENTS

by
Ricky L. Tawekal
N.P. Miharjana

Directorate of Technology and Commercial
PT. PAL - INDONESIA (PERSERO)
(Indonesian Shipbuilding Industry)

ABSTRACT

A vibration analyses of a 3650 DWT Semi Container Ship using MSC/NASTRAN is presented in this paper. Measurements of the full scale ship are used to verify the numerical predictions by MSC/NASTRAN. Two finite element models are made to study the optimum size of the finite element model with adequate accuracy. The results show a good agreement between measurements and and the corresponding numerical predictions where the differences of the lowest superstructure global natural frequency of the two models are less than 5%. The finite element models are then used to predict the effects of structural modification which was done to improve the vibration behaviour.

Introduction

A ship is always excited by various kind of vibration sources. When a ship is subject to short duration loads or periodic forces and moments, global vibration of the superstructure or the hull girder may arise. Structural vibration analysis is either used as a design tool to avoid excitations at natural frequencies which would result in high vibration levels in the hull and superstructures, or it is used to study the effect of remedies to improve the vibration behaviour of existing ships.

A grouping of vibration problems in the superstructure of 47 ships is shown in Table 1 below [1]. The table clearly indicates that the propeller is the main excitation source. Approximately 80% of the cases could be traced back to the propeller pressure impulses as the source of vibration problems. Further, the cases suffering from local deck vibration occur twice as often as those where global vibration of the superstructure is the problem. Although simple local vibration problems dominate, the global vibration problem where the whole superstructure may vibrate in resonance, is very difficult and expensive to solve when found on a ship in service. Due attention should therefore be paid to the natural frequencies of superstructure and its interaction with the hull girder at the design stage.

Table 1. Grouping of 47 ships with vibrations problems in the superstructures

Excitation Source	Type of vibration			Total
	Global	Local	Global/Local	
Propeller	10	27	-	37
Engine	4	-	-	4
Propeller/Engine	-	3	2	5
Sea	1	-	-	1
Total	15	30	2	47

There are 3 (three) main reasons for performing desaign stage predictions or measurements, analyses, and evaluations of shipboard vibration. Those are :

(a) Vibration may cause fatigue damage to important structural elements in the ship

(b) Vibration may seriously impair the proper functioning of essential machinery and equipment

(c) Vibration may result in annoyance and discomfort to the ship's personnel and/or may interfere with the efficient performance of their duties .

A number of analytical methods may be used for hull and superstructure vibration calculations. However, dynamic analyses of large scale structures, like ship and offshore structures, are often performed by a Finite Element Method (FEM) in order to get more accurate results due to the complexity of the mode shapes. This paper provides an example of vibration analyses of a 3650 DWT Semi Container Ship using FEM available in MSC/NASTRAN.

Problem Definitions

A 3650 DWT Semi Container Ship was experiencing an excessive vibration. This was reported by the ship's personnel who were exposured to annoying vibrations during service. Vibration measurements were then took place to identify the vibration problems using *Vibration Analizer of RION*. The picture of the rather simple vibration measurement equipment is shown in Figure 1. The results of measurements are graphically shown in Figure 2.

Based on the measurement results, the acceleration magnitudes and corresponding frequencies are plotted into an ISO DIS 6954 Guide Line diagram to see the level of vibrations occuring on the ship. The plotted ISO diagram can be seen in Figure 3. It can be concluded from Figure 3 that the level of vibrations are above the standards recommended by ISO and, therefore, the structure must be modified to meet the ISO recommended standards and eliminate the problems.

Actually, the structure had been modified by an engineer who has many experiences in ship vibration problems. However, the method which was applied is a trial and error method and does not provide vibration behaviour predictions of the modified structure. This is one of the reasons that finite element analysis is carried out.

Analysis

The measurement results shown in Figure 2 reveal that a resonance occurs at a propeller speed of 162 rpm. The measurement equipment showed a frequency respond of 10.8 Hz at a propeller speed of 162 rpm. Therefore, we concluded that 4-*th* order vibration was occur. The measured accelerations are also drawn in Figure 4 to see in roughly the mode shape of structural vibration which in turn identifies the excitation source of the vibration problem. From the fact that the propeller has 4 blades and from the result of analysis that 4-*th* order vibration is the problem, it is easily concluded that the major source of excitation comes from the propeller.

Vibration analyses of the initial (*pre-modified*) structure is carried out using FEM which was done before any modification take place. Two of MSC/NASTRAN models are created to study the vibration behaviour of the initial and the modified structures. The first model consists of 298 rectangular plate elements (CQUAD4), 12 triangular plate elements (CTRIA3), 470 beam elements (CBAR), 56 concentrated mass elements (CONM2), and 211 nodal points. The second model consists of 1711 rectangular plate elements (CQUAD4), 226 triangular plate elements (CTRIA3), 2276 beam elements (CBAR), 56 concentrated mass elements (CONM2), and 1264 nodal points. The first and second finite element models are shown in Figure 5 and Figure 6 respectively.

