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FOOTBRIDGES. DYNAMIC DESIGN – SELECTED PROBLEMS

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Summary

A good FEM modeling is a key element in engineering part of design of lively footbridge. The paper presents selected problems related to the modeling of the dynamic construction of footbridges.

Keywords: FEM analysis; dynamics; response; damping

1. Introduction

The dynamic behavior of lively footbridge is a complex problem. Recently there have been numerous publications and recommendations related to the dynamic nature of footbridge. Guidelines for footbridge designing give only little information about concept and smart dealing with stiffness and mass distribution in the structure. Also knowingly using the FEM software is advisable. There for in the paper several problems important for dynamic analysis and design are presented.

2. Numerical models of structure and discussion of their effectiveness

In most cases a well-known beam FEM model can solve static and dynamic problems. However in many modern structures simplifications of a beam systems is no more sufficient. Recently FEM software gives us the chance to simulate easy (thanks to the graphics preprocessing) our structure more exactly using continuous flat shell elements and 3D volume elements. The combination of beam, shell and volume elements was used to analyze the footbridge over Woloska street in Warsaw, Poland (Fig.1). Unfortunately for dynamic simulations this type of modeling is very time consuming and not necessary regarding the expected results but an advanced FEM structural model can be helpful in verification of a simplified beam solution. On the base of modal analysis the simplified system can be calibrated and used for dynamics.

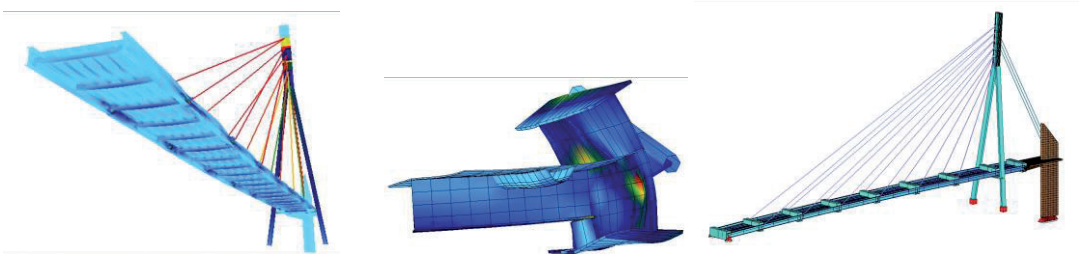

Fig. 1 FEM SOFiSTiK Shell model of Woloska footbridge and (right) beam simplification

3. Time-step Newmark-Wilson (N-W) method. Validation of parameters of method (time-step, damping).

After preparation of FEM structural model, before we start time-step computations two basic problem have to be solved: Time step value and dumping definition. In the full version of the following paper some useful recommendations regarding validation of time step in N-W method and efficiency of defined dumping

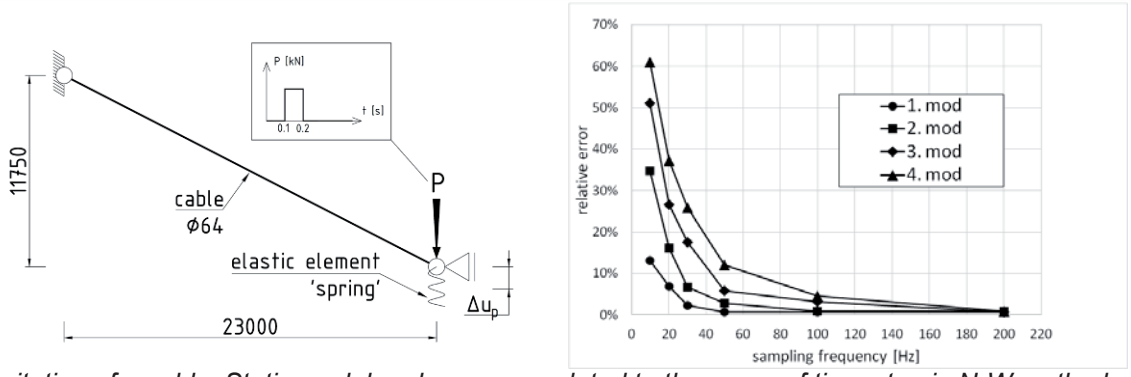

Fig.2 Excitation of a cable. Static model and accuracy related to the range of time-step in N-W method.

4. Non linear geometric effects in dynamics

In the structure were geometric stiffness is important a non linear procedure has to be used in each time step of N-W method. In full version of this paper some more detailed comments are presented.

5. Vertical and horizontal excitation - cause of vibrations.

A lot of work has been done to predict vertical and horizontal response of pedestrian bridge Most of it was focused on interaction of vertical load with vertical response and horizontal load with horizontal response. However modern structures are often design in such way that vertical excitation can cause horizontal vibrations. In full version of this paper a numeric simulation of vertical-horizontal interaction is presented. Examples of real footbridges are included.

6. Intelligent load.

Crouching is discussed as an intelligent load in FEM simulation. Simple procedure of adaptation of pace rate used in M-W is discussed. Load function is presented in the full version of this paper.

7. Dynamic tuning of structure

There are a lot of footbridges where the problem of excitation can be excluded or limited by the smart design of stiffness and mass distribution. Such action can often avoid critical frequency ranges and minimize their expenses on additional artificial damping. Two examples of real footbridges are discussed in the full version of this paper.

Fig.3. Christina and John Markey Memorial Pedestrian Bridge, USA. Design: Rosales + Partners. Photo by Carlos Arzaga. First (1.9 Hz) and second (4,5Hz) dynamic vertical form.

Two ways of dynamic tuning were proposed for footbridge shown on fig 3. The lift of concrete plate position in composite cross section and change of backstays diameter. Both ideas can rise a first vertical eigen frequency from critical range.

8. Conclusions

Recently often architects and artists are designing footbridges. In effect we have a lot of aesthetic and spectacular structures shaped in an unprecedented way. This is a challenge for structure engineer too. Prediction of static and dynamic behavior of the bridge become a problem which can be solved by the FEM modeling. The presented in paper problems (please look to the full version) can effect positively on the correct results in designing stage.