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VISUAL AND AURAL PRESENTATIONS FOR EDUCATION OF ARCHITECTURAL ACOUSTICS

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ABSTRACT
Architectural (environmental) acoustics is one of the essential subjects in environmental engineering in the architectural department of universities. For the class of this subject, it is very important to make efforts and contrivances how to make the students feel familiar to acoustics and recognize its importance in living environments. In this presentation, the contents of the class of architectural acoustics mainly for undergraduate course made by the author are introduced as an example, and some examples of visual and aural demonstration materials prepared for the class mainly in undergraduate course are presented. The contents of the demonstrations are fundamentals of acoustics, basic physiological and psychological acoustics, sound insulation, room acoustics, acoustic simulation (scale modeling and computer simulation), acoustic measurement, etc.

1 - INTRODUCTION

In Japan, the architectural department in universities usually belongs to the engineering faculty and its main subjects are (1) architectural design and history, (2) structural dynamics, and (3) environmental engineering. The field of environmental engineering includes such physical problems as air, light, sound, heat, water and humidity. In addition, physiological and psychological aspects of living environments are becoming important subjects lately. Thus, architectural or environmental acoustics is one of the essential curricula in the environmental engineering.
For the class of this subject, it is very important to make efforts and contrivances how to make the students feel familiar to acoustics and recognize its importance in architectural engineering. In this presentation, some examples of materials of physical, visual and aural demonstrations for the class of architectural acoustics mainly in undergraduate course are introduced.

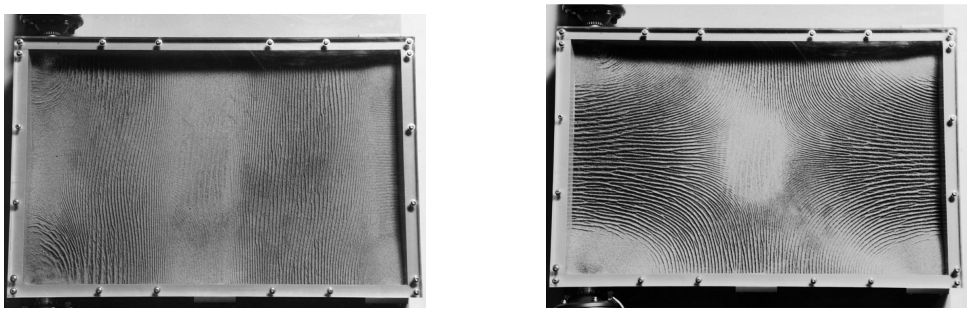
2 - CONTENTS OF THE LECTURE ON ARCHITECTURAL ACOUSTICS AND PHYSICAL-, AURAL- AND VISUAL-DEMONSTRATION MATERIALS

As an example of the lecture on architectural acoustics in undergraduate course, the contents of the lecture made by the author are introduced in the table. These contents are lectured in half a year (about ten times of 1.5 hour class). In the table, physical, visual and aural demonstrations prepared for the class are indicated in the right column. Some of these materials will be demonstrated in the oral presentation by the author in Inter-noise 2000.
In addition to the lecture in the class, technical visit of acoustical laboratory is usually performed to demonstrate various kinds of experiments and measurements which can not be performed in the class.

Chapters and contents		Demonstration
0. Introduction:		
	The aims of Environmental Engineering	
1. Fundamentals of sound		
▶	Sound wave	Physical
	sound pressure, particle velocity, sound speed, wave length, period, frequency	Visual
▶	Audio-frequency range	
▶	Fundamental characteristics of sound wave	
	geometrical attenuation, reflection, diffraction, refraction, interference	Visual
▶	Basic quantities related to sound energy	
	sound power, sound intensity, sound energy density	
▶	Level (dB) expression	Aural
	sound power level, sound pressure level, sound intensity level, sound energy density level	Visual
2. Fundamentals of auditory sensation		
▶	Mechanism of hearing	
▶	Equal loudness contour, A-weighted sound pressure level	
▶	Haas effect	
▶	Masking effect	Aural
▶	Etc	
3. Sound absorption and sound insulation		
▶	Sound incidence, reflection and transmission	
▶	Sound absorption	
	Sound absorption coefficient (definition and measurement)	
	Sound absorption mechanisms and materials	
	Resonance	Physical (Fig. 1, Fig. 2)
▶	Sound insulation	
	Sound transmission coefficient, sound transmission loss	
	Mass law, coincidence effect	
	Sound insulation characteristics of single wall and double leaf wall	Aural
	Measurement of sound transmission loss	
	Sound insulation construction and materials	
▶	*Application of active control to sound insulation	Aural
4. Sound propagation (calculation theory)		
▶	Propagation of a plane wave	
▶	Sound propagation outdoors	
▶	Energy-base calculation of sound propagation	
	Point source (inverse square law)	Aural
	line source, plane source	
▶	Sound diffraction (sound reduction by barriers)	Visual (Fig. 3)
▶	Sound propagation in a room	
▶	Sound transmission between adjoining rooms	
▶	Sound transmission between outside and inside	
▶	Sound reduction in air ducts	