From finite element analysis of model # 1, the lowest global superstructure natural frequency is 11.3 Hz. Similarly, the natural frequency of the lowest global superstructure from model # 2 is 11.12 Hz. The predicted mode shapes of the lowest global superstructure of model # 1 and model # 2 are shown in Figure 7 and Figure 8 respectively.

The two models are then used for further analyses of a modified structure which was carried out to predict the new vibration behaviour. Those analyses are important to make sure that the modified structure will avoid further risk of structural damage and risk of exposure of ship's personnel to annoying vibration due to excessive vibrations.

Discussions

The difference in predicted natural frequencies of model # 1 and model # 2 is only 1.6%. This is very small compared to the difference in number of elements and nodal points between the two models. Therefore, for the purpose of effeciency, model # 1 is considered appropriate for vibration analysis of this type of ship's superstructure using FEM. The difference of predicted natural frequency of model # 1 and the measured natural frequency is 4.6%.

The analysis of the modified structure finite element model gives a predicted natural frequency of 14.9 Hz. For the 4th order vibration due to propeller excitation, the resonance condition may occur at propeller speed of around 223 rpm. This condition will never be achieved since the maximum propeller speed is 165 rpm. Therefore, the modified structure is sufficient to avoid a resonance condition.

More alternatives in structural modification can actually be easily obtained using the finite element model so that the more optimum solution can be obtained.

Conclusions

The finite element method is very useful in structural vibration analyses as a design tool to avoid high vibration levels. Furthermore, in case of an excessive vibration occuring on a ship in service, this method is superior to the others in analising the effect of structural modifications during the redesign process in order to get the more optimum solution. Presently, other more advanced methods have been developed for structural redesign [5,6]. Those methods should be tested for a large scale structures, like ship and offshore structures.

References

[1] Det Norske Veritas, *Vibration Control in Ships*, Det Norske Veritas, Oslo, March 1985.

[2] MSC/NASTRAN *User's Manual, Version 67*, The MacNeal-Schwendler Corporation, Los Angeles, CA, 1991.

[3] Hughes, Owen, *Ship Structural Design*, John Wiley & Sons, Inc., 1983.

[4] Logan, D.L., *A First Course in the Finite Element Method*, PWS-KENT Publishing Company, Boston, 1986.

[5] Bernitsas, M.M., Kang, B.S., and Tawekal, R.L., " RESTRUCT 3.0 : A Program for REdesign of STRUCTures, " Report to The University of Michigan / Sea Grant / Industry Consortium in Offshore Engineering and Publication No. 312, Department of Naval Architecture and Marine Engineering, The University of Michigan, Ann Arbor, Nov. 1989.

[6] Bernitsas, M.M., and Tawekal, R.L., " Structural Model Correlation Using Large Admissible Perturbations in Cognate Space, " *AIAA Journal*, Vol. 29, No. 12, Dec. 1991, pp. 2222 - 2232.

