inter·noise 96
25th Anniversary Congress – Liverpool

INCE: 52

# NOISE EMISSION FROM STADIUMS

J H Granneman & H Huizer

Adviesbureau Peutz & Associés B V, PO Box 696, 2700 AR Zoetermeer, The Netherlands

## 1. INTRODUCTION

Sound emissions from stadiums are becoming more and more important because of the fact that in addition to sporting events, stadiums are used for other purposes, amongst others, popconcerts with a significant sound emission.
Based on actual measurements the sound levels developed inside and outside stadiums during sporting events, popconcerts and public address systems are determined. From these results characteristic sound transmission properties of stadiums have been derived and incorporated in an acoustical calculation model. In particular the sound emission of the Amsterdam Arena (now under construction) in open and closed roof situations has been calculated; taking into account different configurations. From these studies feasible ways to reduce the noise emission from stadiums for several types of event, including the public address system, will be discussed.

## 2. NOISE LEVELS INSIDE STADIUMS DURING VARIOUS EVENTS

Inside stadiums during various sporting events noise levels have been measured. In table 1 a summary of these noise levels is given. The noise levels are more or less representative for medium to large stadiums with a capacity of circa 50.000 spectators. In table 1 also the actual noise levels are given contributed by the public address system during soccer games.
The noise levels given in table 1 refer to the occurring noise levels in public areas.

Table 1 Noise levels inside stadiums during several manifestations

| Manifestation | $L_{eq}$ in dB(A) | $L_{max}$ in dB(A) |
|---|---|---|
| Soccer games (circa 50.000 spectators) | 80-90 | circa 110 |
| Public address system | circa 100 | circa 110 |
| Race-karts (circa 20 machines in action) | circa 95 | circa 105 |
| Motor-cross (circa 20 machines in action) | circa 95 | circa 105 |
| Popconcerts (circa 50.000 spectators) | 95-110 | circa 120 |

The range in given equivalent noise levels in table 1 during soccer games depends mainly on the course and the nature of the game. During enthusiastic periods (home club scoring) equivalent sound levels during several minutes of about 100 dB(A) occur.
The noise levels during popconcerts depend on the sound system (size and location) in the stadium. Figure 1 shows the distribution of equivalent noise levels during the popconcerts in the rebuilt Feyenoord stadium in Rotterdam (based on measurements carried out simultaneously). In all measurement positions during these popconcerts peak noise levels ($L_{max}$, reading "fast") are 10 to 12 dB(A) higher than the given equivalent noise levels.

## 3. SOUND TRANSMISSION TO THE ENVIRONMENT

In order to determine the sound levels in the environment surrounding stadiums, the noise levels can be measured or calculated. For stadiums to be built (or rebuilt) the noise levels will have to be calculated. For this reason acoustical calculation models have to be made. In the acoustical model all relevant sources and their transmission paths are taken into account:
- sound emission through the (open) roof plane;
- sound transmission through closed parts (in general light construction) and, for natural ventilation purposes, partially open parts of the roof above the seating;
- sound emission through other open holes in the perimeter of the stadium such as spectators passages.

It is obvious that the noise contribution to the environment of the noise source representing the open roof plane will be dominant. Only at relative short distance from the stadium (< 200 m) at ground level sound emission through the vertical apertures will be dominant. At short distances the stadium itself is the sound screening object regarding the (open) roof plane.
By modelling the noise sources of the open roof plane one encounters several problems e.g.:
- height of the noise sources in relation to the sound screening objects such as the edge of respectively the roof above the seating;
- distribution (number and location) of noise sources over the roof plane;
- angle of sound radiation; this latter aspect is especially relevant during popconcerts with a sound stage at one of the stadium ends;
- the degree of sound diffusion in the roof plane.

In order to solve these problems and to validate the acoustical calculation model, sound measurements were carried out inside and outside the stadium during popconcerts (see also figure 1). These measurements in several positions were carried out simultaneously with at least one reference position in the stadium. In figure 2 the calculated equivalent noise contours are given as well as the measured noise levels at specific measurement positions. The given noise levels (in dB(A)) are all valid for so called down-wind conditions. The values represent the noise levels during the entire duration of the popconcert (circa 3 hours). As can be seen from figure 2, the effect of the directivity of the noise emission during popconcerts due to the podium setting at one side of the stadium is limited. The limited directivity follows from the fact that the loudspeakers are pointed at the public. The public itself has highly sound absorbing qualities, so a semi-diffuse reverberant sound field will be created in the open roof plane which has a limited horizontal directivity index.
Based on the measurement results it was concluded that the noise sources representing the sound emission through the roof plane should be modelled as plane sources with height coordinates about 2 m underneath the highest top of the roof over the seating.

In general an $L_{eq}$ of 50 dB(A) due to the mentioned events can be expected at the following distances to the perimeter of a stadium:
- soccer games: 100 to 300 m;
- popconcert (open roof): circa 2000 m;
- popconcert (closed sliding roof): circa 1000 m;
- motor-cross: circa 600 m.

