Important moments in the history of structural aerodynamics

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Abstract. There were some important facts in the past that have influenced the development of structural aerodynamics very strongly. The first important event was the breakdown of the Tacoma Narrows Bridge (USA) in the year 1940. The second moment represents the disaster of the cooling towers at Ferrybridge (England) in 1965. In the year 2010 the first time in history the interesting aerodynamic phenomena was observed on the new-built bridge in Volgograd (Russia). It is likely that this event will also stimulate the additional development of the bridge aerodynamics.

1 Introduction

There were some important events in the past that have influenced the development of structural aerodynamics very strongly. They can be marked as faulty moments in the development of structural aerodynamics and in the approach of structure design on the wind load. The first such important event was the breakdown of Tacoma Narrows Bridge (USA) in the year 1940 [1]. The fatal event was the collapse of power plant cooling towers at Ferrybridge (England) in 1965 due to the wind load [1, 2]. In the year 2010 the demonstration of aerodynamic instability was observed on the new-built bridge crossing the river Volga in Volgograd (Russia) [3]. This phenomenon on such type of bridge structure was observed for the first time in the history of bridge engineering. It is likely that this event will also stimulate the additional development of the bridge aerodynamics and it will bring new hitherto unseen knowledge.

2 Collapse of Tacoma Narrows Bridge

In November 7, 1940 the collapse of Tacoma Narrows Bridge (USA) was observed. The native professor of architecture filmed the unique shots of this disaster. Leon Mojsejev was the bridge designer. The bridge was built within two years at the cost of 6. 4 millions US dollars in that time. Mojsejev died of the heart attack three years after the bridge disaster. The bridge was aerodynamically unstable. The loss of aerodynamic stability of the bridge and its collapse occurred under 68 km/h wind conditions, Fig. 1.

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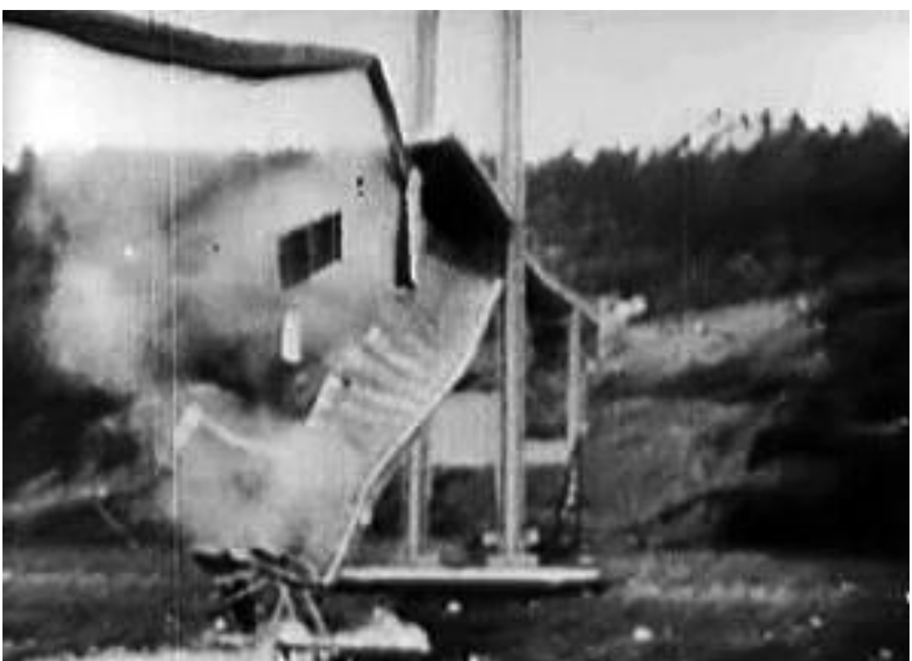

Fig. 1. Collapse of Tacoma Narrows Bridge, November 7, 1940.

What is the significance of this event for bridge engineering? The public blamed Mojsejev for the crash of Tacoma Narrows Bridge, but hurt him unjustly. Until then, no one ever thought that the problems of aerodynamic instability could occur also in relation to the bridge structure and no one would ever dream that the wind could cause the collapse of some bridge construction. Until then there were neither practical nor theoretical instructions how to avoid such situations.