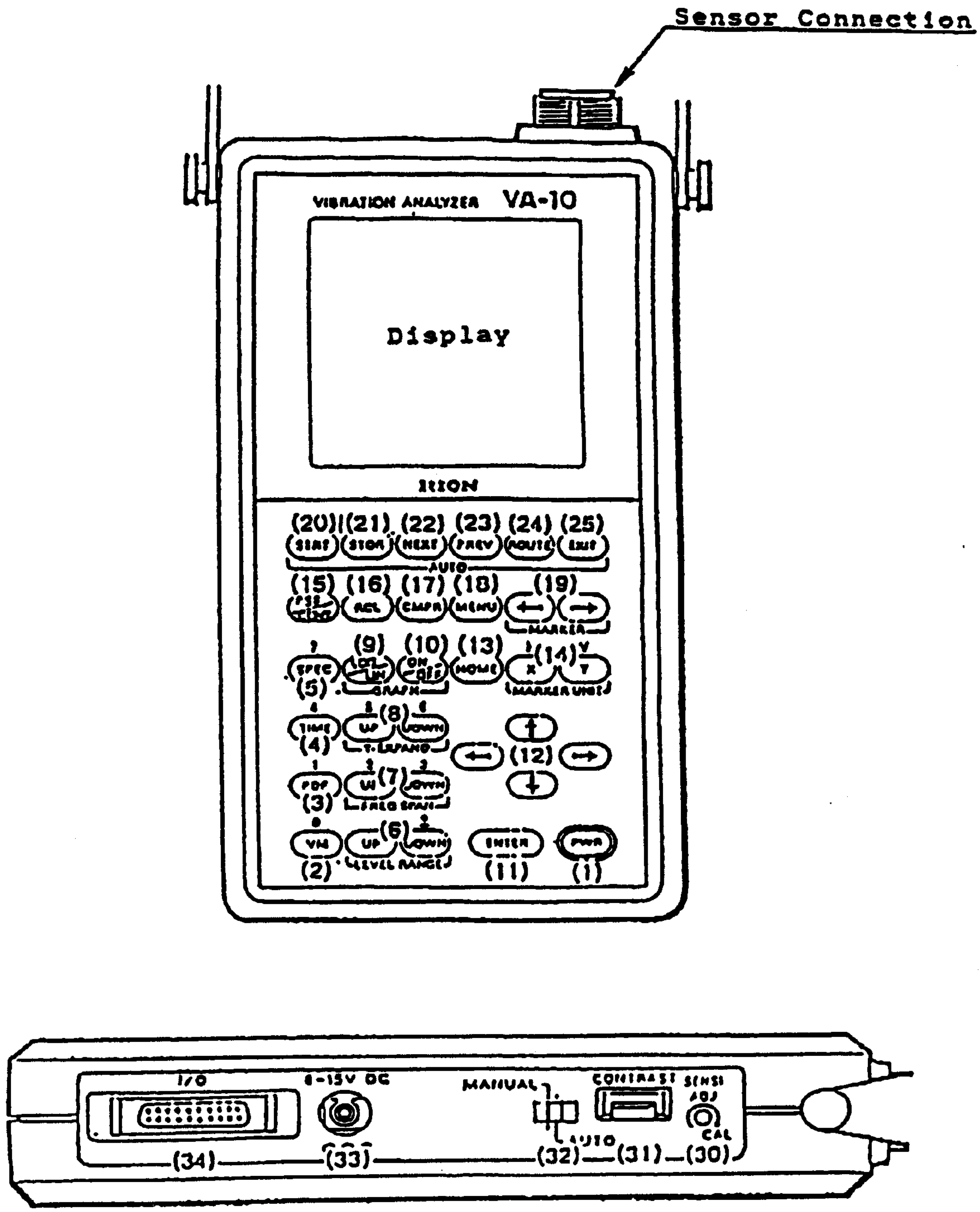

Figure 1 : *Vibration Analizer of RION*

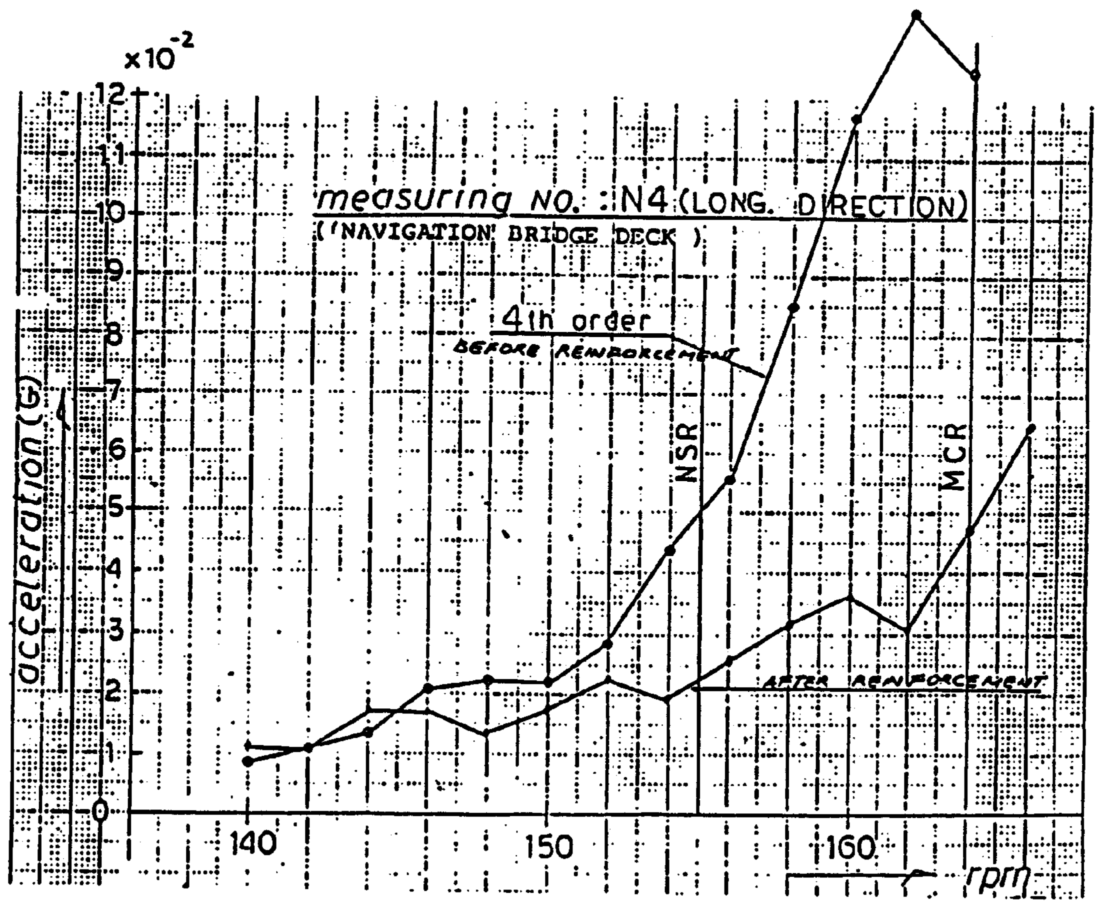

