CHAPTER 1

INTRODUCTION

1.1 Background

The wind loading of buildings involves, in certain cases, considerable complexities that must be taken into account in order to achieve safe and serviceable designs.

One of wind engineering problems that require special attention that, if the building is exceptionally slender or tall, or if it is located in extremely severe exposure conditions, the effective wind loading on the building may be increased by dynamic interaction between the motion of the building and the gusting of the wind. The best method for assessing such dynamic effects is by wind tunnel tests in which the relevant properties of the building and its surroundings are modeled. However, for cases that are not as extreme as to demand a wind tunnel test and for cases of limited budget, alternative analytical and numerical methods for estimating the wind loading are being developed [1].

1.2 Relevance

The development of modern materials and construction techniques has resulted in the emergence of a new generation of structures that are often, to a degree unknown in the past, remarkably flexible, low in damping, and light in weight. Such structures generally exhibit an increased susceptibility to the action of wind. Accordingly, it has become necessary to develop tools enabling the designer to estimate wind effects with a higher degree of refinement than was previously required. Wind engineering is the discipline that has evolved primarily during the last decade, from efforts aimed at developing such tools.

It is the task of the engineer to ensure that the performance of structures subjected to the action of wind will be adequate during their anticipated life from the standpoint of both structural safety and serviceability. To achieve this end, the designer needs information regarding (a) the wind environment, (b) the relation between that environment and the forces it induces on the structure, and (c) the behavior of the structure under the action of these forces [2].

a) The wind environment.

Information on the wind environment needed in design includes elements derived from meteorology, micrometeorology, and climatology.

Meteorology provides a description and explanation of basic features of atmospheric flows. Such features may be of considerable significance from a structural design viewpoint.

Micrometeorology attempts to describe the detailed structure of the atmospheric flow near the ground. Topics of direct concern to the structural designer include the variation of mean speeds with height above ground, the description of atmospheric turbulence, and the dependence of the mean speeds and of turbulence upon roughness of terrain.

Climatology, as applied to the wind environment, is concerned with the prediction of wind conditions at a given geographical locations. Probability statements on future wind speeds may be conveniently summarized in wind maps, such as are currently included in various building codes.

b) Wind-induced forces on structure.

A structure immersed in a given flow field is subjected to aerodynamic forces that, in general, may be estimated using available results of aerodynamic theory and experiments. However, if the environmental conditions or the properties of the structure are unusual, it may be necessary to conduct special wind tunnel tests.

Aerodynamic forces include drag (along-wind) forces, which act in the direction of the mean flow, and lift (across-wind) forces, which act perpendicularly to that direction as shown in Fig.1.1. If the distance between the elastic center of the structure and the aerodynamic center (i.e., the point of application of the aerodynamic forces) is large, the structure is also subjected to torsional moments that may significantly affect the structural design.

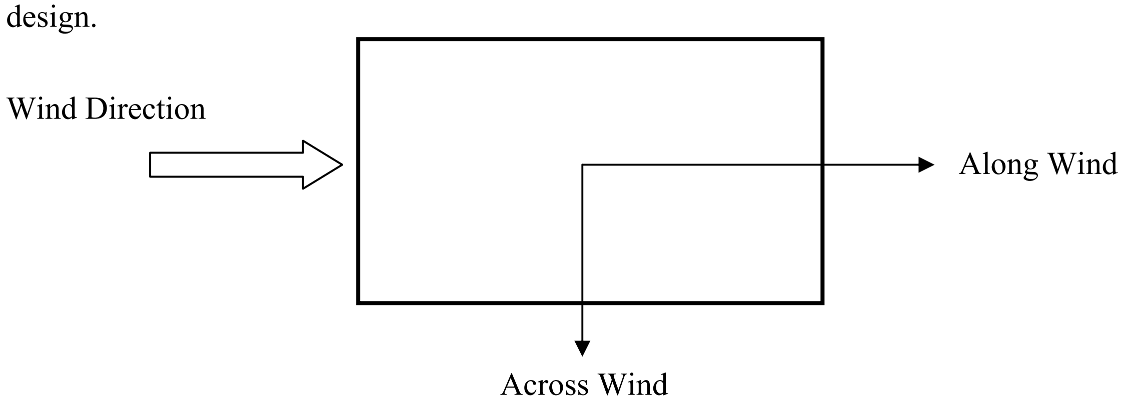

Fig. 1.1 Along and Across Wind Actions

c) Structural response to wind loads.

