

Comparison of Fans' Behavior and Grandstand Dynamic Response during Two Hockey Matches Between the Same Teams

Martin Verner^{1, a}, Michal Polák^{1, b} and Tomáš Plachý^{1, c}

¹Czech Technical University in Prague, Faculty of Civil Engineering, Department of Mechanics, Thákurova 7, Praha 6, Czech Republic

^amartin.verner@fsv.cvut.cz, ^bpolak@fsv.cvut.cz, ^cplachy@fsv.cvut.cz

Keywords: Grandstand, Vibration, Fans' Behavior, Hockey Match.

Abstract. The main aim of two experiments described in the paper was to study ice hockey fans behavior in a selected grandstand sector and simultaneously grandstand vibrations induced by them as the experimental basis for specification of new spectator's crowd load models. These experiments followed on the two series of similar experiments focused on spectators induced grandstand vibrations and fans behavior during some football matches that were performed at the Letná football stadium in Prague in the 2013-14 and 2014-15 seasons. The paper summarizes and compares the basic results of two experiments focused on the fans behavior and its influence on the level of induced grandstand vibrations during two ice hockey games between the same teams. The experiments were carried out at the ice hockey stadium in Pilsen that is the home stadium of the HC Škoda Plzeň ice hockey club.

Introduction

Substantial dynamic forces can be induced by a group of sport spectators moving synchronously. Consequently, grandstand vibration amplitudes which can be seen by naked eye could be occasionally caused. In history, there are known cases when the large vibration of a grandstand caused panic of spectators or even its breakdown in a rare situation [1].

At the present time, the satisfactory dynamic load of grandstands is not described in any standard with acceptable precision. Nevertheless, new dynamic models of spectator's crowd were developed based on stochastic approaches [2, 3]. There is also a lack of real experiments which could be used for verification or improvement of the models [1, 4, 5].

The main objective of the experiments introduced in this paper was to study spectators in a selected grandstand sector during two ice hockey games between the same teams. The experiments were focused on the types of fans behavior, their activity and its influence on the level of induced grandstand vibrations as the experimental basis for specification, improvement and verification of new spectator's crowd load models [2, 3]. These experiments followed two series of similar experiments focused on fans behavior and induced grandstand vibrations during some football matches that were performed at the Letná football stadium in Prague in the 2013-14 and 2014-15 seasons [6, 7].

The experiments were realized at the ice hockey stadium in Pilsen that is the home stadium of the HC Škoda Pilsen ice hockey club (see Fig. 1) during two ice hockey games against HC Mountfield Hradec Králové on November 20th 2015, which HC Škoda won 6:2, and on February 2nd 2016, that HC Škoda lost 3:4.

Description of the Stadium

The basic load bearing members of the stadium roof are cables which are anchored to the perimeter reinforced concrete columns. The reinforced concrete elements that form the surface of the roof above the grandstands are supported by the cables. The roof section above the ice rink is transparent. The grandstand of the HC Škoda Pilsen stadium is the reinforced concrete frame structure consisting of T- shaped horizontal beams, sloping main beams and columns mainly (see Fig. 2). We investigated the sector where the most active fans of the home team were gathered (see Fig. 1). This structure is naturally less sensitive to dynamic excitation than the steel cantilever grandstand observed in the course of the experiments performed on the Letná football stadium in Prague [6, 7].



Fig. 1: The observed grandstand sector, where the most active home fans are usually gathered, without fans (left) and with the most active fans (right)

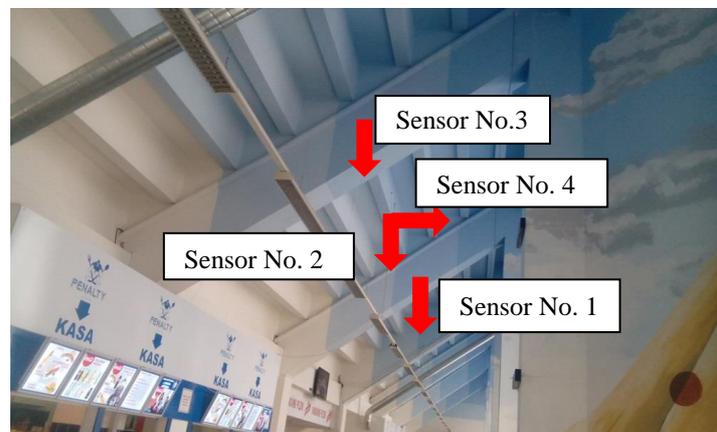


Fig. 2: The bottom view on the sector and the location and orientation of the accelerometers used by carried out experiments.