Figure 2 : *Measured vibration at Navigation Deck*

ISO/TC 108/SC 2

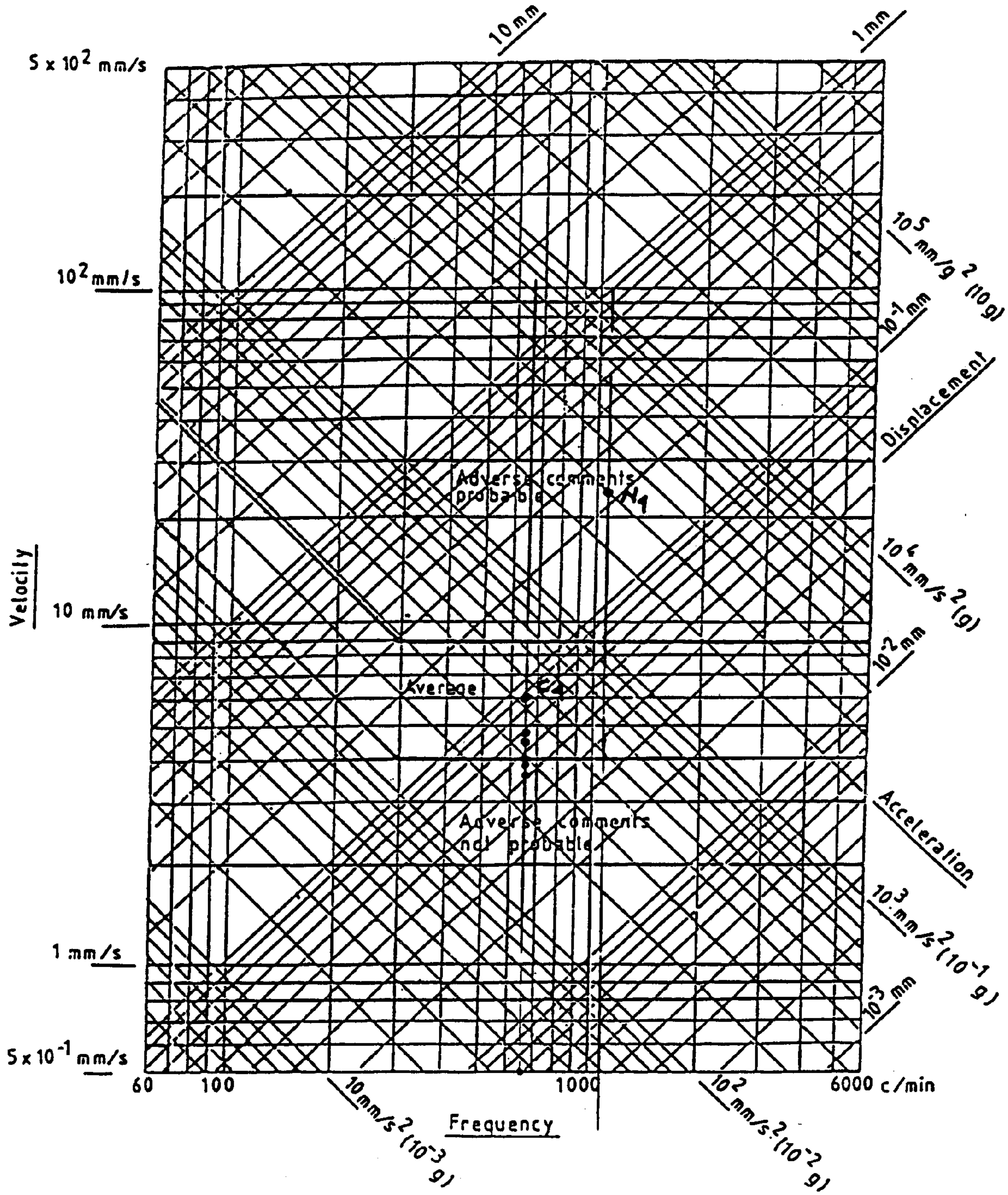

