Assessment of visual comfort of spectators in stadia

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ABSTRACT: Stadia are prestigious buildings, sculptures of urban structure and venues of different competitions, concerts, religious events, visited by large number of people. Spectators, following day-time events in situ or on the TV expect an evenly illuminated pitch, free of sharp contrasts.
The contrast is due to the shadow from the roof and bowl: the shape of the shadow depends on the morphology of the stadium, on the material of the roof, on the time and geographical location.
Self intended transparent or translucent roofs partly eliminate the problem, however besides of visual conditions other aspects should not be forgotten: in summer the exposure of spectators to solar radiation may result in serious thermal discomfort.
A set of numerical simulation has been carried out with different morphological variations, for different orientations and latitudes in order to determine the seasonal number of hours when the visual requirements are met. A method has been developed to determine the size and shape of the necessary transparent part of the roof of a given morphology, for any orientation, latitude and schedule of event. The results facilitate the consideration of the visual conditions in the early stage of the design.

Keywords: stadia, semi outdoor space, visual comfort, design tool

1. INTRODUCTION

Stadia are symbols of towns, prestigious buildings that host diverse events such as sport competitions, concerts and religious meetings. Spectators who follow day-time events expect evenly illuminated pitch, free of accentuated contrasts. So the visual comfort of spectators is associated with the insolation of the pitch. The latter depends on one hand on the geometry of the stadium, especially of the stadium roof and on the other hand on the photometric characteristics of the roofing material.
The present paper illustrates the visual comfort conditions of the spectators in function of the stadium architecture.

2. VISUAL COMFORT CRITERION OF SPECTATORS

Stadia are classified as semi-outdoor spaces [1] as they are covered and open at the same time. They contain some elements, structures that provide *some* protection to the spectators from the outdoor environmental conditions. The most accentuated elements of stadia are the roofs. The modern stadia show a tendency to cover the largest bowl surface possible and so to protect more and more spectators from the environmental conditions.
Both the spectator terrace and the roof can project shadow onto the pitch. The higher the spectator terrace the larger part of the pitch can be shadowed for longer periods because the bowl is deeper.
The roofs of extended surface can project shadow onto the pitch, as well. The shape of the shadow of the spectator terrace and the roof depends on the location of the stadium, the time of the event, the geometry and the orientation of the stadium and the photometric characteristics of the roofing material.
Differently from the spectators terrace the roof can be made of opaque, transparent or translucent materials that influence the quantity of transmitted light.
Self intended transparent roofs may result in less problem of shadow – on the other hand the visitors under a transparent roof may be exposed to the solar radiation which – in summer period – could result in serious thermal discomfort. Thus, transparent roof should not be applied without any further consideration, this is why in the followings opaque roofs only will be analysed.
Based on the daylight studies carried out by the Lighting and Colorimetry Division of the CSTB Nantes on the Stade de France [2] a visual comfort criterion has been defined: no accentuated contrast should appear on the pitch due to the shadow of the roof and the spectators' terrace [3].

Figure 1: Shadow of the roof projected to the pitch

Both the human eye and the camera could have difficulties in the adaptation to the abruptly changing visual conditions; e.g. a ball is flying from an insolated area to a shaded zone. That means that from spectators' visual comfort point of view either a completely insolated or a completely shadowed pitch is favourable.
The insolation of the pitch has been studied through parametric numerical simulations for 10 different stadium configurations.

3. SELECTED STADIUM CONFIGURATIONS

Through the selected configurations the effect of the following geometrical parameters has been studied:

- The slope of the roof
- The overhang of the roof
- The dimension of the central roof opening
- Height of the opening between the roof and the bowl
- Proportion of the length and the height of the stadium

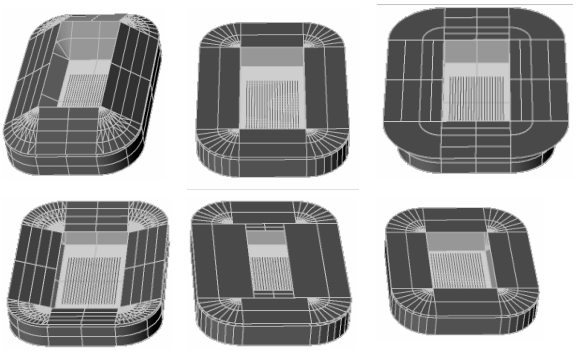

Figure 2: Example of investigated configurations

Each configuration has been modelized in 3D by a program called Rhinoceros. The length of the period during that a given surface of the pitch is insolated has been calculated supposing clear sky by a program called BilEclInt developed by the Lighting and Colorimetry Division of the CSTB Nantes. The pitch insolation has been calculated for all selected configurations for three geographical locations:

