An Analysis of the Fans' Behavior during Two Ice Hockey Games and Its Influence on the Level of Grandstand Vibrations

M. Verner [1,a], M. Polák [1], T. Plachý [1]

[1] *Czech Technical University in Prague, Faculty of Civil Engineering, Thákurova 7, CZ-166 29 Prague, Czech Republic*

[a] *martin.verner@fsv.cvut.cz*

Abstract: Experiments focused on the football spectators behavior and grandstand vibrations were carried out at the AC Sparta football stadium in Prague in the autumn 2013 and repeatedly in the spring 2015 [1, 2]. Two experiments described in this paper continued on above mentioned ones and dealt with the same theme but on the ice hockey games. These experiments were realized at the ice hockey stadium in Pilsen and were focused again on the stadium area where the most active fans of the home team were concentrated. The grandstand in this area is constructed as the reinforced concrete frame load bearing structure. The observed grandstand vibrations were substantially smaller than at the football stadium. It was caused partially by the different grandstand structural systems and also by the dissimilar behavior of football and ice hockey spectators. Other subtypes of fans behavior were distinguished beside the types identified on the football stadium.

Keywords: ice hockey stadium; grandstand; concrete frame structure; sport fans' behavior; vibration; experiment.

1 Introduction

A considerable group of sport spectators moving synchronously could induce substantial dynamic forces. Consequently, grandstand vibrations are caused and they could be occasionally clearly perceptible or even discernible to the naked eye. There are known cases in the history when the undue vibration of a grandstand caused a panic of fans 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. However, new spectator's crowd dynamic load models have been currently developed that are based on stochastic approaches [2, 3, 4]. There is a lack of suitable in situ experiments that could be used as a basis for its improvement or verification [1, 5, 6], and moreover, these experiments are focused only on football matches [5, 6] or pop music concerts [6].

The basic objective of the two experiments described in this paper was to study ice hockey spectators in a selected grandstand sector, its behavior and simultaneously grandstand vibrations induced by them as the experimental basis for specification, improvement and verification of new spectator's crowd load models [2, 3]. 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 [7, 8].

In the paper there is introduced the brief summary and comparison of basic results evaluated by two experiments focused on the fans behavior and its influence on the level of induced grandstand vibrations during two ice hockey games. 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 White Tigers Liberec on September 18th 2015, which HC Škoda lost 2:4, and against HC Comet Brno on October 2nd 2015, that HC Škoda won 4:3.

The grandstand load bearing structure in the observed area, where the most active fans of home team were gathered (see Fig. 2), is the reinforced concrete frame structure consisting of horizontal beams, sloping beams and columns mainly (see Fig. 2 and Fig. 3). 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 [7, 8].

2 The Brief Description of the Ice Hockey Stadium in Pilsen

The Pilsen ice hockey stadium was substantially reconstructed for the last time at the end of the sixties of the 20th century [9].

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 sloping main reinforced concrete beams are anchored on the columns too (see Fig. 3). They help to transfer horizontal load from the roof to the foundation. The T-shaped reinforced concrete beams which create the walking area of the grandstand are supported on the sloping main girders (see Fig. 3).

The capacity of the stadium decreased in the last years from 12 000 to the present 8236. The decrease is caused by changing the standing places to the sitting places. Nowadays, the capacity of standing places (2227 places) is approximately one quarter of the total stadium capacity.

Fig. 1: The exterior view of the ice-hockey stadium in Pilsen.

Fig. 2: The view on the observed grandstand sector, where the most active home fans are usually gathered.