Figure 3 : *Level of Vibrations on ISO DIS 6954 Guide Line diagram*

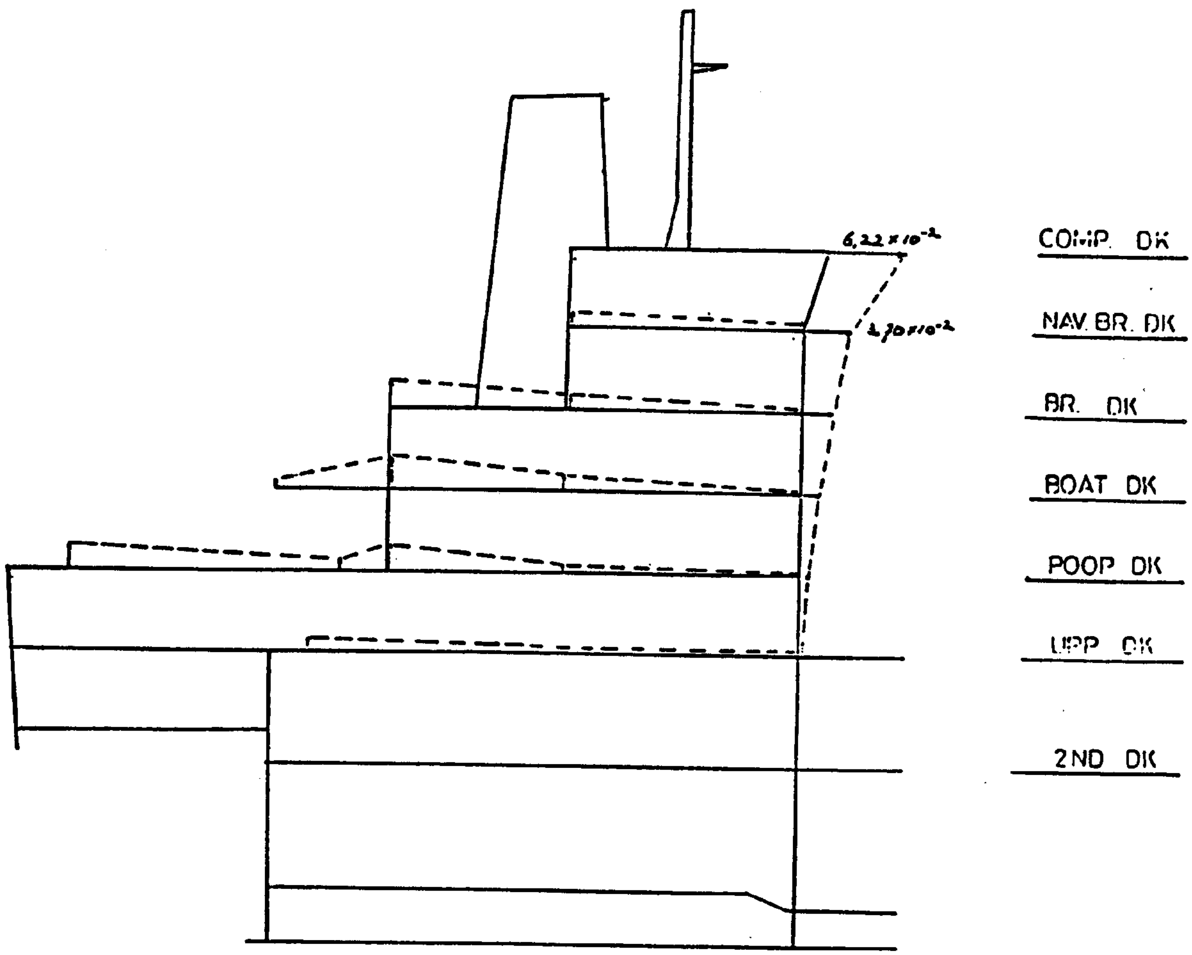

Figure 4 : *Superstructure