- Amsterdam (52°21' North, 4°55' East)
- Nantes (47°12' North, 1°36' West)
- Nice (43°42' North, 7°15' East)

The pitch is 120 m x 80 m and is materialized by 651 points placed to 4 m from each other. Around the pitch there are some place left for the athletic fields. The Fig. 2 illutrates the plan numerical model used for the simulation. The dark zone in the middle represents the pitch.

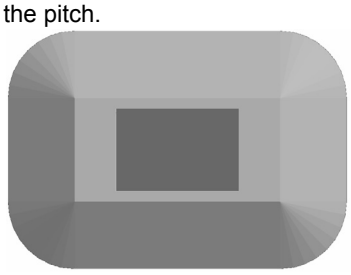

Figure 3: Schematic plan of the stadium model

The effect of the orientation of the stadium has also been investigated. The insolation of the pitch of each configuration has been studied for two orientations:

- Longitudinal axis of the stadium oriented north-south
- Longitudinal axis of the stadium oriented north-west-south-east

The results have been illustrated on a calendar diagram that consists of iso-lines representing the periods of the year when given percents of the pitch are insolated. The horizontal axis of the diagram shows the hours of a day, the vertical axis the months of the year. The following six zones are distinguished on the diagram:

- 100% - completely insolated pitch (A)
- 75-100% (B)
- 50-75 % (C)
- 25-50 % (D)
- 0-25% (E)
- completely shaded pitch (F)

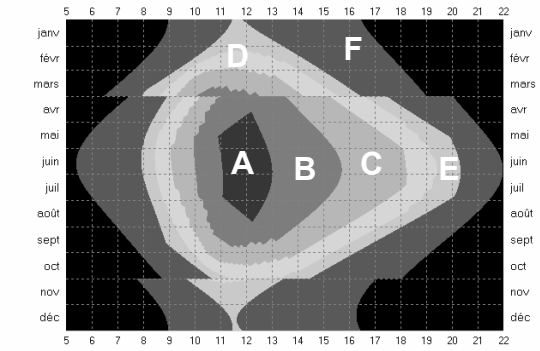

Figure 4: Example of calendar diagram

The surfaces corresponding to each zone are represented on a pie graph. The different pie parts indicate the length of the period of the year (the number of hours) during that the pitch is hit by direct solar beam.

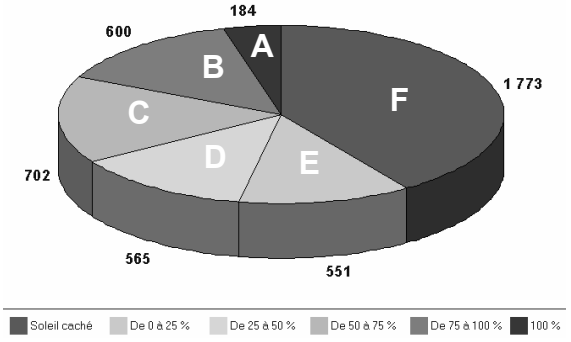

Figure 5: Example of pie graph

The results of the simulation show that the proposed factors (the geometry, the orientation, the geographical location) have significant effect on the insolation of the pitch, and consequently on the visual comfort conditions of the spectators.

4. EFFECT OF THE ROOF SLOPE

Modern stadia roof can be horizontal, rising towards the pitch or sloping towards the pitch. The effect of the three type roof on the pitch insolation has been investigated.

