Doctoral Dissertation
Doctoral Program in Civil and Environmental Engineering (32.nd cycle)

Static, Dynamic, and Stability Analysis of High-rise Buildings

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Summary

The analytical formulation of a simplified method that allows the static, dynamic, and stability analysis of a high-rise building is proposed in the present work.

This thesis is the natural extension, development and improvement of a project started a few years ago by Prof. Alberto Carpinteri, author of a formulation that allows the preliminary analysis of a tall building. Originally this formulation was rather limited and only allowed the analysis of a few types of structures. Over the years, also thanks to the contribution of Prof. Giuseppe Lacidogna and Dr. Sandro Cammarano, new models have been introduced and a more advanced calculation code has been created.

In 2016, after completing a Master Thesis and joining the Doctoral Program in Civil and Environmental Engineering (32nd cycle) at the Politecnico di Torino, I became involved in this project.

As a matter of fact, I created the graphical interface of the calculation code, greatly simplifying its use and improving the interpretation of the results. Subsequently, to make a further improvement to the formulations relating to static and dynamic analysis, with a focus on structures that present irregularities in plan and height, I implemented the analysis of framed tube structures, and diagrid (in collaboration with Eng. Domenico Scaramozzino). Eventually, I dealt with the stability analysis, a topic which is important but virtually absent in the literature.

The objectives of this thesis are to illustrate the analytical formulations and the operational methodology underlying the calculation code developed. In this context, simplified analytical formulations have been developed which describe the behavior of tall buildings in a simple, intuitive way and with the use of simple resources and techniques. This computer tool combines the advantages of analytical formulations, including simple and intuitive input, absence of mesh and few unknowns, with the advantages of computer software, such as its great potential for calculation and the ability to view the results on screen with graphs and three-dimensional models.

However, the greatest strength of this analytical code is the reduced processing time, which makes it suitable for use in preliminary analysis and structural optimization. In these phases, in order to find the best compromise between material

strength, deformation and construction cost, it is necessary to vary one parameter at a time (thickness of each shear wall, size of cross sections of beams and columns, etc.) making it necessary to create thousands of different models. In this context, as can be easily understood, the speed of calculation is a determining factor that has a significant impact on the cost and on the planning times.

The thesis is divided into six chapters, each of which is dedicated to a particular aspect of the study of high-rise buildings. It was important to give ample space to bibliographical references, as, in addition to providing a description of the problem from multiple points of view, it can be an important starting point if the reader wants to delve deeper into the topics covered.

Chapter 1 provides an overview of the evolution of tall buildings. It also reviews the main construction typologies, as well as providing a basic description of structural behavior.

Chapter 2 illustrates the simplified analytical formulations that lead to the determination of the stiffness matrices of the vertical bracings that are mainly used to contrast the transversal displacements caused by the horizontal loads acting on a building.

Chapter 3 describes the analytical procedure that allows the static analysis of a tall building, by means of which it is possible to determine the floor displacements and the stresses in each structural element.

Chapter 4 shows a simplified procedure that permits the mode shapes, natural frequencies, and periods of vibration of a high-rise building to be determined. To demonstrate the effectiveness of the algorithm, the results of the analysis of a tall building recently built in Turin are presented: the Piedmont Region Headquarters Tower. The comparison between the results obtained using the analytical algorithm and those obtained using a commercial Finite Element software allows the accuracy of the proposed formulation to be verified.

In Chapter 5, an analytical formulation is presented which allows the stability analysis of a thin-walled open-section beam and, by extension of the method, of a high-rise building. With this method, a generalization of Euler's Theory (axial buckling) and of Prandtl's Theory (lateral-torsional buckling) is introduced. Furthermore, an energy-based method is defined that allows the non-uniform torsion equation obtained by Vlasov to be determined through a procedure described in Chapter 2.

Finally, Chapter 6 is dedicated to the conclusions drawn and to a concise description of the results achieved, also making reference to future possible developments.