AURAL/VISUAL MATERIALS FOR THE LECTURE ON ARCHITECTURAL ACOUSTICS

PACS: 43.10.Sv, 43.55.Ka

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ABSTRACT

In the lecture on architectural acoustics in universities, aural (audio) presentation is very effective as well as visual presentation. In this paper, some examples of aural/visual materials regarding basic physiological/psychological acoustics, the effect of reverberation, sound insulation, concert-hall acoustics, acoustic simulation and acoustic measurements are introduced with actual demonstration.

INTRODUCTION

In the universities in Japan, architectural department usually belongs to 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. Recently, not only such physical problems but also physiological and psychological aspects of living environments in buildings and urban areas have become important subjects. Among the environmental engineering, architectural/environmental acoustics is one of the essential curricula.
For the class of this subject, it is necessary to make efforts and contrivances to make the students feel familiar to acoustics and recognize its importance in architectural design and engineering. In this presentation, some examples of materials for aural and visual demonstrations for the class of architectural acoustics mainly in undergraduate course are introduced.

CONTENTS OF THE LECTURE ON ARCHITECTURAL ACOUSTICS AND AURAL/VISUAL DEMONSTRATIONS

As an example of the lecture on architectural acoustics in undergraduate course, Table 1 shows the contents of the lecture by the author. These contents are planned to be lectured in half a year (about ten times of 1.5 hour class). As a matter of course, a textbook is prepared for the lecture and theoretical explanation is made by using the blackboard. In addition to these ordinary ways of lecture, aural and visual presentations are often performed as the supplements. The basic acoustical phenomena should be demonstrated by physical experiment or computer simulation. For example, Helmholtz resonance and normal modes in an enclosure can be easily demonstrated by Kundt's experimental technique. Such basic acoustical phenomena as sound diffraction, interference, standing wave can be demonstrated by computer animation technique.

In the lecture on acoustics, aural presentation is essential and effective. For example, the reason why the decibel scale is used in acoustics, level difference, masking effect, the difference of reverberation time, sound insulation characteristics of various kinds of walls should be explained with aural demonstration. In the following table, these aural/visual materials prepared by the author are indicated.
In addition to the lecture in the class, technical visit to acoustical laboratory is usually performed to demonstrate various kinds of experiments/measurements and sound field simulation which can not be performed in the class.

Table 1 Contents of the lecture on architectural (environmental) acoustics in undergraduate course
(**V**: visual presentation, **A**: aural presentation, **P**: physical demonstration)

0. Introduction : Outline of environmental engineering and architectural acoustics

1. Fundamentals of sound

- Sound wave [**V**]
  Sound pressure, particle velocity, sound speed, wave length, period, frequency, etc.
- Audible frequency range
- Fundamental characteristics of sound wave [**V**]
  Geometrical attenuation, reflection, diffraction, refraction, interference, etc.
- Basic quantities related to sound energy
  Sound power, sound intensity, sound energy density
- Level (dB) expression [**V**, **A**]
  Sound power level, sound pressure level, sound intensity level, sound energy density level

2. Fundamentals of auditory sensation

- Mechanism of hearing
- Equal loudness contour, A-weighted sound pressure level, loudness level, etc. [**V**, **A**]
- Haas effect
- Masking effect [**A**]

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 [**P**/**V**]
- Sound insulation
  Sound transmission coefficient, sound transmission loss
  Mass law, coincidence effect
  Sound insulation characteristics of single wall and double leaf wall [**V**, **A**]
  Measurement of sound transmission loss
  Sound insulation construction and materials
  *Application of active control to sound insulation

4. Sound propagation (calculation theory)

- Propagation of a plane wave
- Sound propagation outdoors
- Energy-base calculation of sound propagation
  Point source (inverse square law), line source, plane source
- Sound diffraction (sound reduction by barriers) [**V**]
- Sound propagation in a room [**V**, **A**]
- Sound transmission between adjoining rooms
- Sound transmission between outside and inside
- Sound reduction in air ducts

5. Room acoustics

- Characteristics of room sound field [**A**]
- Comprehension based on wave acoustics
  Standing wave, normal mode in an enclosure [**P**/**V**]

- Hypothesis of diffuse sound field
- Reverberation and echo
  Reverberation time (definition, calculation and measurement)
  Optimum reverberation time [**A**]
- Evaluation of room acoustics
  Physical indices for the evaluation of subjective impression
- Room acoustic design [**V**, **A**]
  General (introduction of concert halls and theatres)
  Room shape and sound diffusion
- Acoustic simulation techniques [**V**, **A**]
  Scale modeling
  Computer simulation

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, etc.)