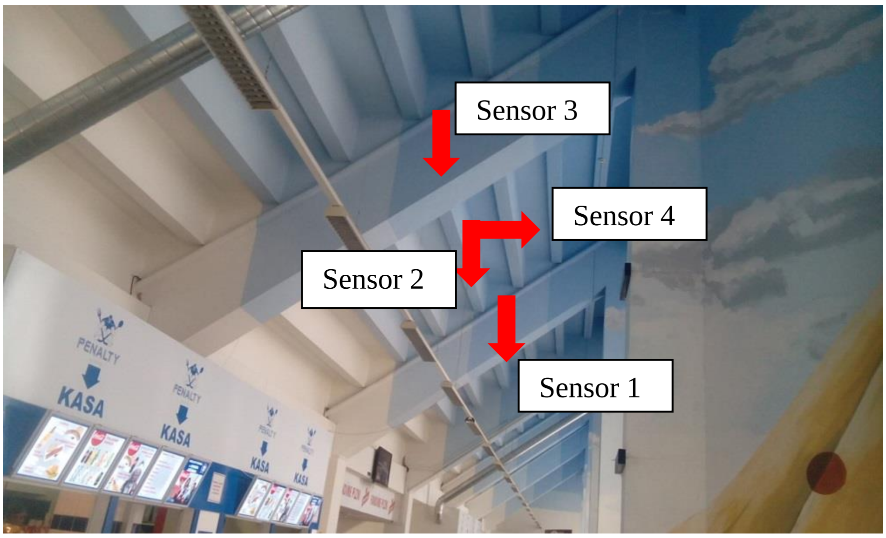


Fig. 3: The bottom view on the observed grandstand sector and the location and orientation of the accelerometers used by the carried out experiments.

Based on the experiences from the previous experiments [7, 8] it was decided to monitor the stadium sector, where the most active supporters of the home team are gathered (see Fig. 2). This section that is in Czech language also called “Kotel” is located in the part of the stadium, where the fans have to stand the whole match because of no installed seats there,

3 The Brief Description of the Experiment Arrangement

The grandstand vibrations were observed on the bottom surface of the grandstand in three points (see Fig. 3). The four piezoelectric sensors Brüel&Kjær of type 4507 B005 were used for the both experiments.

Two acceleration transducers (sensor 1 and sensor 3 in Fig. 3) were placed in the middle of the span of two sloping main grandstand girders and they recorded acceleration in the vertical direction. The remaining two transducers (sensor 2 and sensor 4 in Fig. 3) were placed in the middle of the T-shaped reinforced concrete beam, the first one measured the vertical accelerations and the second one horizontal transversal accelerations. There was chosen a T-shaped beam on which the highest concentration of the core of fans was supposed. The measurement system Pulse and Front-end 3050-B-040 Brüel&Kjær were used for data acquisition.

The results from accelerometers gave us the idea about the influence of types of spectator behavior on the levels and features of the grandstand structure vibrations. It was also important to determine the cause of the observed vibrations during the experiment. For this reason the studied area of the grandstand was monitored by camera placed on the opposite sector of the stadium.

The experiments were realized during two ice hockey games of the Ice Hockey Extra League and concretely during the second and the fourth league rounds. The first observed match was played on September 18th 2015 between the teams HC Škoda Pilsen and HC White Tigers Liberec. The home team lost 4:2 when it was losing the whole match. The goals of the home team were scored by Indrák (30 min) and Hossa (59 min) and the goals of the second team were scored two times by Radivojevič (12 and 60 min) and by Jelínek (33 and 44 min). The first observed game was broadcast live on television.

The second observed match was played on October 2nd 2015 between the teams HC Škoda Pilsen and HC Kometa Brno. The home team won 4:3 even if it was losing 1:3 during the second third. The goals of the home team were scored by Indrák (15 min), Sklenička (36 min) and two times Lev (39 and 54 min). The goals of the second team were scored by Čermák (3 min), Hruška (24 min) and by Zohorna (24 min).

In both observed games the team of Pilsen was fighting for the leading position in the League.

