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THECOMPARISON OF TWO DIFFERENT SPORTING EVENTS BASED ON THE TYPICAL BEHAVIOR OF THE ACTIVE SPECTATORS AND GRANDSTAND VIBRATIONS INDUCED BY THEM

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Abstract. The paper describes especially the typical behavior of two active spectators crowds involved in two substantially different sporting events, namely, ice hockey games and a biathlon world cup competition. In both cases, spectators behavior was observed together with grandstand structure dynamic response to their cheering activities. The experimental results obtained during both events were mutually compared and discussed whether the dynamic loading and its effects on the grandstand structures are similar for the two compared spectators crowds.

Keywords: Behavior of fans, grandstands, vibrations of grandstands.

1. Introduction

Hereinafter, the research of the dynamic response of the steel construction induced by audience of different sport events is emphasized. Actual research, which follows the one focused on dynamic response of the tribune induced by football fans [1], is focused on two different winter sports – ice hockey and biathlon. Selection of these sports is not accidental. Ice hockey is one of the most popular sport in Czech Republic. Biathlon was chosen because of the unique mounted construction which has been considered and the attendance of biathlon races which is still growing in numbers in Czech Republic. The goal of the observation was to find out, if the behavior of the audience is recurrent as well as their influence on the response of the construction. For both sports the following assumption is taken – audience does not induce construction by the jumping in contrast to football etc., audience induces construction by the applause, handclapping.

2. Measurement method

The piezoelectric sensors Brüel&Kjær type 4507 B005 were used for all the experiments. Pilsen, the four sensors were placed on the bottom flange of ice arena construction. Two sensors, No. 1 and 3, measured horizontal acceleration of the girders. Another two sensors installed in the middle of the transverse girder/beam. Sensor No. 2 and No. 4 were used for measuring horizontal and vertical acceleration respectively see Fig 1. Number of the measurement sensors was limited to four sensors by the character of the measurement link.

Nine sensors were installed, two measurement links were applied (4 and 5 channel) in Nové Mŷsto na Moravě. Acceleration in all directions measured on three points of the construction, In accordance with experiment in Pilsen. Two construction points, no. 1 and 3, were located on the stands of the steel construction and one point, No. 2, was located in the middle of the plank span see Fig. 2.

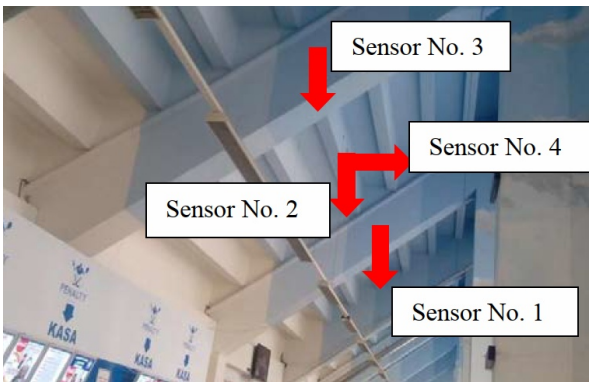

Figure 1. Location of sensors at the grandstands [2].

The behavior of the audience was recorder using the camera. The installation placement of the camera was chosen in accordance to not to raise suspicion of the audience. The camera was installed on the opposite tribune nn Pilsen,. The camera was installed on the television tower left from construction in Nové Město na Moravě. The distance between camera and recorded place was approximately 100 m in both cases.

2.1. Description of construction

2.2. Ice arena Pilsen

The construction of the ice hockey stadium in Pilsen began in 1950. The overall reconstruction of the stadium took place including roof construction and stand reconstruction in 1969. Since 1969, among other reconstructions, the building envelope has been replaced and the concrete construction rehabilitated. Construction of the stadium is made of reinforced concrete skeleton/frame see Fig.3.

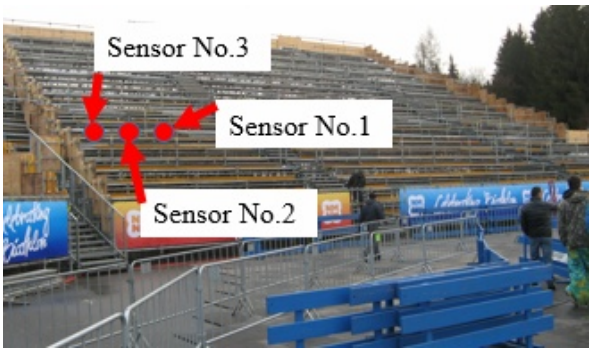

Figure 2. Location of sensors at the grandstands and measuring axis sensors [3].

