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An Optimization design Approach of Football Stadium Canopy Forms Based On Field Wind Environment Simulation

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Abstract

After the issue of General Plan of Chinese Football Reform in 2015, the development and construction of football stadium in China was put on an important agenda. Field wind environment will make a serious impact on players' performance and game result， while canopy form plays great effect on field wind environment. The primary intention of this research is to reveal the relationship between field wind environment and canopy forms based on CFD simulation of wind environment, then construct an optimization design approach of football stadium canopy form . STAR-CCM + 9.04.009 is set as simulation platform in this paper. As for the current developing status of football game in China, a 30,000-capacity medium-sized football stadium model is proposed for research object. And then CFD simulation is carried out on the canopy section profiles and the canopy connection permeability, different external wind speed such as 5 m/s, 10 m/s, 15m/s ,flows into the model from east side in all the cases. Furthermore, the wind field distribution uniformity and wind speed variation stability are taken as the evaluation criterion. In this way,the impact mechanism which different canopy forms play on the field wind environment in football stadium is attempted to characterize from the experimental results. Finally the proposal of the football stadium optimal design strategies are put forward .

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Keywords: football stadium; canopy forms; field wind environment; CFD simulation

1. Introduction

After the issue of General Plan of Chinese Football Reform in 2015, the development and construction of football

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Table 1. Some cases that strong wind affected the results of football matches in recent years

Time	Place	Both sides	Beaufort Wind Scale	Results
2006-03-13	Cagliari,Italy	Florence VS Cagliari	10	Players injured, game interrupted
2012-01-22	Alkmaar,Netherlands	Alkmaar VS Ajax	6	Alkmaar lost top spot[2]
2012-03-01	Haifa, Israel	Maccabi Haifa VS Dynamo Kyiv	About 7	Resulting own goal[3]
2012-10-28	Marseille, France	Marseille VS Lyon	About 7	match postponed[4]
2013-11-3	Stoke,UK	Stoke City VS Southampton	6	Most long-distance goals in Premier League history[2]
2014-12-10	Basel, Switzerland	Basel VS Liverpool	6	Liverpool was eliminated in the champions league[2]
2014-02-13	Manchester,UK	Manchester city VS Sunderland	7	match Postponed[5]
2014-02-13	Liverpool,UK	Everton VS Crystal Palace	6	match Postponed[5]
2017-02-8	Vigo,Spain	Celta de Vigo VS Real Madrid	7	match postponed[6]
2017-02-8	La Coruna,Spain	Deportivo La Coruna VS Betis	7	match postponed[7]

stadium in China was put on an important agenda.[1] As an outdoor sport, football is affected by the weather inevitably. Because of the relationship between resistance and quality, wind plays a great influence on the football trajectory and velocity. The field wind environment plays an important impact on players' performance and game results(Tab. 1). FIFA stipulates the standard football weight is 410-450 grams at the beginning of the game.[8] Under the influence of the wind, the football speed and flight trajectory is easy to change. In addition, the wind will cause obstruction to the referee's sight line, thus affecting their right judge the facts related to the game. Canopy forms is an important factor affecting the field wind environment. In this paper, we will discuss the influence of different canopies on the wind environment in football field, which provide design reference for football stadium construction.

2. Wind influence on football stadium design

A design process generates a description of a design object which satisfies a given set of design requirements and fulfils a given set of design process objectives. During the design process, both the partial description of the design artefact and the design requirements and process objectives change, often evolving from an abstract definition toward measurable criteria. [9] In earlier phases of design, assessing the fulfilment of design requirements relies on the insight of the designer and focuses on a limited range of performances (like functional and esthetics). For other performances (like most of the engineering related aspects), the assessment is usually postponed. Considering the impact choices made during conceptual design have on the success of the design solution. Enlarging the set of performances assessed at an early stage, enhances inter-disciplinary ,and creates a visual link between form and numeric performance evaluations, which can reduce the investment in poor performing solutions. [10]Wind performance based building design has received quite some attention in the past, especially in the arenas. A computational fluid dynamics (CFD) mathematical method is usually applied for wind flow analysis.[11-14]Three-dimensional steady state RANS(Reynolds-averaged Navier-Stokes) CFD simulations were used in combination with the new Dutch wind nuisance standard to assess pedestrian wind comfort around a large football stadium in Amsterdam, before and after the addition of new high-rise buildings. [15] RANS model simulations was also presented to determine the wind flow pattern to evaluate the influence of both overall stadium geometry and roof slope on the area of the stand that is wetted by wind-driven rain, which provides some design guidelines to avoid this type of spectator discomfort. [16-17] Isothermal CFD simulations of coupled urban wind flow and indoor natural ventilation were presented to assess the influence of wind direction and urban surroundings on the air change rate per hour(ACH) of a large semi-enclosed stadium. [18] CFD mathematical models were developed using ANSYS Fluent software to evaluate the wind flow patterns around and inside the future football stadium retrofit design in West Lafayette, IN. [19] CFD simulations for a prototype of a railway station shelter were conducted to predict the local wind velocities in and around the shelter. [20] Ventilation analysis was conducted by CFD simulations towards the development of optimised conditioning strategies. [21] Several CFD simulations of the three-dimensional airflow with heat and mass transfer in a complex geometry indoor swimming pool were performed to evaluate the weather effect on the indoor atmosphere. [22] Recent validation efforts of CFD for wind performance studies for these