4 The Types of Spectator Behavior Observed by the Experiment

During two studied hockey games the very similar types of spectator behavior were observed as the types, which were monitored during the football matches [7, 8]. It means these ones - static state (all fans stand statically and watch the game passively only), walking and running, jumping, bouncing, swaying, hand clapping, goal scoring and the Mexican wave. The more detailed description of the recognized types of football spectator behavior is stated in the reference [8].

However, same differences could be found. During the football matches that are described in references [7, 8] the spectators used four types of jumping, by three of them, the spectators are joined together in separated lines and jump synchronously. The more significant difference is the limited application of these types of jumping by the ice hockey fans. In the two observed ice hockey games actually jumping as a type of cheering was not applied at all (see Tab. 1). The other noticeable difference is that the ice hockey spectators used more often the cheering type with hand clapping which could be moreover divided to three subtypes.

The first subtype of hand-clapping (the basic hand-clapping) means the spectators stay only on the spot and the applause is realized at chest level. This subtype appears most frequently in a situation when the fans praise players for a nice action.

During the second subtype of hand-clapping the frequency of the applause is controlled by a drum. The clapping frequency could be slow or could accelerate or the applause could combine different rhythms. The spectators lightly bend of their knees in the controlling rhythm in this subtype.

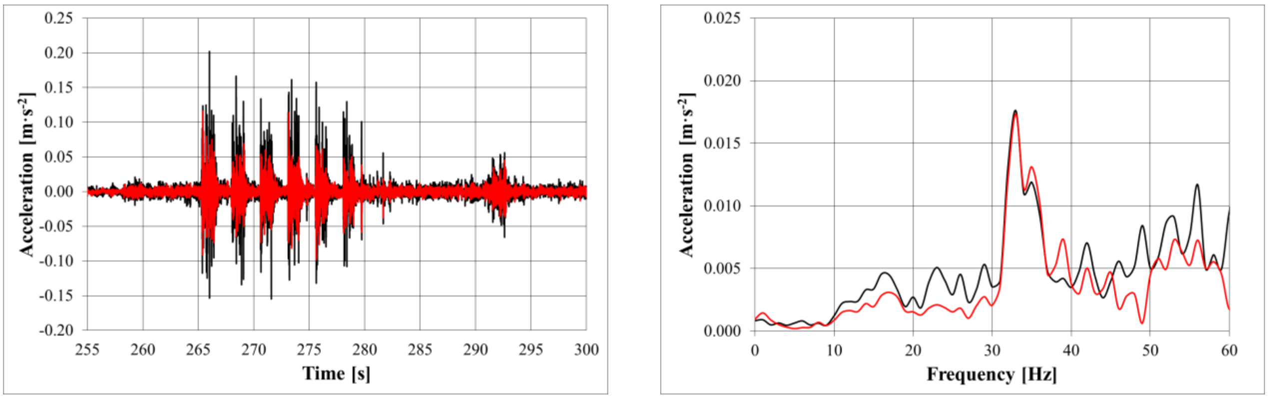
The third subtype of hand-clapping means the spectators stay only on the spot and their hands applaud above their heads. This subtype is impressive to look at. Fans like to use it for accentuation of the readiness to support their team.

5 The Brief Description of the Experiment Basic Results

The both described experiments were carried out during the overall game time. The behavior of spectators during breaks was not monitored.

