Sound Field Analysis of Monumental Structures By the Application of Diffusion Equation Model

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Abstract

Sound energy distribution patterns within enclosed spaces are the basic concerns of architectural acoustics. Energy decays are utilized for major acoustical parameter estimations, while spatial energy distribution and flow vectors are indicative in the analysis of sound energy circulation and concentration zones. Until recently, basic methods in acoustical analysis of real-size or virtual spaces have been the acoustical simulations depending upon the ray, image, and/or beam tracing algorithm based simulation software, scale-model tests, and if applicable the field tests. Some former researches proved the potential of diffusion equation model (DEM) as an alternative tool for room acoustics-predictions.

In this study the acoustical field of a real-size monumental structure is analyzed by using diffusion equation model. The local acoustic energy density in rooms with perfectly diffuse reflecting walls is named to be diffusion model, which is based on the mathematical theory of diffusion to the sound field within an enclosed space. Due to its computational efficiency and provided advantages as of spatial energy density and flow vector analysis, DEM is chosen to be a viable tool for explaining sound fields of complex architectural spaces; in this case a multiple-domed superstructure.

For applying DEM over the solid model of the superstructure, basic PDE interface of COMSOL Multiphysics® is utilized. The sound energy and flow decays are obtained through point evaluation. The time dependent solution is analyzed via COMSOL Multiphysics® slice, volume and arrow volume (flow vector) plot groups. Results are compared to field tests and ray-tracing simulations. The comparative analysis of different solutions indicates good agreement for basic reverberation time estimations. Both DEM application and ray-tracing simulation have the flexibility of experimental analysis in compare to fixed/limited receiver locations of field tests. On the other hand, COMSOL Multiphysics® based DEM solution is superior to ray-tracing simulations in respect to its high computational speed, and additional outputs as of spatial energy and flow vector analysis. This study emphasizes finite element modeling by DEM application to be considered as a practical and scientific method of room acoustics predictions, particularly for in-depth sound field analysis. The future work of this research will include the multiple-slope energy decay investigations on single space structures

with specific architectural attributes by the application of diffusion equation model.