The Experiment Arrangement

Four piezoelectric acceleration transducers Brüel&Kjær of type 4507 B0 were placed under the investigated sector of the grandstand to measure the response caused by the most active fans (Fig. 2). The same transducers were used for both experiments. Two transducers (Sensors No. 1 and 3 in Fig. 2) were placed in the middle of two sloping main girders of the grandstand to measure vertical accelerations. The remaining two transducers were placed in the middle of the T-shaped beam to measure vertical (Sensor No. 2 – Fig.2) and horizontal (Sensor No. 4 – Fig. 2.) accelerations. The behavior of fans (Fig. 1 – right) was monitored by camera placed on the opposite side of the stadium.

Results

The fans' behavior and the induced response of the grandstand were monitored during two ice hockey matches between the same teams HC Škoda Plzeň and HC Mountfield Hradec Králové. Very similar types of spectators' behavior were observed during two studied hockey games as the types, which were monitored during the football matches [6, 7]. It means these ones - static state, walking and running, jumping, swaying, hand clapping, goal scoring and the Mexican wave. However, some differences could be found. During the ice hockey matches, the fans did not use the jumping type of cheering at all. The other difference is that the ice hockey spectators used more often the cheering type with hand clapping. The comparison of the vertical and horizontal accelerations in the middle of the monitored beam induced by the cheering of type hand clapping observed during two matches between the same teams are shown in Fig. 3 and Fig. 4.

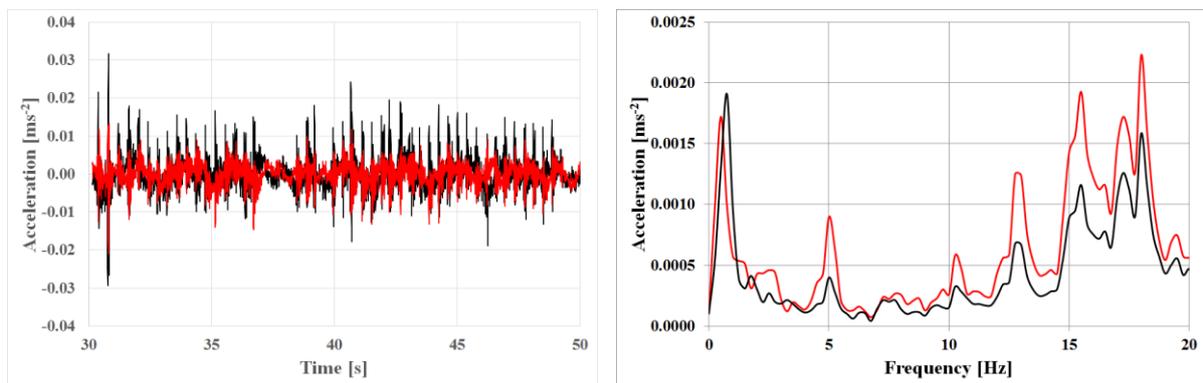


Fig. 3: The vertical (red) and horizontal (black) accelerations in the middle of T-beam caused by the hand clapping type of cheering - November 20th 2015.