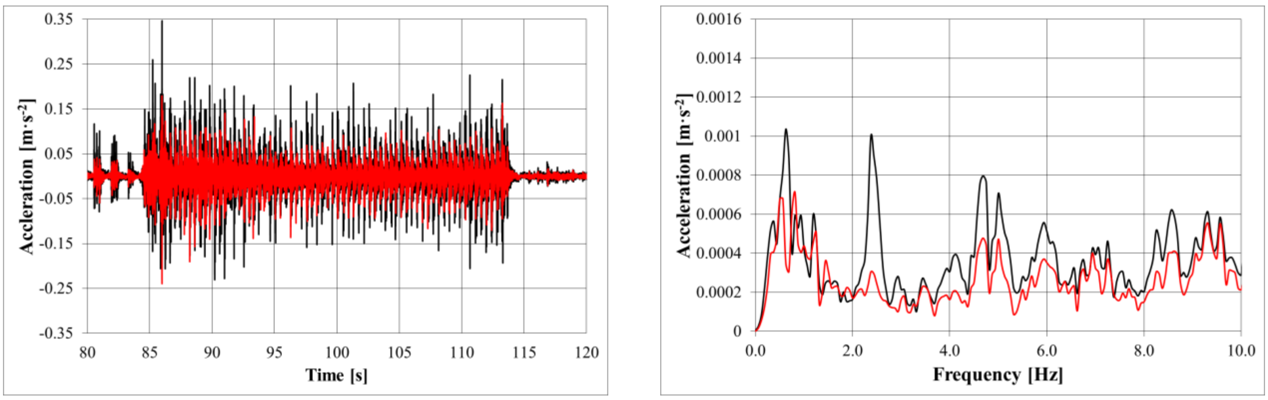
The comparisons of the time behavior and the respective frequency spectrums of the vertical acceleration in the middle spot (the sensor 2) for the significant game situations (the opposing team scored goal, the home team scored goal, the cheering with the hand clapping of the 1st subtype, the home fans celebrate the victory) are shown in Fig. 4 to Fig. 9.

The different types of fans behavior were observed in detail in the course of the both games based on the camera records of the studied grandstand area. The evaluated time duration of the specific types of the spectator behavior and their percentage on the overall game time are stated in the Tab. 1.



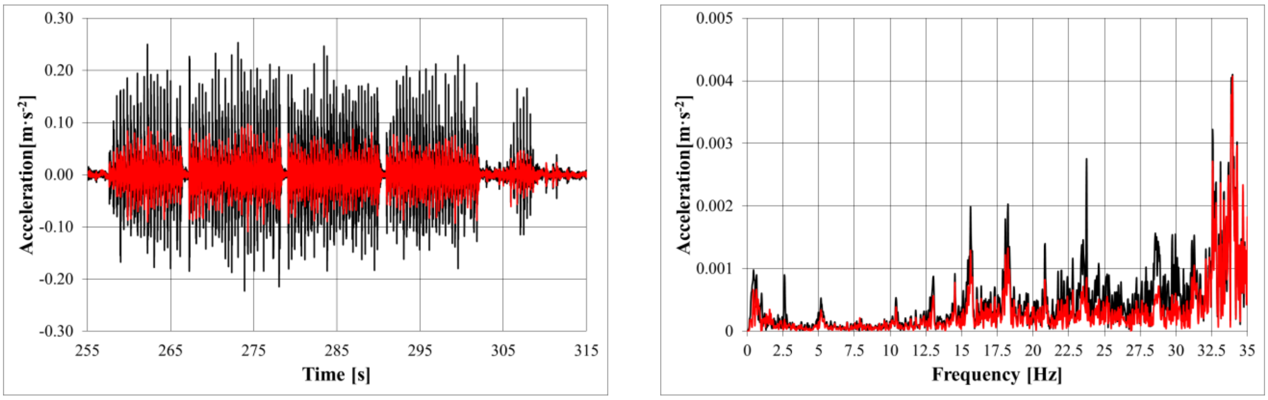
a) the acceleration time records b) the respective frequency spectra

Fig. 4: The grandstand vertical and horizontal vibrations which were measured in the middle spot (sensor 2 and sensor 4) in the situation when the opposing team scored fourth goal in the first game.