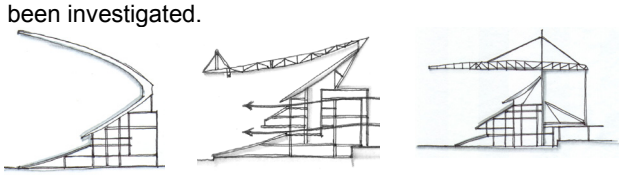

Figure 6:

Rising roof Sloping roof Horizontal roof

The Fig. 7 shows the influence of the roof slope on the lengths of the period during that the luminous conditions are uniform on the pitch. In other words, when the pitch is completely insolated or is completely shaded. The length of this period is explained in percents and is related to the total number of the hours per year during that the sun is above the horizon. A sloping roof towards the pitch is represented by a negative value; that raising towards the pitch are marked by positive values.

The Fig. 7 illustrates that there is no significant difference between the results of the investigated three geographical locations. It illustrates also that the roof slope has prevailing effect on the visual conditions on the pitch of a stadium of about 80000 spectators: a horizontal roof results in uniform luminous conditions about 27% of the period during that the sun is above the horizon, however a sloping roof towards the pitch by 15° gives about 40% A rising roof by 30° towards the pitch has the same effect; it increases the length of the period of good visual conditions in comparison to a horizontal roof. Nevertheless, a rising roof toward the pitch by 15° gives about similar results to a horizontal roof.

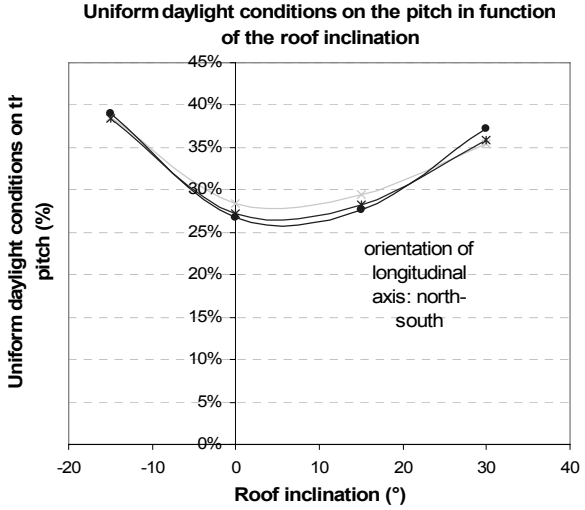

Figure 7: Effect of the roof inclination on the visual conditions of the pitch with a north-south oriented longitudinal axis. The curves from the top to the bottom at inclination 10° belong to the following locations: Nice, Amsterdam, Nantes.

The Fig. 8 shows that the longest period during that the pitch is completely insolated belongs to a sloping roof towards the pitch: it is about 15-20% of the period of the year during day-time. In contrast, a horizontal roof and a slightly rising roof towards the pitch reduce the lengths of the mentioned period to ~5%. A roof of a more accentuated slope (30°) reduces further this length.

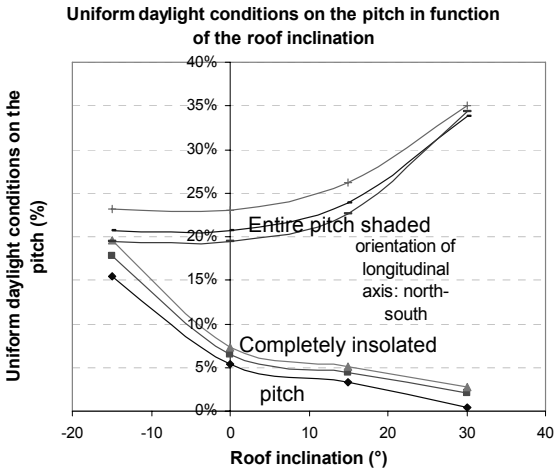

Figure 8: Effect of the roof inclination on the insolation of the pitch with a north-south oriented longitudinal axis. The upper family of curves from the top to the bottom at inclination 10° belong to the following locations: Amsterdam, Nantes, Nice. The lower family of curves from the top to the bottom at inclination 10° belong to the following locations: Nice, Nantes, Amsterdam.

The Fig. 8 shows also that the length of the period during that the pitch is completely shaded by the roof is the longest for a sloping roof towards the pitch and a horizontal roof. The length of this period decreases as the roof rises towards the pitch. A roof that raises towards the pitch by 30° results in a period during that the pitch is completely shaded of about 35%.

The orientation of the stadium affects significantly the insolation of the pitch.

