The Development & Analysis of a Large Variable Acoustics Space

Abstract #: 2pAAa8

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Columbia College Media Production Center

- Built in 2010 as Columbia’s first new construction project
- Designed to be an interdisciplinary facility to be used by many departments: film, theater, audio engineering, & acoustics.
Motion Capture Studio
Variable Acoustics Space

- Originally designed solely for motion capture use (film, game design, etc.)
- The large space was underutilized, allowing for the integration of acoustics.

- 50’ x 40’ – 19.5’ Ceiling
- Concrete floor, sprayed K-13 ceiling (~2” thick)
- Tectum wall absorption
Diffuser/Absorber Box Construction

Goal:
- Cover 3 walls of the MOCAP space from 0’ - 10’ high
- Create lightweight, cost-effective reversible panels – 2’ x 2’ x 1’
- One side diffusive, one absorptive
- Incorporate other variable elements (reflector panels, curtains, mats)

Materials:
- Corrugated plastic ‘exoskeleton’
- Three layers of Roxul Insulation: RHT-80, 60, & 40 (black felt top)
- 1” center support board
- Thermo-molded diffuser panels: Effective freq. range: 200 – 600Hz
Diffuser Installation

- Three depth design
- Lightweight plastic – tradeoff in balancing production costs
- Created acoustic issues: potential resonance and unwanted additional absorption
- Needed to stiffen the system without adding too much weight

Solution:
- Fill internal cavity with expanding foam (like Great Stuff)
- Foam applied with a long hose, directed to locations
- Jig created to standardize the construction, allowing the joining of the center board and diffuser
• Diffuser/Board combos inserted into final construction jigs for assembly
• Foam shot into diffuser sides to complete the fill process and adhere internal components to external shell
• Roxul attached to center board with panel spikes – edges sealed with spray adhesive
Mass Box Production

- Construction conducted in stages over an entire semester
- Diffuser/boards assembled first, combined with Roxul & external shells, and finished/cleaned
- To aid in production, Columbia College ASA chapter was involved in multiple ‘build parties’

Total Boxes Constructed: 301
Support Frame Construction

- Frame assembled by Columbia’s engineering staff while boxes were being constructed
- Made from anodized aluminum and bolted to walls
- Designed to snugly fit created boxes and allow for easy removal
- Built in front of installed Tectum
Variable Acoustics Space Completion

Absorptive Room Condition
Variable Acoustics Space Completion

Diffusive Room Condition
MOCAP Material Testing

Roxul Material Absorption Coefficients

Constructed Box Absorption Coefficients
Multiple room conditions were measured to determine baseline metrics:
1. Reverberation Time
2. Frequency Response
3. Time Response

- 12 Microphone positions
- 2 Source conditions:
  1. Point Source – Center (Dodecahedron)
  2. Speakers arranged in quadrature (QSC K10s)
MOCAP Testing Conditions

**Diffusive:**
1. Fully Diffusive
2. Curtains Spread
3. Curtains Bunched
4. No Mat

**Absorptive:**
5. Fully Absorptive
6. Curtains Spread
7. Curtains Bunched
8. No Mat
MOCAP Full Room Analysis Data

Reverberation Time:
- Data gathered for RT using T10, T20, T30, & manual decay extrapolations
- Displayed values are from 12 microphone positions – min, max, & average
- T20 values shown – most reliable data
- Differences between diffusive/absorptive:
  125 Hz: .21s   1 kHz: .12s
  250 Hz: .16s   2 kHz: .13s
  500 Hz: .12s   4 kHz: .13s
MOCAP Full Room Analysis Data

Frequency Response Data:

- Microphone positions 1 – 6 shown (Center area microphones)
- Exterior microphones (7 – 12) excluded due to absorption or speaker directivity
- Average level 2 – 3 dB higher in diffusive condition
- Min – Max difference 2 – 5 dB larger in diffusive condition
- Pink Noise Stimuli
MOCAP Full Room Analysis Data

**Time Response:**
- Data for microphone position 11 shown
- Direct & 1\textsuperscript{st} order reflection (floor) very close in time & magnitude
- Diffusive wall reflection (~ 20 ms) much stronger (6 – 8 dB)
- Diffusive steady state room level also stronger through recorded response time
The diffusive properties of each box side were tested and compared.

Time response data collected (as well as frequency & RT data) for each condition – diffusive/absorptive.

2 microphone positions utilized – orientated on same image plane.

One parallel with speaker setup – one outside speaker dispersion.
Side Wall Testing Results

Diffusive Time Response:
- 1st order reflection much stronger & subsequent decay significantly dispersed (much smoother decay)

Absorptive Time Response:
- Lower reflection level & much quicker decay

Mic: 7 ft. from wall
MOCAP Room Recording Setup

- Audio recordings were gathered within the space to listen to the quality of 3 room conditions (fully diffusive, fully absorptive, & diffusive with no mat)
- 3 anechoic recordings generated through displayed speakers
- Acoustic guitar at 8 ft. & 20 ft.
Variable Acoustics Space Recording Demonstration

- Recordings made with 3 microphone setups:
  1. Earthworks M50 Testing Mics (in stereo)
  2. Shure SM-57 Dynamic Mics (in ORTF stereo)
  3. Apex 210 Figure 8 Ribbon Mics (Blumlein pair)

- Tracks recorded for each microphone in each room condition using 5 different stimuli – 45 individual recordings collected

- Tracks below used Aphex mics and blumlein recording technique

<table>
<thead>
<tr>
<th>Bath Tocatta en Fugue in D minor</th>
<th>Female Singing</th>
<th>Acoustic Guitar (8 ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully Absorptive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fully Diffusive with no mat</td>
<td></td>
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</table>
MOCAP Testing Conclusions

• Diffusive & Absorptive wall conditions show a difference in reverberation times & time response plots
• Diffusive condition was shown to effectively scatter sound vs absorptive
• Objective metrics do not fully account for perceptual effects experienced in the MOCAP
• Initial floor reflection heavily influential to sound quality

Future Testing:

• Investigate reflector panel influence on both objective & subjective metrics (in various room/panel orientations)
• Quantify scattering coefficients of the diffusers
• Coordinate efforts with CCC Audio Arts department to establish & optimize open air recording techniques in the MOCAP
• Conduct subjective perceptual tests to quantify the discernibility between room conditions
• Many, many more possibilities…
Thank You!
Any Questions?

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