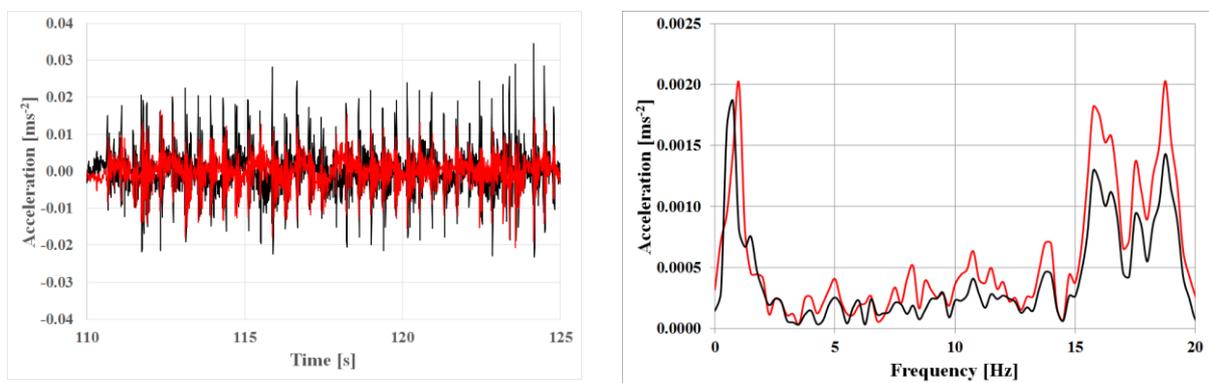


Fig. 4: The vertical (red) and horizontal (black) accelerations in the middle of T-beam caused by the hand clapping type of cheering - February 2nd 2016.

Conclusions

The paper compares the results of two experiments focused on the fans behavior and its influence on the level of induced grandstand vibrations during two ice hockey games between the same teams HC Škoda Plzeň and HC Mountfield Hradec Králové. During both experiments, the same types of cheering were observed and the character of the dynamic response induced by spectators was very similar too (Fig.3 and Fig. 4), only the amplitudes depend on the number of fans presented in the observed stadium sector. The character of

cheering was categorized to different types as for football matches [6, 7]. During the ice hockey matches, the fans did not use the jumping type of cheering at all in contrary to football matches. The Table 1 summarizes the fans involvement in main types of cheering during the last third of both monitored games when the fans are usually most active. There are no big differences between both games.

The paper has been supported by the Czech Science Foundation project No. GA15-15728S.

Table 1: The time duration and fans involvement in the particular types of cheering evaluated during the last third of two studied ice hockey games.

	1 st match			2 nd match		
	Time [mm:ss]	Fans involved in cheering [%]	Standard deviation [%]	Time [mm:ss]	Fans involved in cheering [%]	Standard deviation [%]
Static state	09:22	96	5	09:30	98	2
Hand clapping	18:15	63	21	17:41	68	19
Swaying	02:04	68	25	04:23	69	22
Goal scoring	00:19	88	11	01:36	97	4
Mexican wave	00:40	13	4	00:00	0	0

References

- [1] C.A. Jones, P. Reynolds, A. Pavic, Vibration serviceability of stadia structures subjected to dynamic crowd loads: A literature review, *Journal of Sound and Vibration* 330 (2011) 1531–1566.
- [2] O. Rokos, J. Maca, Stochastic approach in the human-induced vibration serviceability assessment of grandstands, in *proc.: Proceedings of the IX International Conference on Structural Dynamics EURO-DYN2014 (2014)*, eds. A. Cunha, E. Caetano, P. Ribeiro, G. Müller, Faculdade de Engenharia da Universidade do Porto, Porto Portugal, pp. 2591-2598.
- [3] O. Rokos, J. Maca, The response of grandstands driven by filtered Gaussian white noise processes, *Advances in engineering software* 72 (2014) 85 – 94.
- [4] P. Reynolds, A. Pavic, Vibration performance of a large cantilever grandstand during an international football match, *Journal of Performance of Constructed Facilities* 20 (2006) 202 – 212.
- [5] A. Caprioli, M. Vanali, A. Cigada, One year of structural health monitoring of the Meazza Stadium in Milan: Analysis of the collected data, in *proc.: Proceedings of the 27th Conference and Exposition on Structural Dynamics 2009 IMAC-XXVII (2009)*, Society for Experimental Mechanics Inc., Orlando Florida USA, 9p.
- [6] M. Verner, M. Polak, T. Plachy, An Experimental Study Focused to Spectators-induced Vibrations of a Cantilever Grandstand during two Sport Matches, in *proc.: Proceedings of 53rd International Conference on Experimental Stress Analysis 2015 (2015)*, eds. P. Padevet, P. Bittnar, Czech Technical University in Prague Faculty of Civil Engineering, Český Krumlov, pp. 460–465.
- [7] M. Verner, T. Plachy, M. Polak, An Experiment Focused on Fans Behaviour and Induced Grandstand Vibrations during a Football Match, *Applied Mechanics and Materials* 837 (2016) 75–78.