mode shape based on measurements*

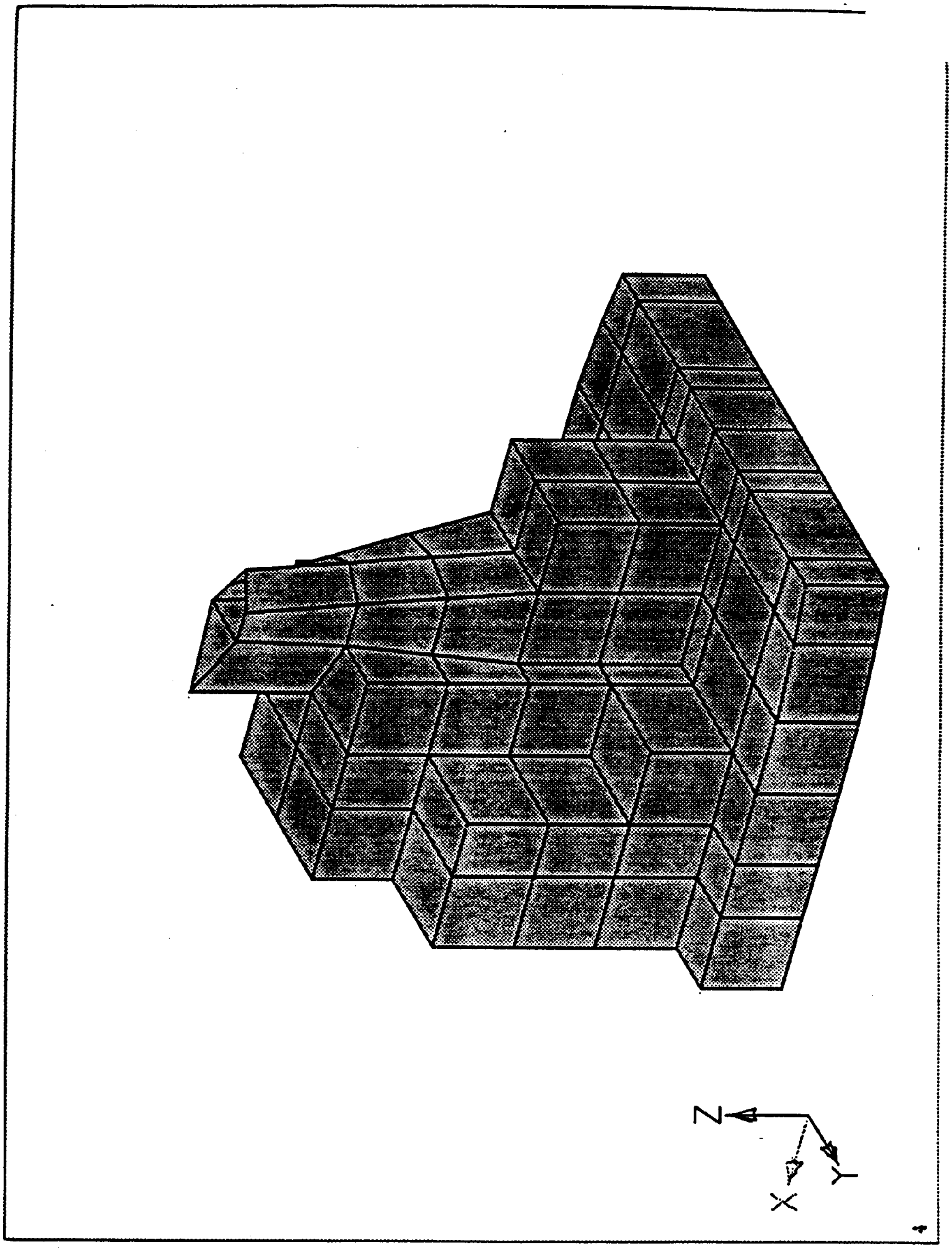

Figure 5 : *Finite Element Model # 1*