Because the aerodynamic forces are dependant on time, the methods of structural dynamics may have to be employed to determine the response. Furthermore, the random character of this dependence requires that elements of the theory of random vibrations be applied to the analysis. In certain cases, it may be necessary to perform an aeroelastic analysis, that is, a study of the interaction between the aerodynamic and the inertial, damping, and elastic forces, with the purpose of investigating the aerodynamic stability of the structure.

Under the influence of dynamic wind loads, typical high-rise buildings oscillate in the along-wind, across-wind, and torsional directions. The along-wind motion primarily results from pressure fluctuations on the windward and leeward faces, which generally follows the fluctuations in the approach flow, at least in the low frequency range. Therefore, along wind aerodynamic loads may be quantified analytically utilizing quasi-steady and strip theories, with dynamic effects customarily represented by a random-vibration-based "Gust Factor Approach" [3, 4, 5, and 6]. However, the across wind motion is introduced by pressure fluctuations on the side faces which are influenced by fluctuations in the separated shear layers and wake dynamics [7]. This renders the applicability of strip and quasi-steady theories rather doubtful. Similarly, the wind-induced torsional effects results from an imbalance in the instantaneous pressure distribution on the building surface. These load effects are further amplified in asymmetric buildings as a result of inertial coupling [8].

Due to complexity of the across wind and torsional responses, physical modeling of fluid-structure interactions remains the only viable means of obtaining information on wind loads, though recently, research in the area of computational fluid dynamics(CFD) is making progress in numerically generating flow fields around bluff bodies exposed to turbulent flows [9,10].

Clearly, a disadvantage to physical modeling is the time, cost, and resources required to conduct a wind tunnel analysis, furthermore, in the preliminary design stage.

1.3 Objective and scope

This study is concerned with the along-wind-induced loads on the flexible buildings, taking into account the dynamic effects. In this research, both analytical and numerical studies have been carried out, focusing on the dynamic response. The numerical studies were performed using commercial finite element software package FLUENT which supports a techniques of computational fluid dynamics (CFD).

The objective of the current study may be summarized as follows:

1– To examine some of the major international building codes and standards, their treatment of dynamic effects, and how well those estimates compared with measured wind tunnel data for the case study building.

2– To numerically simulate the case study building using the techniques of Computational Fluid Dynamics (CFD).

3– To verify the adequacy of the developed numerical model by comparing the predicted numerical results with the data measured in wind tunnel test and values evaluated by the building codes and standards. The developed numerical model should be able to provide a good agreement in terms of along-wind- induced loads.

4– To perform a parametric study of different cases of flexible buildings with different dynamic properties subjected to different wind environments using the adopted numerical modeling in order to assess its ability to evaluate the along-wind-induced loads.

1.4 Outline of the thesis

In Chapter 1, Introduction Chapter, includes overview for the wind induced loads on buildings and its dynamic effect for flexible buildings, the chapter includes also the objective of the research and finally the thesis outline.

In Chapter 2, a review of relevant literature to bring out the background of the study undertaken in this dissertation. The researches contributions which have a direct relevance are treated in greater detail. Some of the historical works which have contributed greatly to the understanding of the wind loading on structures are also described.

In Chapter 3, verification of the adequacy of the developed numerical model for the case study building by comparing the numerical results with the data measured in wind tunnel test and values evaluated by the international building codes and standards. The international codes and standards highlighted by this study are those of the American Society of Civil Engineers (ASCE7-2005), National Building Code of Canada (NBC-2005), Australia-New Zealand Standard (AS/NZS1170.2-2002), and Egyptian code of practice (ECP 201-2008).

In Chapter 4, A parametric study of different cases of flexible buildings with different dynamic properties (plan aspect ratio, height, and fundamental period) subjected to different wind environments (terrain roughness) using the adopted numerical modeling and compare it with the values obtained from the above mentioned international building codes and standards in order to assess its ability to evaluate the along-wind-induced loads.

Finally, chapter 5 presents extended summary and final conclusions which can be derived from this study. Moreover, suggestions for future work are also pointed out.