9. Extra class (technical visit to acoustic laboratory)

- Anechoic room, reverberation room
- Demonstration of acoustic experiments/measurements, sound field simulation, psycho-acoustics, etc.

EXAMPLES OF VISUAL DEMONSTRATION

In the oral presentation by the author in this congress, some examples of aural and visual demonstrations will be introduced. As the examples of the demonstrations, sound propagation in rooms of different shapes, the effect of sound diffusion treatment are shown in snap-shot in the following pages.

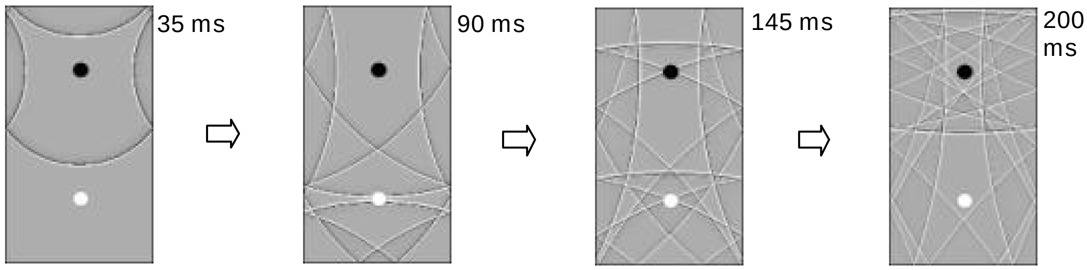
CONCLUSIONS

In the class on architectural acoustics dealing with various acoustic problems in general living environments, aural and visual demonstrations are very important and effective to achieve students' comprehension and familiarity to acoustics.

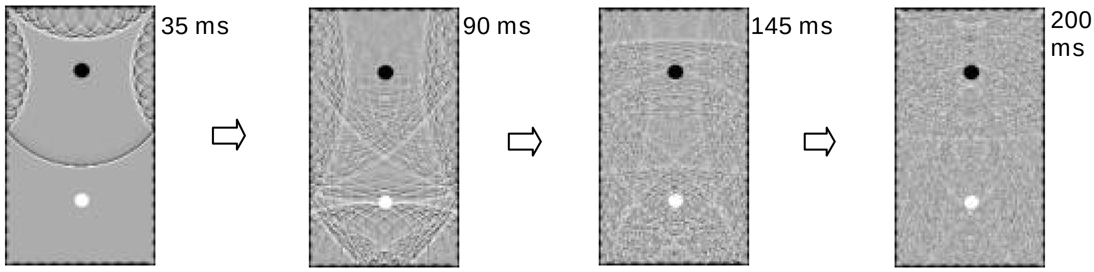
Architects are very sensitive to visual objects but, generally speaking, they are sometimes careless about non-visual phenomena like sound. To make them be conscious of the importance of acoustics, acousticians have to make effort to contrive effective visual and aural demonstrations.

These days, computer technology has much advanced and it can be a very strong tool for the class. 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.

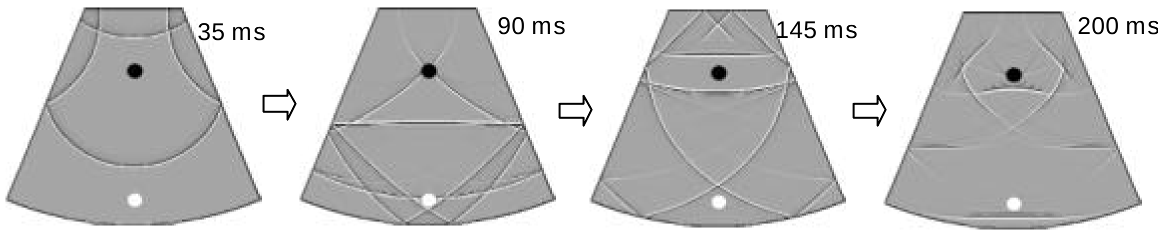
To develop such kinds of educational tools, it is important to make effort to develop new materials and to exchange ideas and information. An excellent and leading material for acoustic demonstration is the CD-ROM "Auditory Demonstrations" issued by the Acoustical Society of America, which includes a lot of materials for aural demonstration and are very effective for the class.