## 4. REDUCTION OF NOISE EMISSION

The Amsterdam Arena will be provided with a sliding roof. From calculation results it appears that a sliding roof when closed produces a noise reducing effect limited to maximum 3 dB(A) at distances up to circa 200 m. The reason for this is the presence of relatively large vertical apertures under the roof over the seating for natural ventilation purposes which cause horizontally directed sound emission. At greater distances (> 1000 m) a higher noise reduction (up to 15 dB(A)) can be expected.
Additional noise reduction can in principle be achieved by application of sound absorbing material underneath the roof over the seating which is also essential for a good speech intelligibility. During soccer games the noise reduction can be up to 4 dB(A). However the reduction during popconcerts is limited to circa 2 dB(A); this is because the sound crew of the performing artiste(s) will maintain a certain (high) noise level on the audience area.
In order to realise maximum allowed noise levels in the adjacent environment during pop-concerts, in the Feyenoord-stadium a noise control monitoring system is under development. If excessive noise levels inside the stadium occur, the sound crew will be ordered to reduce the level of the loudspeaker system.

## 5. NOISE EMISSION DUE TO THE PUBLIC ADDRESS SYSTEM

At soccer games, or as far as noise emission concerns comparable events, the public address system can be considered as a relevant sound source and a cause of complaints in the environment. The technical possibilities to reduce the sound emission to the environment, with satisfactory speech intelligibility are studied for several stadiums [1].
In most cases public address systems can be divided in two employed systems: a central cluster system and a distributed loudspeaker system.
At circa 100 m of the perimeter of the stadium maximum noise levels can be up to 75 to 80 dB(A) due to a public address system with a central cluster. The distributed loudspeaker system causes circa 15 dB(A) lower sound levels in the community than the central cluster system on the roof, and is therefor in favour. In general it appears that with a distributed loudspeaker system either better speech intelligibility can be achieved at the same sound level or the same speech intelligibility can be obtained at a lower sound level than with a cluster system. The basic principle is that by directing sound towards the audience area less reverberant noise is created, which causes a better speech intelligibility and less noise emission to the environment.

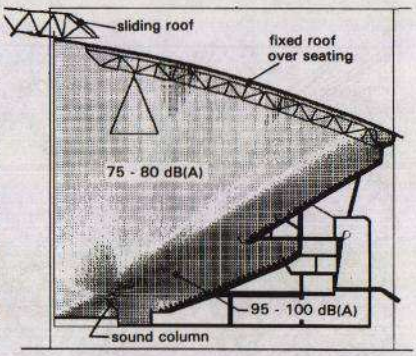

Fig 3: Sound field distribution in Amsterdam-Arena due to specially designed public address system

In situations with a roof above the seating respectively a completely closed roof a satisfactory speech intelligibility is hard to obtain, because of the long reverberation times (without audience: 3,5 to 4 s respectively about 7 s in relevant octave bands). In the closed roof situation sound absorption is essential, for instance at (parts of) the roof. In these situations the application of sound columns on ground level with special directional properties are recommendable. The sound is directed to the audience with a very small vertical coverage angle, using electronic technics, subsequently delaying the signal to the sources of the columns [2]. In figure 3 the calculated sound field distribution due to this directivity system is given. In the seating area noise levels up to 100 dB(A) occur, while in not relevant parts of the stadium 20 dB(A) lower sound levels are to be expected.

## 6. REFERENCES

[1] F. Breuer, K. Rijk and V.M.A. Peutz: 'Untersuchung zur Informationsoptimierung bei gleichzeitiger Verminderung der Störwirkung bei Außenlautsprecheranlagen', Rep. VB2, Ministerium für Umwelt, Raumordnung und Landwirtschaft, Düsseldorf, Germany, 1988.

[2] J. van der Werff: "Design and implementation of a sound column with exceptional properties", 96th AES Convention, Amsterdam, 1994.

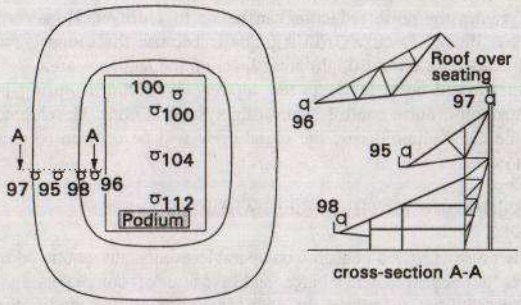


Fig 1: Measured equivalent dB(A)-noise levels in the Feyenoord stadion during the popconcert

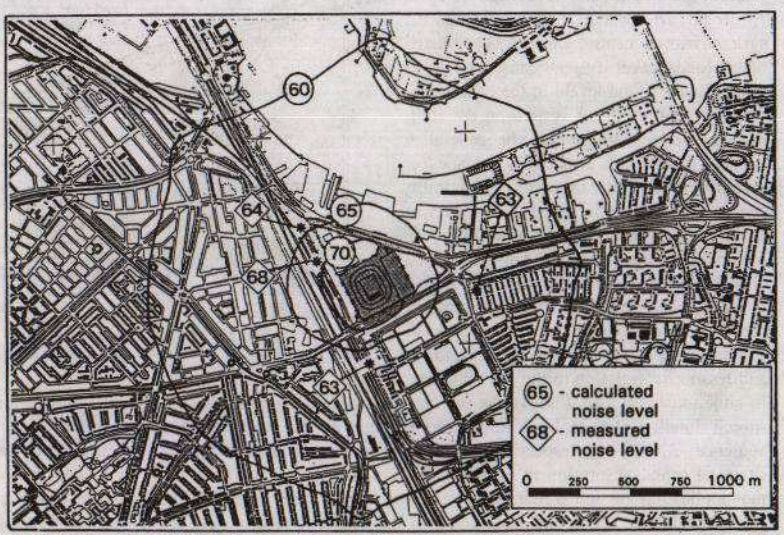


Fig 2: Equivalent dB(A)-noise contours in the environment of the Feyenoord stadion