Chapters and contents		Demonstration
5. Room acoustics		
▶	Characteristics of room sound field	Aural
▶	Comprehension of based on wave acoustics	
	Standing wave, normal mode in an enclosure	
▶	Hypothesis of diffuse sound field	
▶	Reverberation and echo	Aural
	Reverberation time (definition, calculation and measurement)	
	Optimum reverberation time	
▶	Evaluation of room acoustics	
	Physical indices for the evaluation of subjective impression	
▶	Room acoustic design	
	General (introduction of concert halls and theatres)	Visual
	Room shape and sound diffusion	Visual and Aural (Fig. 4, Fig. 5)
	Scale modeling	Visual and Aural (Fig. 6)
	Computer simulation	Visual and Aural (Fig. 7)
6. Vibration and structure-borne sound		
▶	Fundamentals of vibration	
	Mass-spring system, vibration isolation, damping	
▶	Propagation and radiation of structure-borne sound	
7. Measurement and assessment of environmental noise and vibration		
▶	Fundamentals of the assessment of noises	
	Loudness, Noisiness, Annoyance	
▶	Noise indices (L_{AE}, L_{Aeq}, $L_{\mathrm{A}N}$, etc.)	
▶	Assessment of environmental vibration	
8. Assessment of acoustic performances of buildings and building elements		
▶	Air-borne sound insulation	
▶	Floor impact sound insulation	
▶	Noises in rooms (HVAC noise, building equipments noise)	
9. Extra class (technical visit of acoustic laboratory)		Various kinds of demonstration (Fig. 8)

Table 1: Contents of the lecture on architectural (environmental) acoustics in undergraduate course.

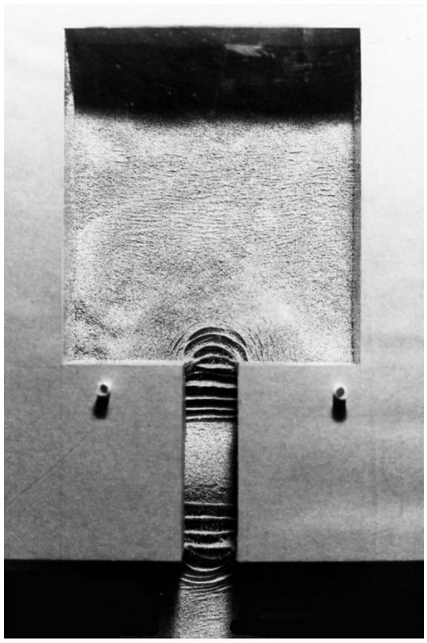


(a): 0−2 mode. **(b):** 1−1 mode.

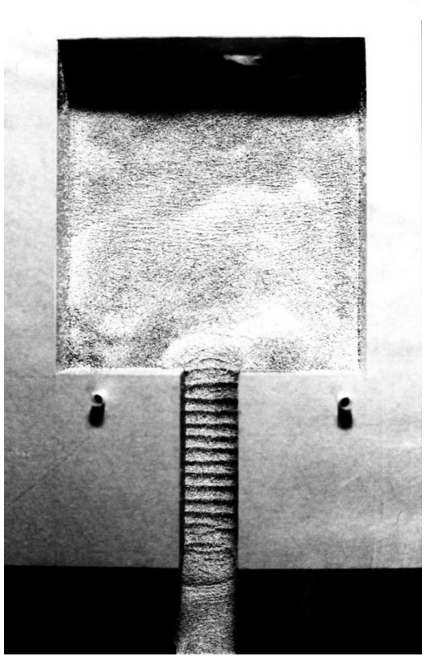
Figure 1: Kundt's experiment for the visualization of resonance in a 2-D enclosure.

3 - EXAMPLES OF VISUAL DEMONSTRATION

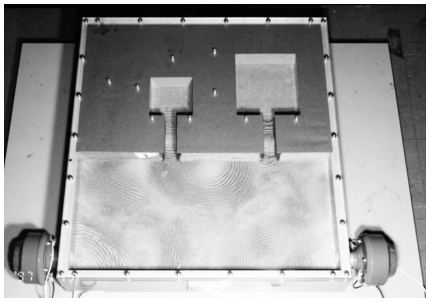
In the oral presentation by the author in this congress, some examples of visual and aural demonstrations will be introduced. Here, some examples of physical and visual demonstrations are shown in photographs and figures in the following pages.