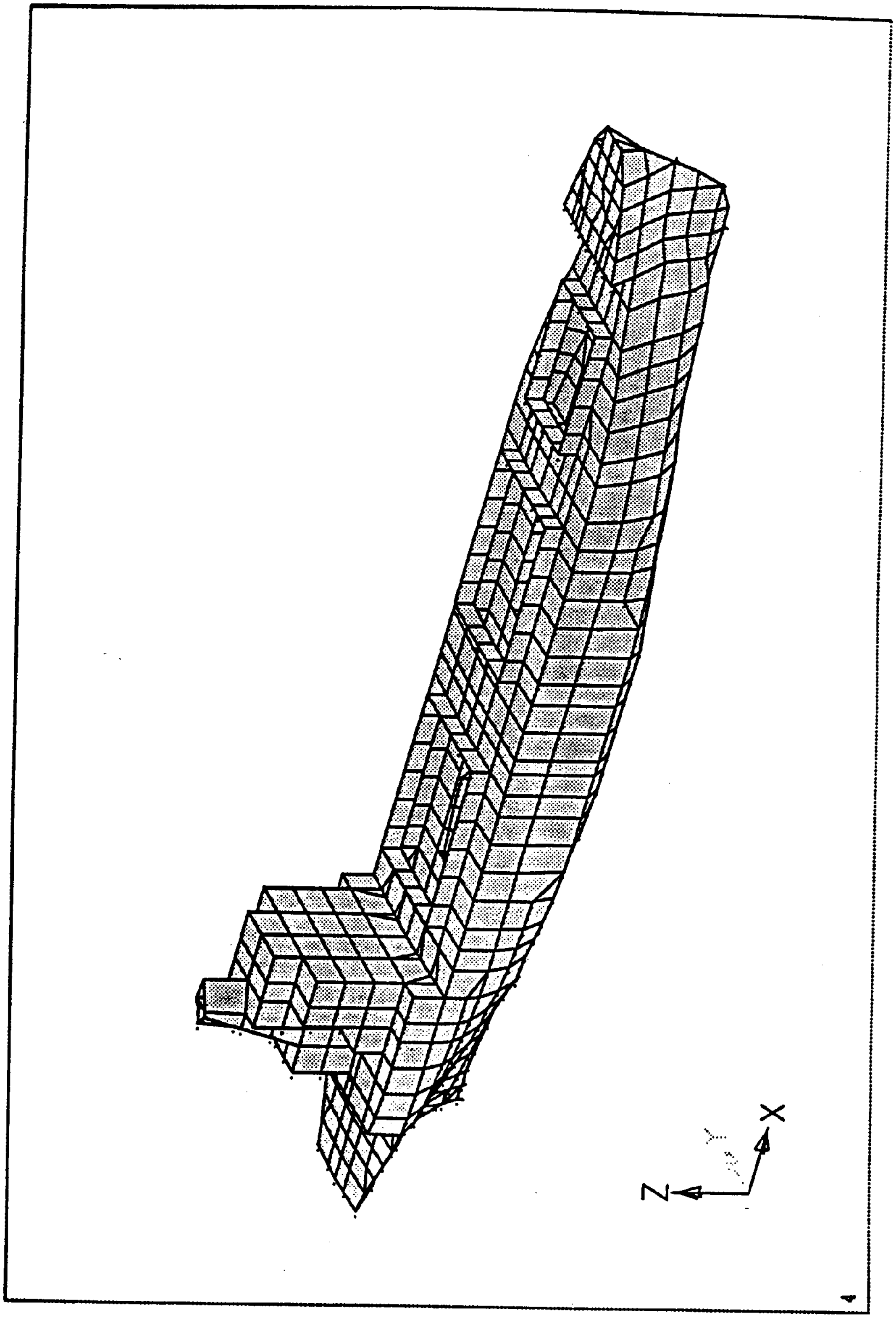

Figure 6 : *Finite Element Model # 2*

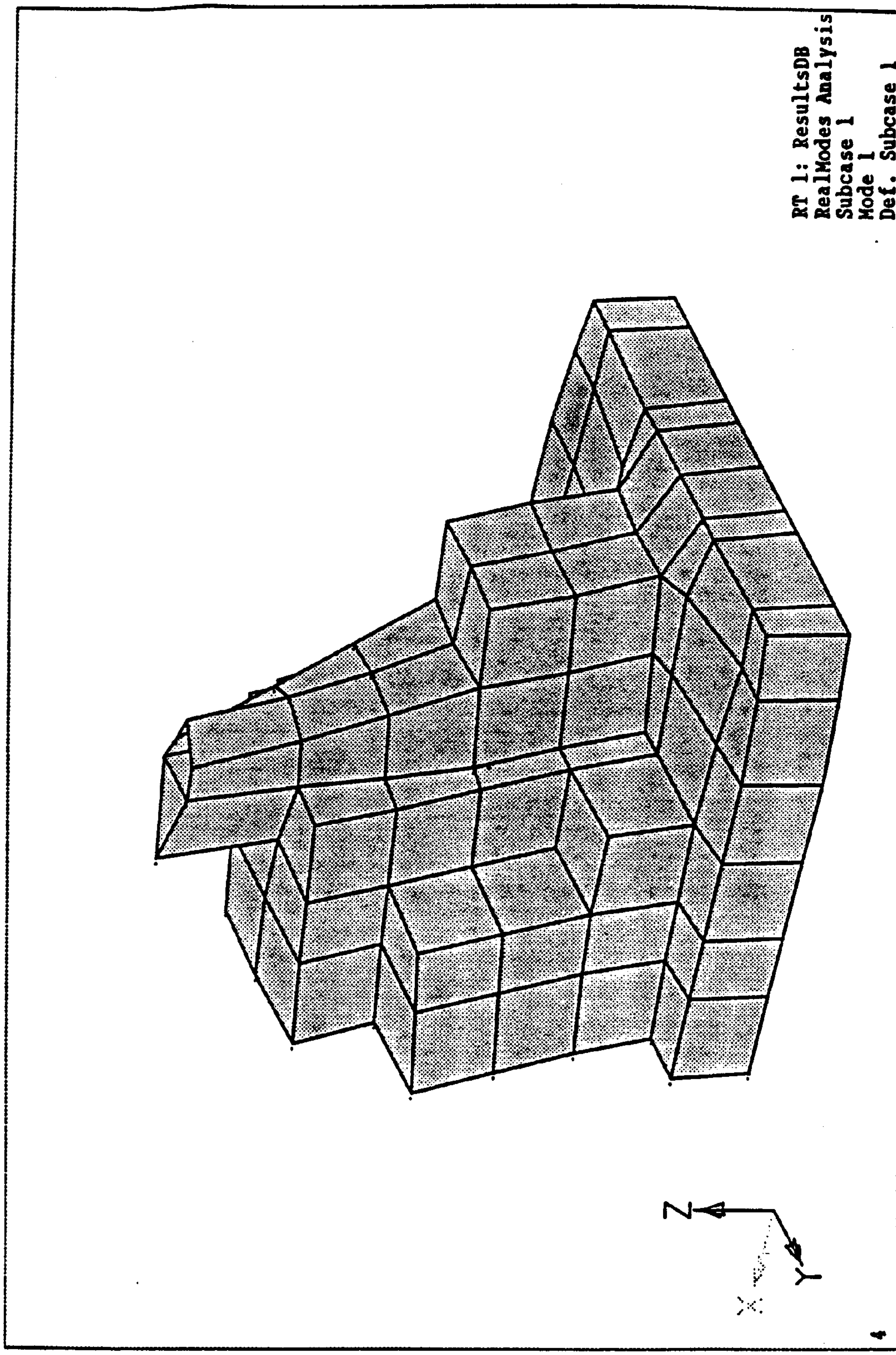