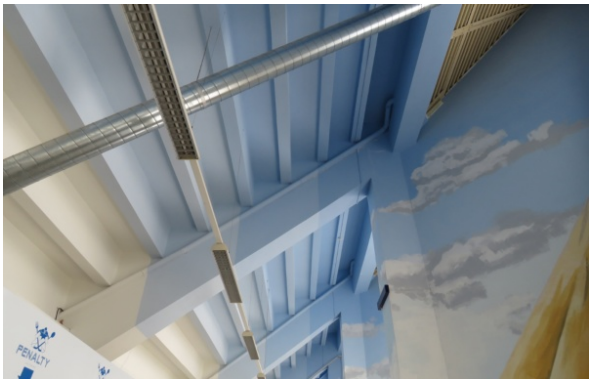

Figure 3. Construction of the stands of the ice stadium.

The main girders are fixed to the columns. The girders support transverse panels of a L-shape. There is no evidence of any project documentation of the ice arena. Therefor the basic level of documentation – passport was drawn up where the basic construction elements are described including dimensions. Based on the passport the whole construction is considered to become monolithic. The modal analysis was performed and the first measured eigenfrequency of the stand was 12.5 Hz (evaluated by the software MeScope).

2.3. Biathlon stadium Nové Město na Moravě

In the biathlon stadium there is a permanent reinforced concrete grandstand. Audience capacity of the stadium could be extended by the temporary steel stands. These steel stands are based on modular scaffold pieces, steel planks and poles and could be built up to 14 m above ground. In accordance with safety requirements the jumping on the steel stand is forbidden see Fig 4.

Figure 4. Construction of prefabricated stands.

There is no reliable mathematical model describing dynamic behavior of the jumping crowd based on the information of the scaffold stand manufacturer. According to the only technical readout focused on dynamics of scaffold stands – British standard, the evaluation of the dynamic load has to be performed if and only if the first eigenfrequency is smaller than 8 Hz. The modal analysis of the steel stand was performed and the first measured eigenfrequency of the stand was 3.0 Hz (evaluated by the software MEscope).

2.4. Spectators behavior

Spectators behavior was assessed using the video recording see Fig 5. Different types of behavior were recognized on the record. The total time of each

FIGURE 5. Position of the camera relative to the monitored area [4, 5].

The type of spectator behaviour	The time during for the game [%]
Static state	23.6
Walking and running	5.5
Jumping – all type	-
Bouncing	1.1
Swaying	15.9
Hand clapping – all types	51.3
Goal scoring	2.6
Mexican wave	-

TABLE 1. Behavior of fans HC Škoda Plzeň vs. HC Kometa Brno (2.10.2015).

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Mexican wave	-

TABLE 2. Behavior of fans IBU NMN 2019 – Women Mass Start (18.12.2016).

behavior type was added up through the whole recording.

The seven behavior types were recognized during the hockey matches. Static state – spectators are standing on the tribune without any other activity; Walking and running – recorded at the beginning and at the end of the match when spectators walk in and out of the stadium; Bouncing – bouncing of knees when heels do not loose contact with the floor; Swaying – the spectators rock their bodies back and forth and to the sides; There were recognized 3 types of Hand clapping – 1) normal applause, clapping hand in front of the chest, 2) clapping hands over head, 3) clapping hands move from the place in front of the chest above head, all of them are considered as one type behavior Hand clapping; Goal scoring and Mexican wave (the sitting spectators are rising, one row after another and wave their hands above their heads) see at the Tab 1.

The four behavior types were recognized during biathlon races see at the Tab 2. There are two types excluded. Jumping is forbidden on the biathlon competitions and therefore was not recognized. And second type – Goal scoring is excluded inherently. The experiment did not consider Mexican wave because this type of behavior took place during competition breaks when the crowd was not recorded.

3. RESPONSE OF STAND

The main part of the experiment was focused on the dynamic response of the stand. Fourier transformation on the measured acceleration of different part of the stand was applied leading to excitation frequen-

cies induced by spectators. Each type of behavior is represented by different excitation frequency. One can see similarity in terms of excitation frequency for all the types of behavior.

4. Summary

Two different sporting events, the ice hockey games and biathlon race, were compared mutually in the paper. The described experiments proved our expectations based on previous observations [1, 2].