(a): Open-pipe resonance.



(b): Helmholtz resonance.



(c): Apparatus for the visualization.

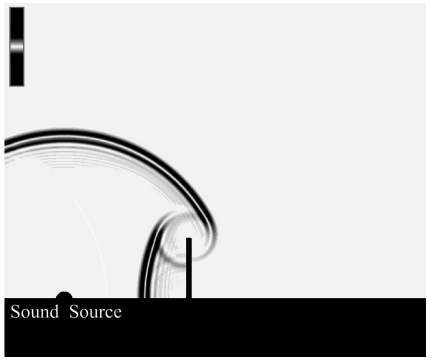
Figure 2: Kundt's experiment for the visualization of Helmholtz resonator.

4 - CONCLUSIONS

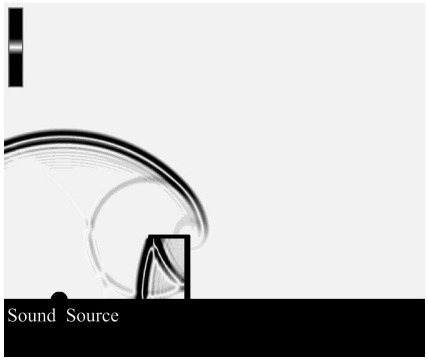
In the class of architectural acoustics dealing with various acoustic problems in general living environments, visual and aural demonstrations are very important and effective to achieve students' comprehension on acoustics. Generally speaking, architects are very sensitive to visual objects but sometimes they are careless about non-visual phenomena like sound. To make them sympathetic to acoustic aspects, demonstrations are very important.

These days, computer technology has much advanced and it can be very strong tool for the class as well as research. On the other hand, it is also very important to make students get sense of intuitive comprehension about physical phenomena. For this purpose, demonstration by physical experiment is still essential.

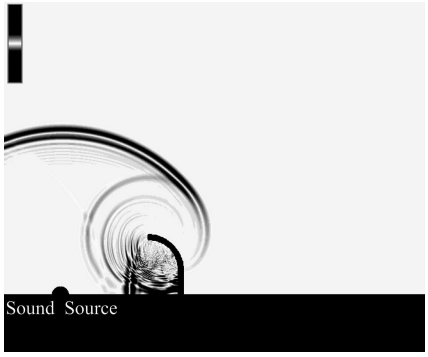
In this presentation, only some limited examples of demonstrations on architectural acoustics are introduced. To develop such kinds of educational tools, it is important to make effort to develop new materials and to exchange ideas and information. Lastly, the author would like to introduce the CD-ROM "Auditory Demonstrations" issued by the Acoustical Society of America, which includes a lot of materials for aural demonstration and are very effective for the class. In the Acoustical Society of Japan, the Technical Committee on Acoustic Education has been organized and started surveys and researches of the contents and methodology on acoustic education in each level of education.



(a): Straight barrier.

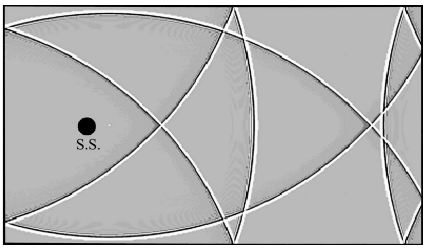


(b): Inverse-L type barrier.

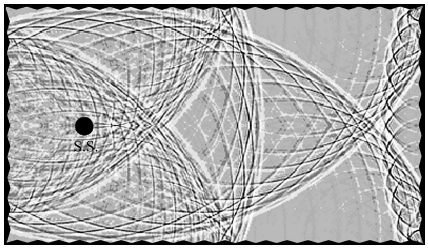


(c): Curved barrier.

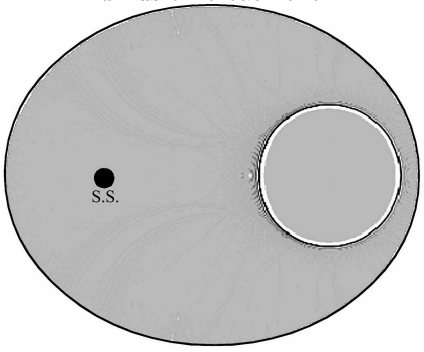
Figure 3: Computer animation of sound diffraction over three types of barriers.