Figure 7 : *Predicted mode shape of model # 1*

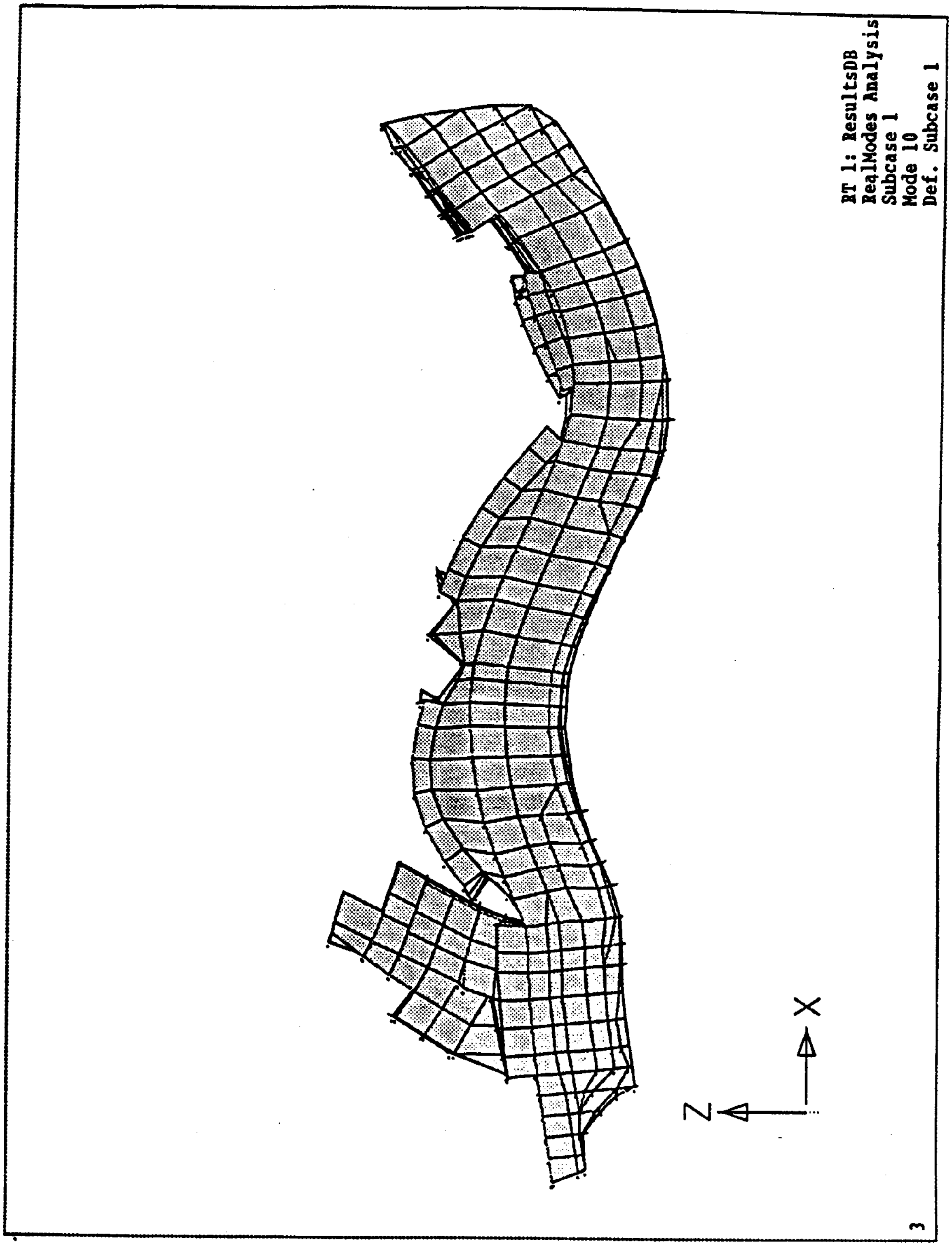

Figure 8 : *Predicted mode shape of model # 2*