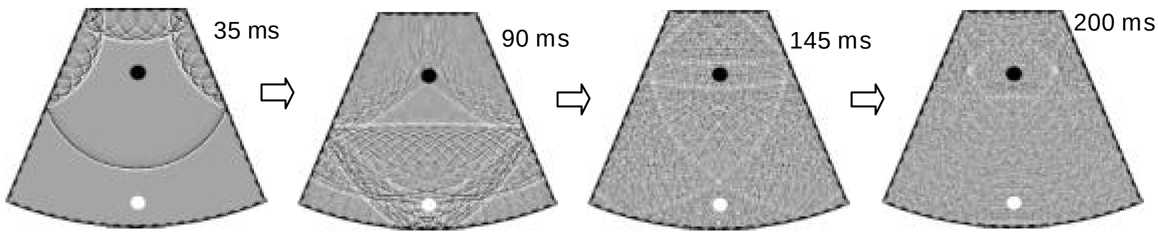
(a) Rectangular room (without diffusion treatment)



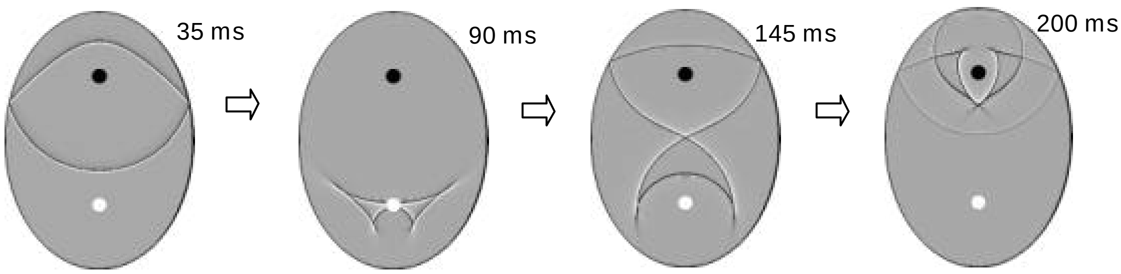
(b) Rectangular room (with zigzag diffusion treatment)



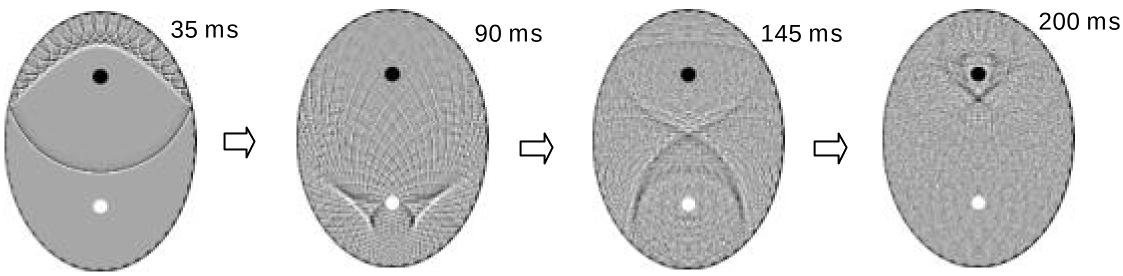
(c) Fan-shaped room (without diffusion treatment)



(d) Fan-shaped room (with zigzag diffusion treatment)



(e) Elliptic room (without diffusion treatment)



(f) Elliptic room (with zigzag diffusion treatment)

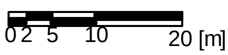


Fig.1 Sound propagation in a rectangular, fan-shaped and elliptic rooms with/without diffusing treatment.

