Dynamique des structures

Scientific article review

By Jean Le Luyer

Article: Inverse substructure method for model updating of structures

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Introduction

The study of the mathematical model of a structure is time consuming. Supercomputer are an option, but are expensive and not often free. Simple structure can be calculate with personal laptop but when it comes to super structure patience can easily come out of hand. The reason that explain this high number of necessary calculation is that with the traditional method, each time a node or an element of the structure has been analyzed, the whole structure has to be re-analyses to update to this new data. Furthermore it is very frustrating for the structural engineer to go through the whole calculation of the structure when his goal is only to understand the effect of a change, like a damaged element. This article is written by structural researchers of the finest university in china, and present a new method of calculation that allows the engineer to save lot of time.

The idea is simple, try to have a method that would only study the part of the superstructure, not having to do an update of the whole structure each calculation and so gain a lot of computing time. With this substructure method, calculated part of the structure can then be reassembled together to obtain the global model of the superstructure. This allows parallel computation, which is more efficient and less vulnerable to data errors. The sub goal is to reduce the needed measurements on the structure, which is very costly and time-consuming on a superstructure. With this substructure method only local measures are needed. We will try to explain the method and then show the efficiency of the method on a simple laboratory structure, and on a superstructure to show its accuracy.

How does it work?

The goal is to update the model of the structure. Between the original designed structure and the finished structure or a tired constructed structure, the model is not the same. To update a structure measure are taken on the existing structure after sending a vibration message. The same message is applied to the mathematic model. The difference of response is used to compare element between the existing structure and its model.

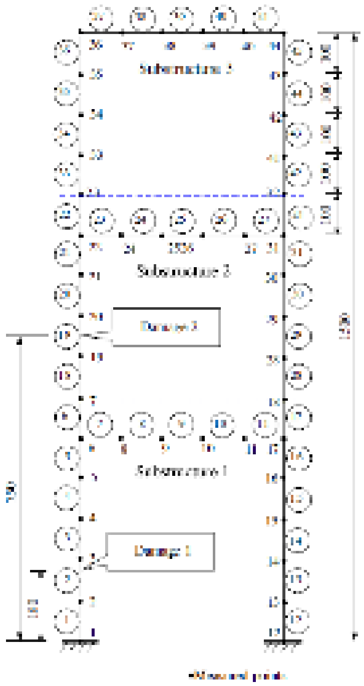
The main goal is to update the flexibility matrix. The updating method change elements of this matrix to obtain a closer response to the ones obtained with the measures made. The same calculation is then redone to obtain a better result, over and over each time using the previous obtained model. These iterations are made until a satisfying small difference is shown.

But one iteration can be long to compute. The substructure method of updating model allows less calculation, simply because it has less elements. The difficulty is to take in comprehension the defined border of the substructure. Substructures can be defined as fixed-free when one border is attached to the defined ground, or free-free when its border are only another substructure. By using an orthogonal projector method, the author of this article managed to take in consideration the defined border of the substructure while applying the classic updating method to only the substructure.

The mathematic method is explain with the full measures of each degree of freedom of a structure but also with partial measures showing its possible effectiveness on a real application. The next two examples shows results obtained with this new method in comparison with the global approach.

The effectiveness of the method on a simple laboratory structure

The studied structure is 1m50 tall steel structure composed of 3 substructures of the same dimensions. In total this structure is divided into 44 nodes and 45 elements.