The spectators behaved in similar way during both compared sport events. The two most used behavior types in the course of the ice hockey games were static state and hand clapping. The same two types were most often utilized by spectators also during the biathlon race. Moreover, it is evident that fundamental excitation frequencies for individual behavior types are very similar for both compared events. It may be remarked that the first natural frequency of the temporary steel grandstand (3.0 Hz) is comparable to the basic excitation frequency (2.7 Hz) evaluated during the type of behavior – bouncing, see Fig. 9.

On the other hand, the level of induced grandstand vibration was quite different. The highest vibration level recorded on the temporary steel grandstand during the biathlon race was 1.2 m/s^2 and It was substantially higher in comparison to 0.18 m/s^2 that was registered on the reinforce concrete grandstand in the course of the ice hockey games.

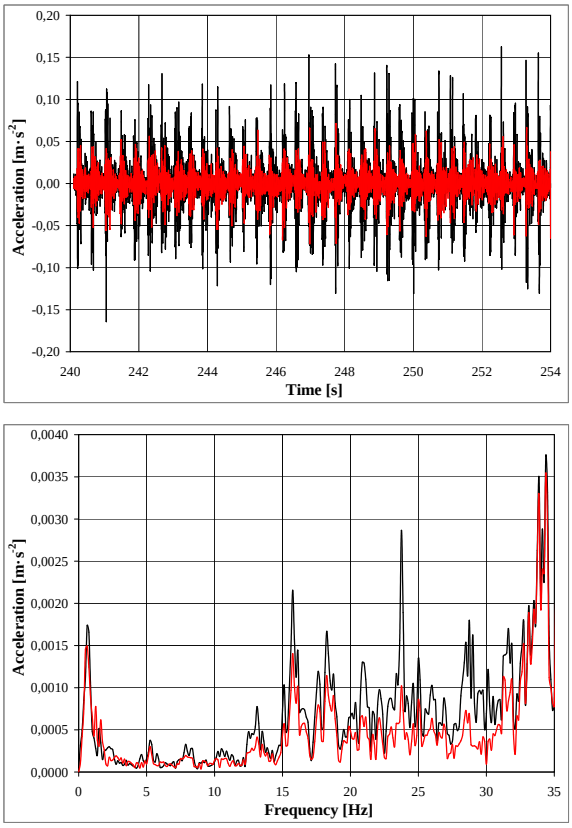

Figure 6. Ice-hockey, dynamic response of the stand - Hand-clapping [2].

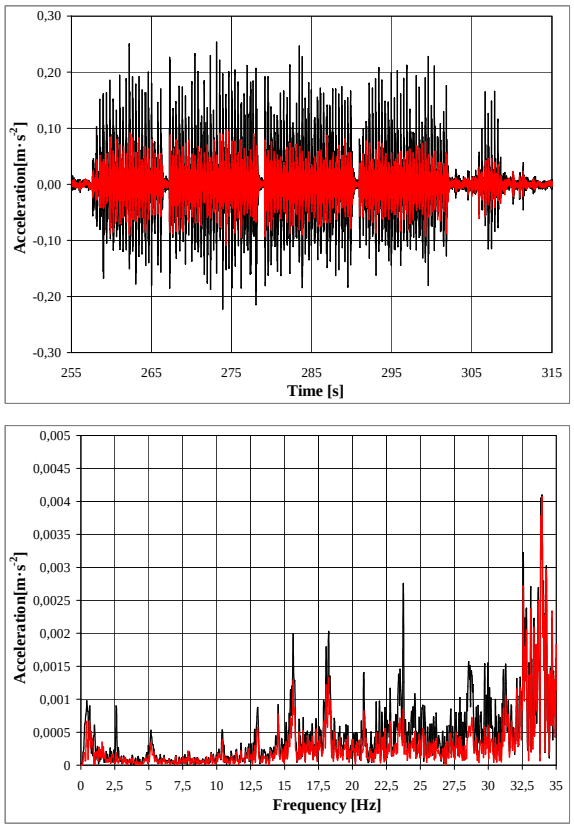

Figure 7. Ice-hockey, dynamic response of the stand - Scored goal [2].