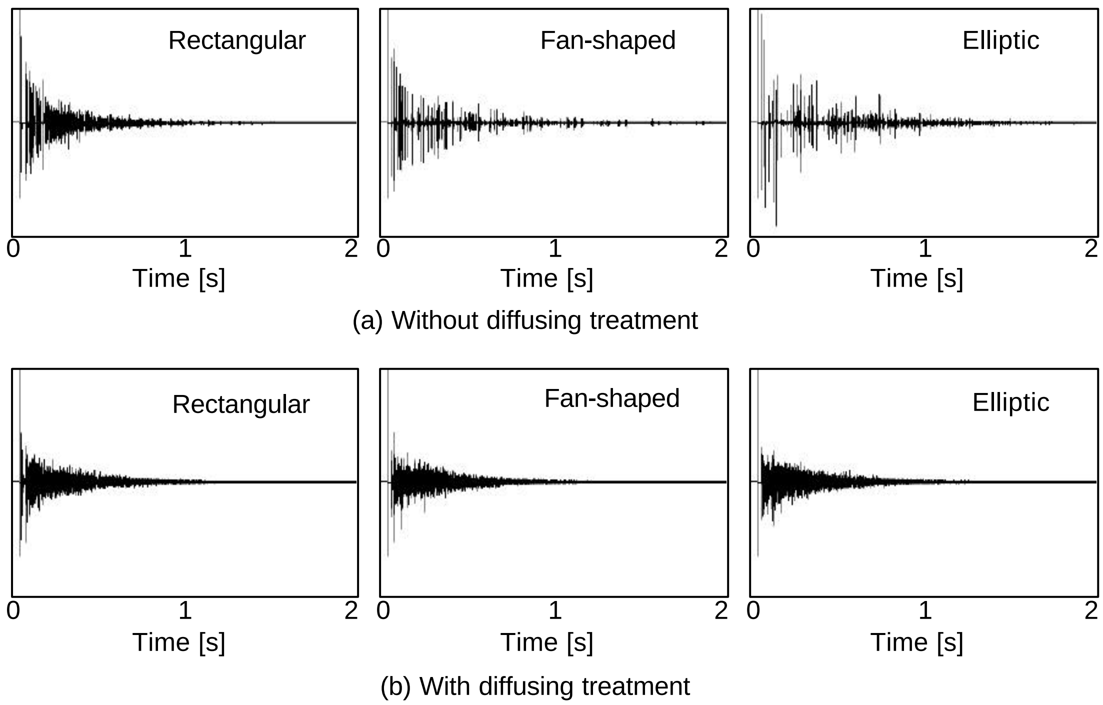


Fig.2 Impulse responses at the receiving points shown in Fig.1.
(They can be compared by aural presentation.)

