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Dynamic Analysis of Fixed Offshore Structures Using Load-dependent Ritz Vectors

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1. Introduction

The evaluation of the dynamic response analysis of large structures by vector superposition requires in its traditional formulation the solution of a large and expensive eigenvalue problem. A new method using load dependent vectors for systems subjected to fixed spatial distribution of dynamic loads was introduced by Wilson *et al.*[1]. This study aims to discuss and compare results obtained from these two methods.

2. Reduction method (Normal vectors and Ritz vectors)

Solving dynamic equation of motion leads to eigenvalue problem to find natural frequencies and mode shapes of the structure. Traditional way of solving this eigenvalue problem is independent of exerted load on the structure and depends only on the geometrical and physical properties of the structure. In 1982 new method was invented by Wilson *et al.* [1], where he used one load pattern to solve the eigenvalue problem, which is called "load-dependent Ritz vectors method". Taking into account the effect of load has several advantages over the traditional method. 1-With fewer vectors, better results can be obtained. 2-All calculated Ritz vectors are useful (there is no orthogonality between Ritz vectors and loading vector, therefore all vectors will contribute to response) where this is not valid for normal modes and selection is necessary in choosing appropriate vectors. 3-Computation time for Ritz vectors is less than normal vectors, thus it is more economical, especially for large structures. In this study, subspace algorithm, presented by Leger [2] is used to generate Ritz vectors.

3. Mathematical model

A two dimensional jacket-type offshore structure, subjected to regular and random sea waves, has been studied (Fig.1). Modified Morison's equation is used to evaluate wave forces, and dynamic interaction between structure and surrounding fluid is considered. For random waves, Pierson-Moskowitz spectrum is utilized to express sea state. Two methods are used to reduce the size of the problem, namely, traditional normal mode superposition method and load-dependent Ritz vectors. Newmark-β method is used to obtain the modal response of reduced system in time domain.

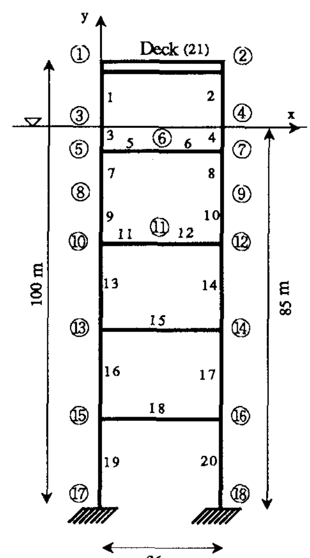

Fig. 1 Simple tower model

4. Results and discussion

1-For displacements which are global responses, in case of regular and random waves, both methods give very good approximation (Fig.2).
2-In regular waves, for critical responses (such as moments at members subjected to strong wave load) normal vectors fail to give acceptable approximation (Fig.3), but for global response such as base moment or shear, the results are acceptable. Ritz vectors give solutions with high accuracy (Fig.4).
3-For random waves also the same conclusion can be drawn. For critical responses, normal vectors do not give acceptable results (Fig.5). But results from Ritz vectors are closer to exact solution (Fig.6).

As Ritz method is load dependent, selection of these load patterns are very important. In case of regular waves it seems that only two load patterns are enough to give good approximation (as concluded by Leger [2]). However for random waves, the process of choosing these load patterns are not so easy and results can be affected strongly by number of load patterns (Fig.6 and Fig.7), where Relative Error Index (REI) is defined as follows:

$$REI = \frac{ap - ae}{ae}$$

where, $ap = \left(\sqrt{\frac{1}{n}\sum_{i=1}^{n} y_i^2} \right)_{approximate}$, $ae = \left(\sqrt{\frac{1}{n}\sum_{i=1}^{n} y_i^2} \right)_{exact}$,

y_i is the response in time domain and n is number of data.

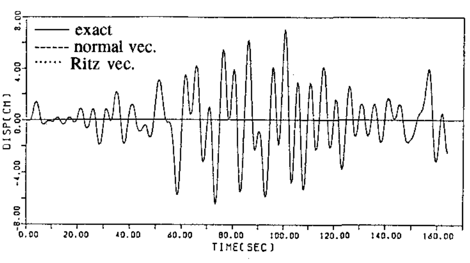

Fig. 2 Deck displacement using 4 normal vectors and using 4 Ritz vectors (2 load patterns)

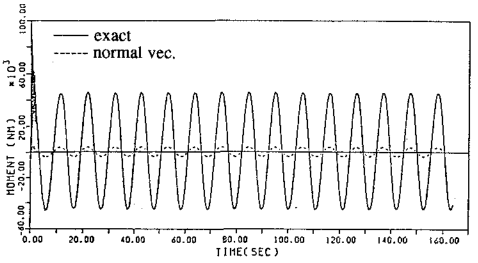

Fig. 3 Moment at grid no. 11 using 4 normal vectors

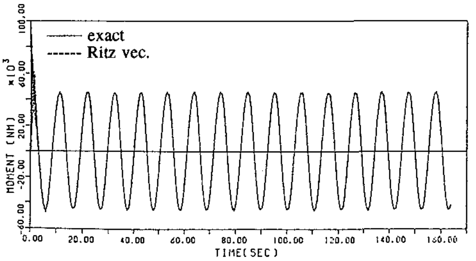

Fig. 4 Moment at grid no. 11 using 4 Ritz vectors (2 load patterns)

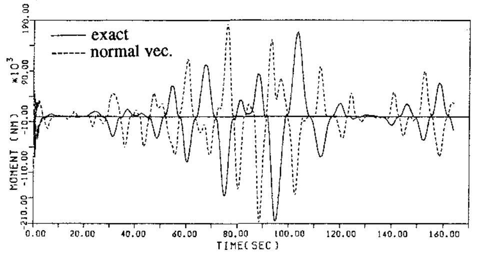

Fig. 5 Moment at grid no. 11 using 8 normal vectors

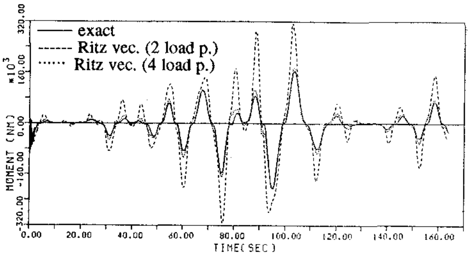

Fig. 6 Moment at grid no. 11 using 8 Ritz vectors based on 2 load patterns and 4 load patterns

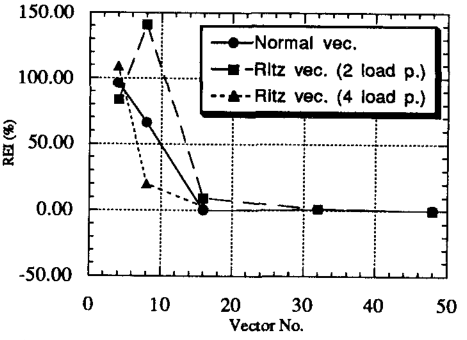

Fig. 7 Relative Error Index (REI) value for moment at grid no. 11

4. References

1) E.L. Wilson, M.W. Yuan and J.M. Dickens, Dynamic analysis by direct superposition of Ritz vectors, *Earthquake Engineering and Structural Dynamics,* **10**, 813-821 (1982)

2) P. Leger, Load dependent subspace reduction methods for structural dynamic computations, *Computers and Structures,* **6**, 993-999 (1988)