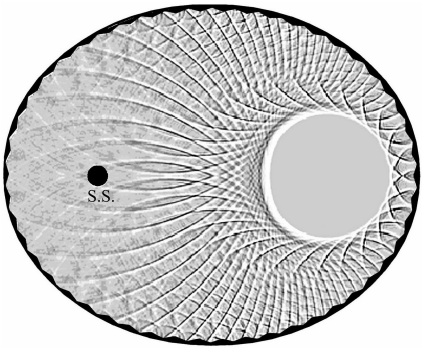
(a): Rectangular shape without diffusion treatment.



(b): Rectangular shape with diffusion treatment.

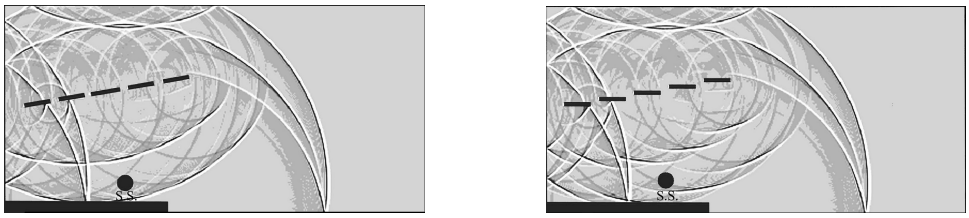


(c): Ellipse shape without diffusion treatment.



(d): Ellipse shape with diffusion treatment.

Figure 4: The effect of diffusion treatment on the sound field in rooms.



(a): In straight arrangement. **(b):** In terraced arrangement.

Figure 5: Sound reflection by the hauged discrete reflectors on the stage.

Figure 6: 1/10 scale model experiment for acoustic design of concert hall.

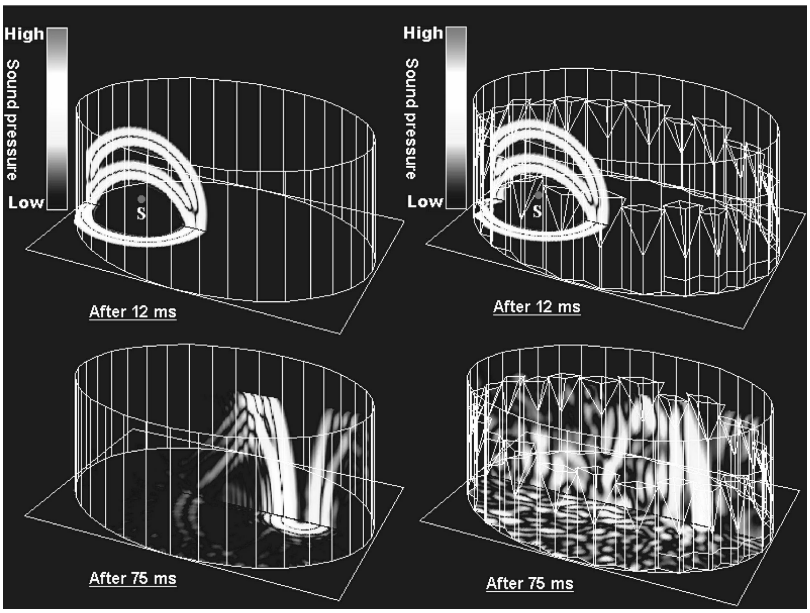
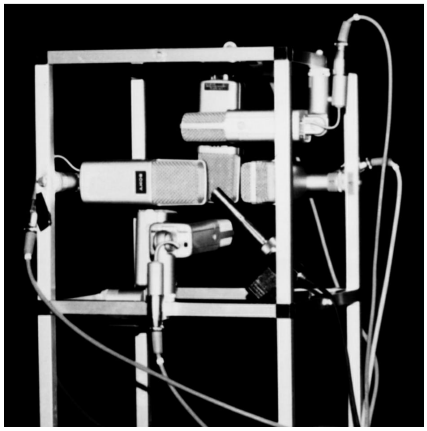
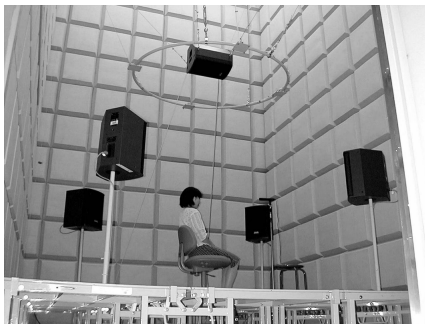


Figure 7: Computer simulation on sound diffusion in a hall.



(a): 6-channel mic. system.



(b): Reproduction system in an anechoic room.

Figure 8: 6-channel recording and reproduction system for auralization experiments.