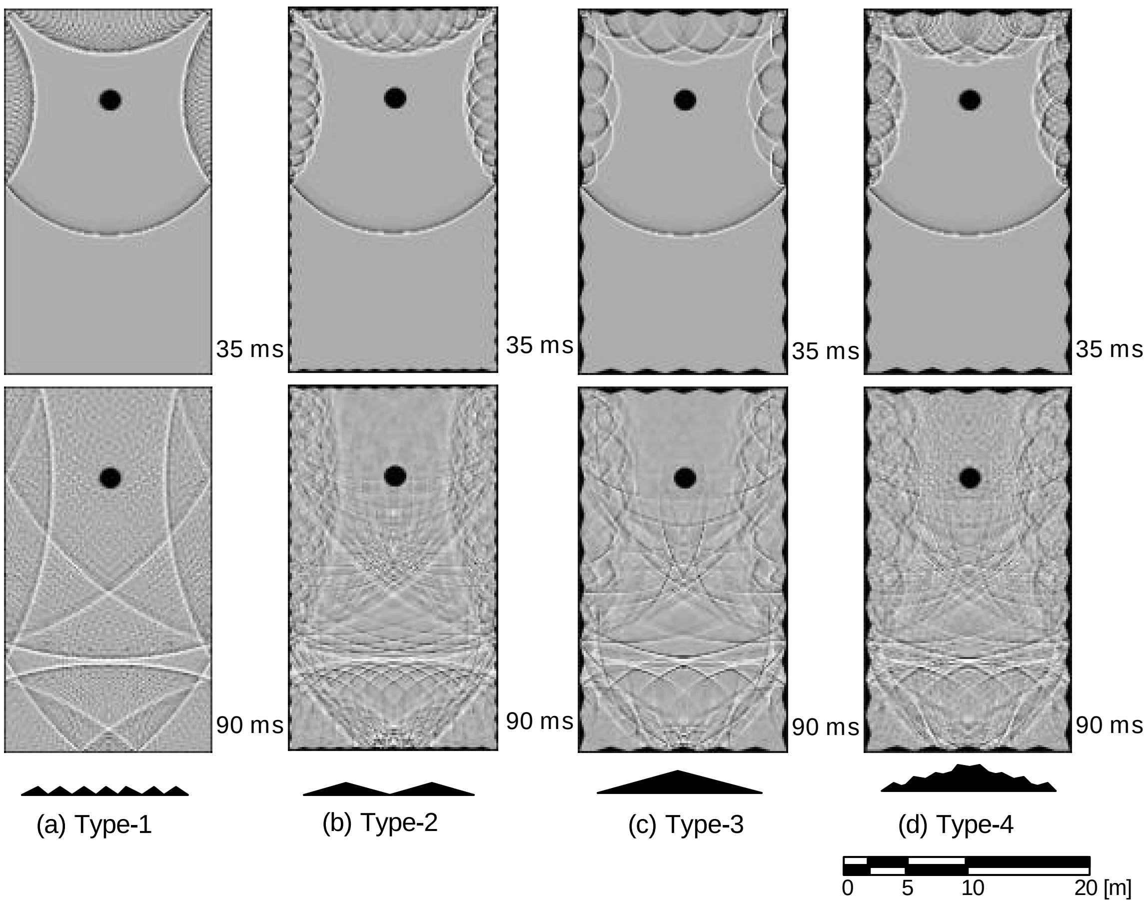
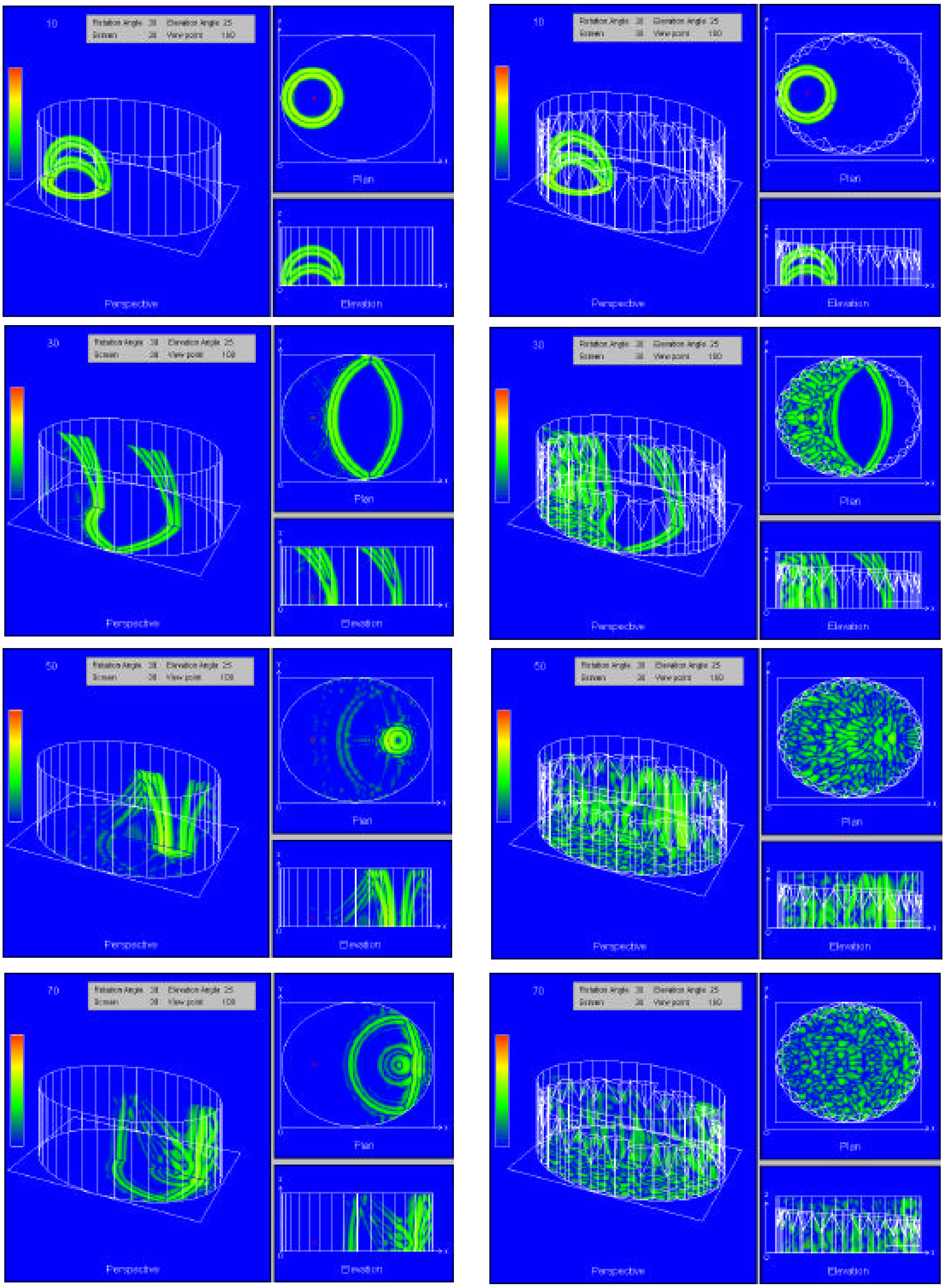


Fig.3 Comparison of sound propagation in the rectangular room with four types of diffusing treatments



(a) without diffusing treatment (b) with diffusing treatment

Fig.4 Comparison of sound propagation in a 3-dimensional elliptic hall with and without diffusing treatment.