The basic aerodynamic instability phenomena were already known at that time. Phenomena such as buffeting -caused by alternating impacts of wind on both sides of the structure due to turbulent air flow, galloping - movement generated flowing around curved and sharp-edged profiles resulting from the uneven tearing the air stream at different edges of diagonal wrap oscillating object, diffraction torsional flutter - resulting from the laminar flowing around the slim profile in the presence of inertial coupling, Strouhal effect – vibration of circular sections perpendicular to the wind direction caused due to alternate in the roll vortices on both sides of the structure, engineers already knew. But no one expected that these phenomena could be significantly applied to bridge constructions. Tacoma Narrows Bridge accident initiated intense theoretical and mainly experimental aerodynamic bridge construction research. Therefore this moment can be considered as a faulty moment.

3 Group effect

Another event that can be regarded as a faulty moment in the development of structure aerodynamics took place on November 1, 1965 in England at Ferrybridge, Fig. 2. The conclusions which were drawn from this event have direct impact on bridge construction as well. The cooling towers crash at Ferrybridge brought engineers to the conclusion that the isolated building structure behaves under wind loads diametrically opposed to that of the same object in a group of other objects (i.e., a group effect).

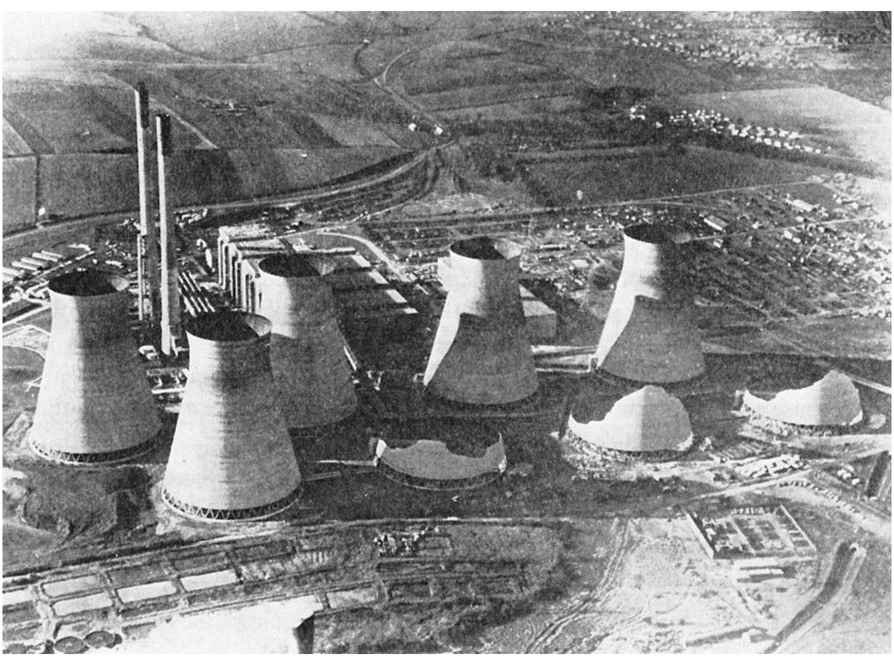

Fig. 2. Collapse of cooling towers in Ferrybridge, November 1, 1965.

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This fact significantly influenced experimental research in the wind tunnel. The engineers have realized that it is necessary to simulate the environment in the vicinity of the tested object.

4 New aerodynamic reality on the bridge in Volgograd

In October 2009 seven km long section of the bridge over the river Volga in Volgograd was put into operation. The bridge has a total length of 29.833 km. Seven kilometer stretch was built within 13 years. Circa 57 millions EUR were invested. This is a type of continuous beam composite steel-concrete construction. In May 2010 an unusual phenomenon was observed on the bridge. The section of the bridge around 1 km long was oscillating with amplitudes of 1 m, Fig. 3. These oscillations were caused by wind.

Fig. 3. Vibration of the Bridge in Volgograd, May 2010.

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This event is interesting since it was the first ever observed case where the bridge with continuous beam on solid supports was aerodynamically unstable and vibrated due to the wind load in the same way as suspension bridges. This phenomenon is new to engineers, until now unprecedented aerodynamic reality. It is therefore very likely that this event also significantly affects the further development and exploration of bridge aerodynamics and it will bring us new previously unrecognized knowledge. Since then bridge designers have to consider the fact that even the bridge on solid support may under some circumstances be aerodynamically unstable and can oscillate due to the wind load as suspension bridges.

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