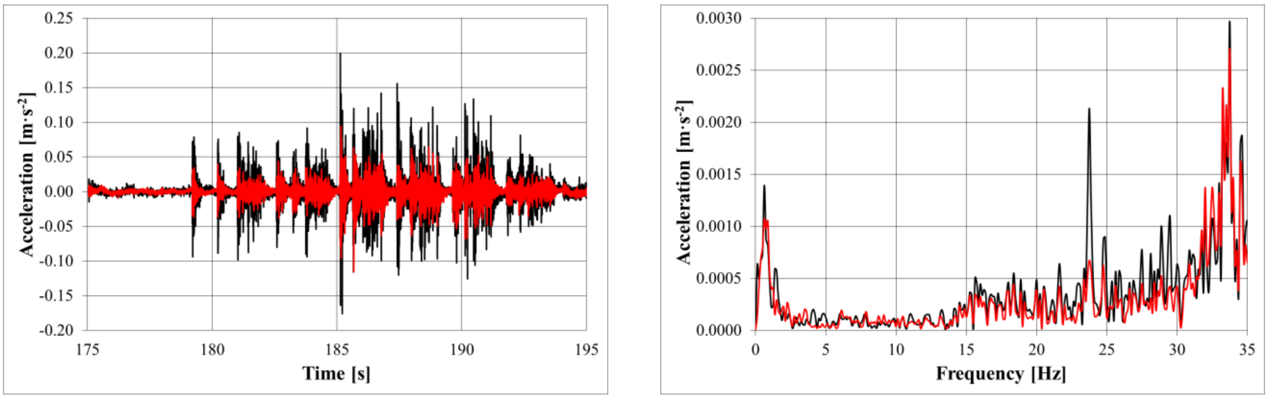
a) the acceleration time records b) the respective frequency spectra

Fig. 5: The grandstand vertical and horizontal vibrations which were measured in the middle spot (sensor 2 and sensor 4) in the situation when the home team scored the second goal in the first game.



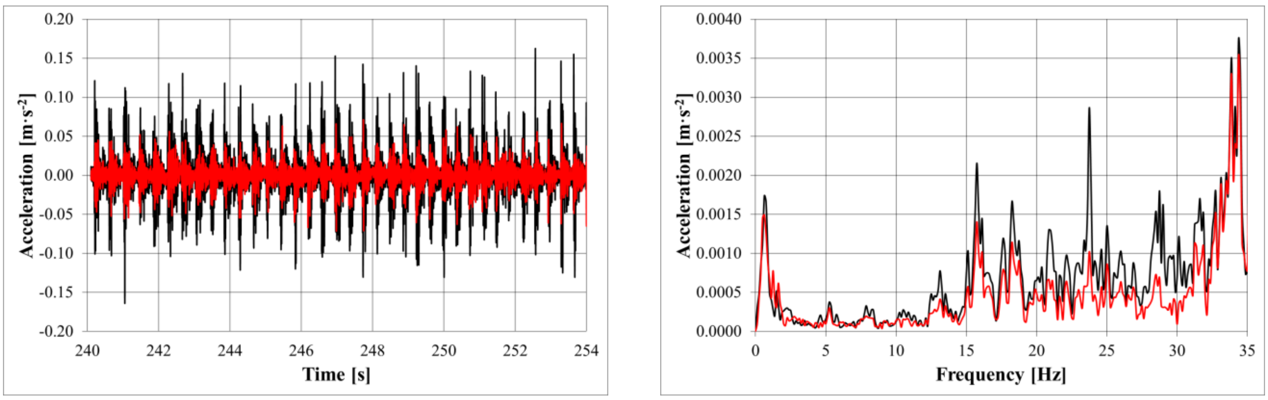
a) the acceleration time records   b) the respective frequency spectra

Fig. 6: The grandstand vertical and horizontal vibrations which were measured in the middle spot (sensor 2 and sensor 4) in the situation when the home team scored winning goal in the second game.