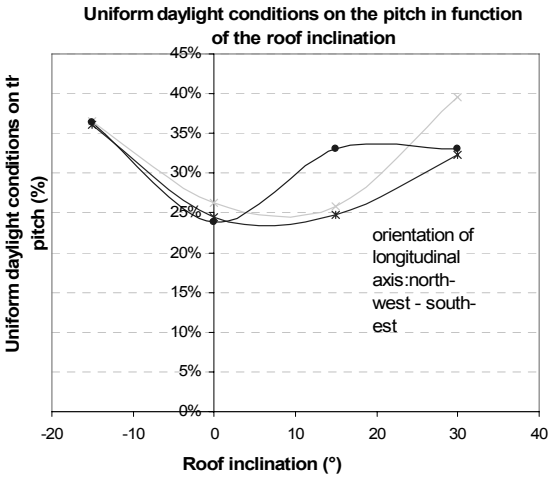

Figure 9: Effect of the roof inclination on the insolation of the pitch with a north-west south-east oriented longitudinal axis. The curves from the top to the bottom at inclination 10° belong to the following locations: Nice, Amsterdam, Nantes.

The suggested orientation of the longitudinal axis is the interval of N +45° W and N +20° E for all types of stadia [4]. The Fig. 9 illustrates that a rotation of 45°, so a stadium with a longitudinal axis oriented towards north-west – south-east reduces slightly the length of the period of uniform visual conditions on the pitch.
However the lengths of this period has augmented significantly for a stadium of rising roof by 15°; it is equal by the value belonging to a roof that rises by 30°. This is due to the increase of the period during that the entire pitch is shaded. The Fig. 10 shows that the lengths of the mentioned period for both types of rising roof are practically equals, about 32%.

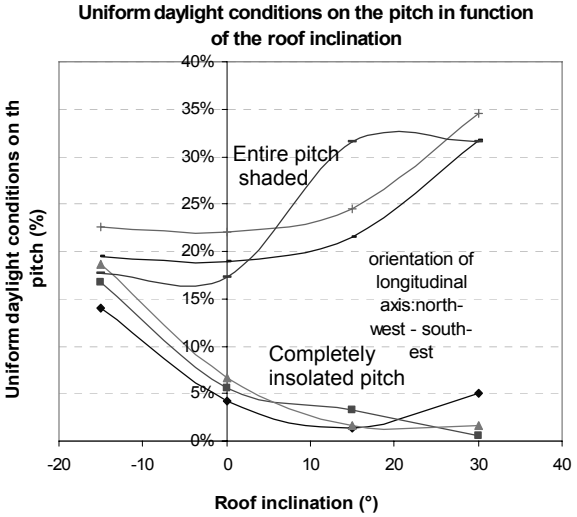

Figure 10: Effect of the roof inclination on the insolation of the pitch with a north-west – south-east oriented longitudinal axis. The upper family of curves from the top to the bottom at inclination 10° belong to the following locations: Nice, Amsterdam, Nantes. The lower family of curves from the top to the bottom at inclination 10° belong to the following locations: Nantes, Nice, Amsterdam.

The lengths of the completely insolated periods for a stadium with a north-west – south-east oriented longitudinal axis are close to those of oriented a north-south for a horizontal and a sloping roof towards the pitch. In case of a slightly rising roof (15°) towards the pitch the lengths of this period decreases slightly for a north – south orientation comparing to a north-west – south-east orientation.

Nevertheless, the period of the uniform luminous conditions on the pitch can be prolongated (up to a limit) by a careful solar design concept that is based of the determination of the location of the opaque and transparent or translucent roof parts [3].

5. CONCLUSION

The visual conditions on the stadium pitch that affect the visual comfort of spectators depend on several parameters, such as the stadium architecture, the orientation of the building, the geographical location and the photometric characteristics of the roofing material. The luminous conditions on the pitch have been studied through systematic parametric numerical simulations using the program BilEclInt for selected stadium configurations and at three locations: Amsterdam, Nantes and Nice. The effect of the stadium architecture, in particularly that of the roof, has been demonstrated by the results belonging to the parameter “roof inclination”. The simulations have been carried out for opaque roofs and spectators’ terraces supposing clear sky. The results illustrate that some slight geometrical modifications can result in considerable changes in the luminous conditions on the pitch, and in consequence in the visual comfort of spectators.

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