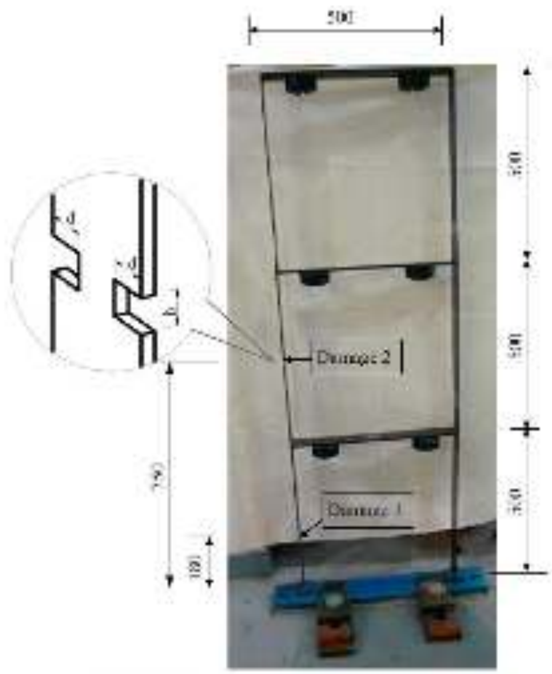
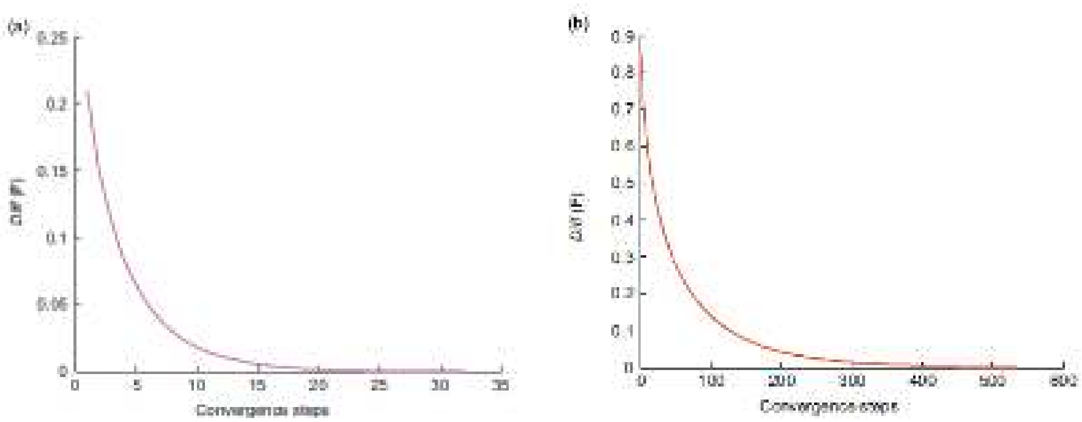


Fig. 2. Overview of the frame structure and the experimental damage configuration (unit: mm).

The global method was used to obtain the main flexibility matrix of the structure to be then compared with the matrix obtained with the substructure method. The number of iteration needed to obtained the matrix was noted until it could reach a certain precision (10^-6 of error compared to the experimental measures).

The substructure method reached the precision after only 32 iterations while the global method had to make more than 500 iterations for the same result.



On the left the result of the substructure method and on the right the result of the global method

This new method has then been use to test the efficiency of the model after being updated. With comparison with the experimental result, there is 2.56 percent of error with the non-updated model and 0.77 with the updated model showing the efficiency of the new substructure model.

The second interesting part is the ability of this model to detect damaged elements of the structure. Two elements of the laboratory structure has been voluntary damaged for the experience. By using the non-damaged model obtain before the second experiment, an update was made using the substructure method and the measurement made on the damaged structure. The results, delivered in a column chart showing the percent of difference of spectral response function, clearly shows the damaged part of the structure (the other percent of difference are considered as noise).