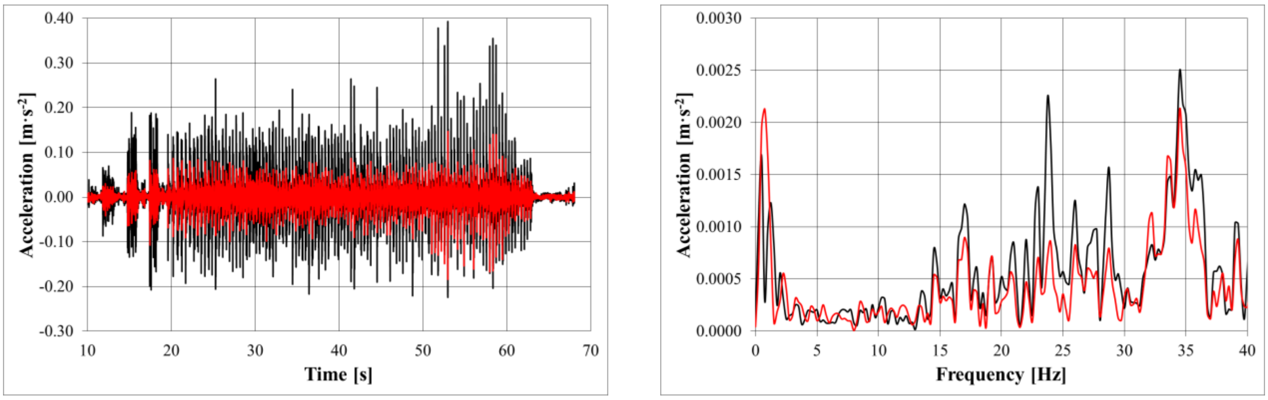
a) the acceleration time records   b) the respective frequency spectra

Fig. 7: The grandstand vertical and horizontal vibrations which were measured in the middle spot (sensor 2 and sensor 4) in the moment when the home fans gathered in the analyzed grandstand sector used the cheering with the hand clapping of the 1st subtype (the basic hand-clapping) during the second game.



a) the acceleration time records   b) the respective frequency spectra

Fig. 8: The grandstand vertical and horizontal vibrations which were measured in the middle spot (sensor 2 and sensor 4) in the moment when the home fans gathered in the analyzed grandstand sector used the cheering with the hand clapping of the 2nd type (the gradually accelerated hand-clapping directed by the drum) during the second game.



a) the acceleration time records b) the respective frequency spectra

Fig. 9: The grandstand vertical and horizontal vibrations which were measured in the middle spot (sensor 2 and sensor 4) in the situation when the home fans celebrated the win at the end of the second game.

Tab. 1: The time duration of the particular types of spectator behavior evaluated during the two studied ice hockey games.

The type of spectator behavior	The time duration for the first game [min]	The time duration for the first game [%]	The time duration for the second game [min]	The time duration for the second game [%]
Static state	27:13	23.6	21:03	14.9
Walking and running	6:20	5.5	0:51	0.6
Jumping – all types	0:00	0.0	0:00	0.0
Bouncing	1:14	1.1	1:05	0.8
Swaying	18:24	15.9	22:36	16.0
Hand clapping – all types	59:23	51.3	90:09	64.0
Goal scoring	3:00	2.6	4:49	3.4
Mexican wave	0:00	0.0	0:16	0.2

6 Conclusion

The results of the fans behavior analysis realized during two ice hockey games show that the behavior of ice hockey spectators is dissimilar in comparison with football ones. For example, other subtypes of fans behavior were distinguished beside the types, which were recognized at the football stadium [8], and it was observed that the ice hockey fans more often apply the behavior type hand-clapping that was used more than half the playing time (see Tab. 1) in both observed games.

The observed grandstand vibrations were substantially smaller than in the football stadium [7, 8]. It was caused partially by the different grandstand structural systems and also by the dissimilar behavior of football and ice hockey spectators.

It was observed that the life broadcast of a game on a television reduces noticeably the number of spectators present at the stadium. The examined grandstand vibrations were consequently smaller too during the broadcast game.

Acknowledgement

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

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