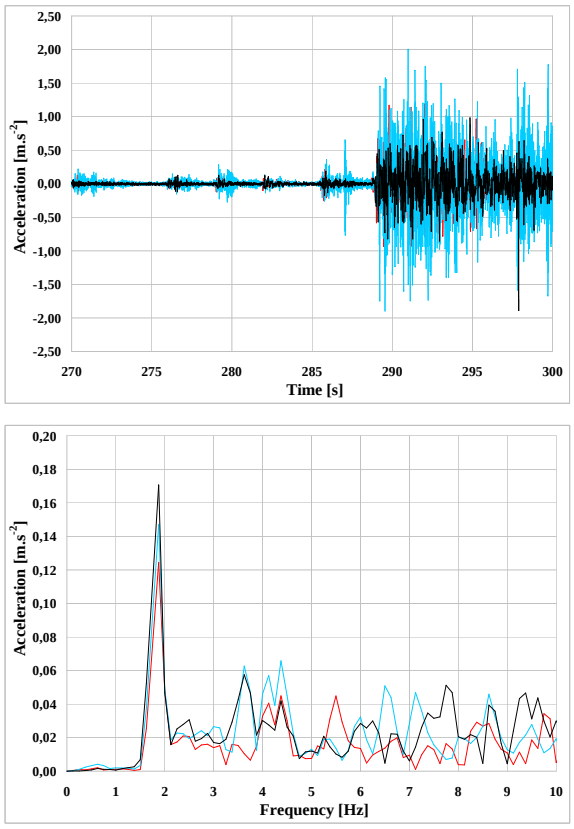

Figure 8. IBB, dynamic response of the stand – Hand-clapping after shoot [3].

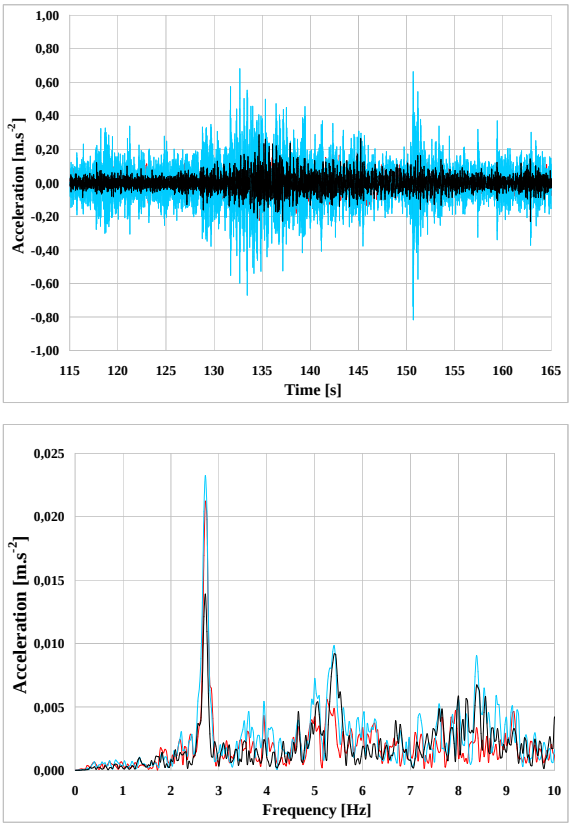

FIGURE 9. IBB, dynamic response of the stand – Bouncing – axes y [3].

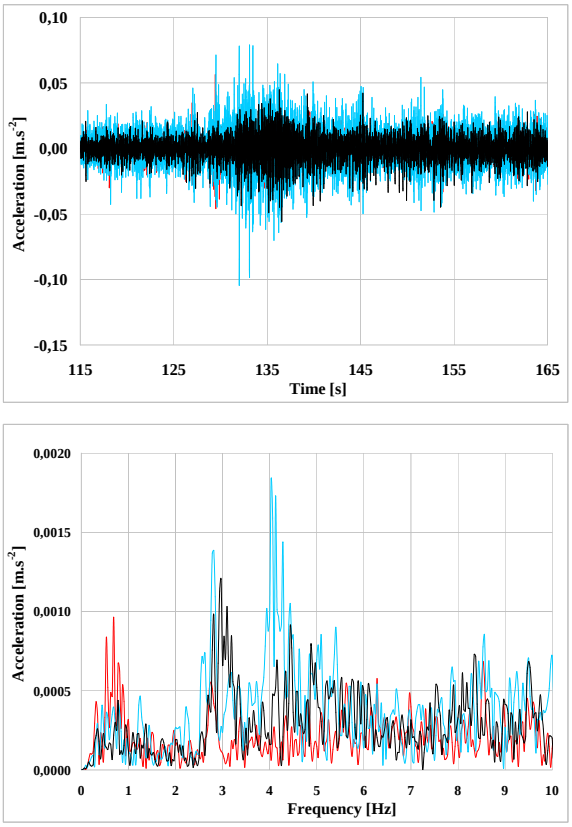

FIGURE 10. IBB, dynamic response of the stand – Bouncing – axes z [3].

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