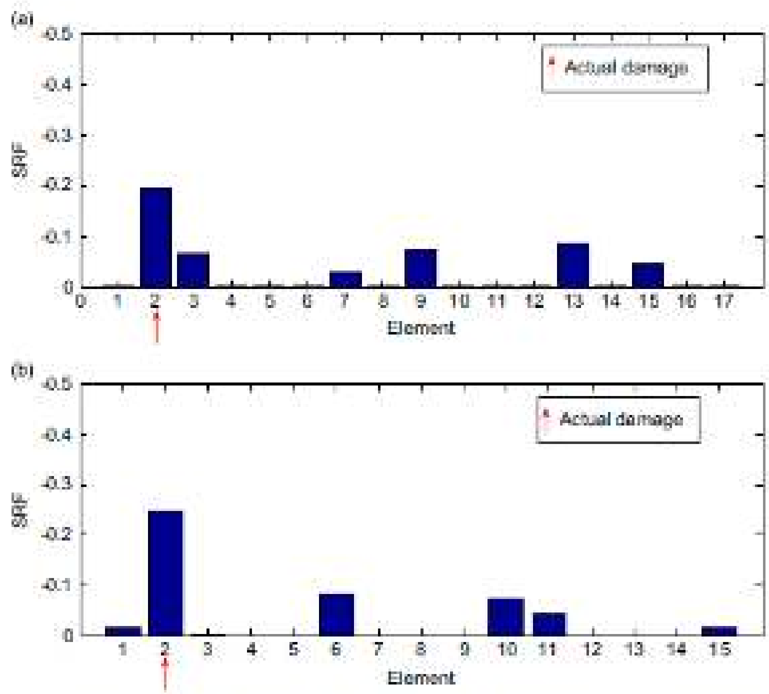


Fig. 9. SRF values of the second damage configuration. (a) First substructure and (b) second substructure.

The global method was also applied to detect damaged part, and result shows the same quality of result than the one obtained with the substructure method. As a first conclusion the substructure method has no advantage on the quality of result to update the model or finding damaged part. But this study was made on a small structure, were computing time is short. The real power of the method can only be find on the study of large-scale structure.

The accuracy of the method on a super structure: Guangzhou Tower

The guangzhou telecom tower is a 600m hight structure, with a 457m hight outer steel structure. The experiment will be based on this particular structure which can be decomposed into 8738 elements, 3671 nodes and 21690 degree of freedom. For short; we are dealing with a superstructure.

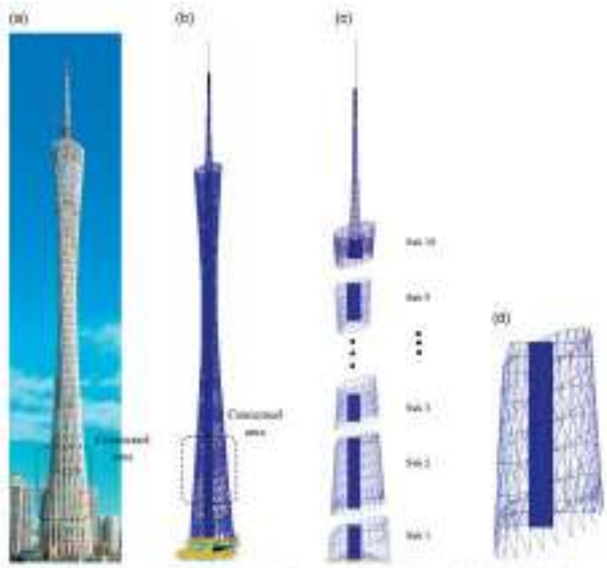


Fig. 12. Guangzhou New Television Tower and the FE model: (a) Landscape view, (b) global model, (c) divided substructures and (d) concerned substructure.

The global method used on the structure implied a matrix for the global structure of the size of 21690x21690 and took 1.27h for an iteration, and 17.88h for the total process. For the new method, the structure was divided in 10 substructures. The operation took 1.69h to process the whole substructure which means that in the case of the study of a particular part of the structure, the substructure method can be 10 times faster.

Conclusion

This article present a new model of updating method for structure, and especially for really large one. The idea is to divide the study of the structure into multiple substructures, employed as semi-independent structure. The structural update is then only apply one or each of them, allowing an independent, and most important, shorter study. The result can then be assembled together to obtain the update model of the whole structure. The main advantage of this new model is the time saved on computer calculation time, by the fact that the work can be divided on multiple computer or in the case of the study of a single part of the structure. On top of that experimental measures are only needed on the local area of the study, reducing a lot the price of the structural update. The efficiency of this new substructure model has been successfully shown with two examples. The simple laboratory structure has shown the effectiveness of the sub-structure method and its ability to recognized damage part of the structure. The application on the Guangzhou Tower successfully showed the accuracy of the method when applied to a superstructure. This new model of updating method is on a good road to be promising method to remove the weight of long computer calculation for large-scale structures.