Acoustical Performance of Small Height Earthen Berms

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Project Background

- **Small Height Earthen Berms**
  - Follow up to BPS 2017 earthen berm study
  - Generally six feet or less in height
  - Most are three to five feet in height

- ODOT has performed ~ 100 noise measurements on berms of various heights and lengths
  - Developed small height earthen berm database

- **Initial observations**
  - Many berms are providing a higher level of noise reduction than expected.

- **Goals of this study**
  - Research existing berm literature
  - Collect additional field measurements
  - Analyze ODOT’s database data
  - Evaluate berm performance
  - Identify performance trends
  - Examine use of small height earthen berms for highway noise abatement in addition to conventional noise walls?
ODOT’s Small Height Earthen Berm Database

- ODOT’s database inventory is statewide
  - Developed over past two years
  - Includes field measurement data and physical berm characteristics

- ODOT field measurement overview
  - Two measurements at each berm location (top of berm and directly behind at the toe of berm)
  - Contiguous 10-minute field measurements
  - Traffic counts during measurements
  - Posted speed
  - Time of day and meteorological data
  - Physical data (height, length, relative elevation of roadway and receptor in relation to the berm)
  - For this study, field measurements were taken at five berm locations previously measured by ODOT to compare results
Collection of Additional Small Height Earthen Berm Data

- Latitude/longitude data collected in the database.
- Additional physical berm data was obtained to characterize each berm and to compare individual berms with other similar berms, including:
  - Roadway elevation at the edge of pavement (EOP).
  - Distance from EOP and ground elevation at toe of berm.
  - Distance from EOP and ground elevation at top of berm.
  - Distance from EOP and ground elevation behind berm.
  - Percentage of slope at the front of each berm.
  - Berm surface characteristics.
Additional Field Measurements

- In May 2018, additional field measurements were taken at five earthen berm locations previously measured by ODOT in 2016 and 2017.

- The purpose of the measurements was to compare measured sound levels, as well as TNM-predicted sound levels (FHWA Traffic Noise Model 2.5), for consistency:

  - All five berms (whether using 2016/2017 field data, TNM model, or 2018 field data), show sound level reductions above the “5 dBA substantial reduction threshold”. “10 decibel reduction is cutting the noise in half.” “A 5 decibel reduction is considered a benefited receptor.” “For a noise barrier to meet criteria, at least 1 receptor must receive a minimum 7 decibel reduction.”
Data Analysis

How an Earthen Berm Reduces Sound Transmission

- Noise and noise impact may be described in terms of “source, path, and receiver”.
- ODOT abates traffic noise by disrupting the noise path by constructing noise barriers.

Traffic noise has three pathways - transmitted, absorbed, and reflected.

Almost all of the transmitted path is absorbed by the mass of the berm.

The diffracted path is the path that reaches the receiver and is the pathway of concern for noise abatement.
Analysis of Small Height Earthen Berms by Functional Classification

- Each berm in ODOT’s database was categorized based on the functional classification of the adjacent roadway.
- Roadways within each functional classification typically have similar characteristics (traffic, speed, right-of-way, etc).
  - **Minor Arterial Roadway (7 berm locations)** – Lower traffic volume, speed and % trucks; short distance separating noise source and receiver.
  - **Principal Arterial Roadway (20 berm locations)** – Similar setting to Minor Arterial with higher traffic volume and higher % trucks.
  - **State Route (15 berm locations)** – Higher traffic volume, speed and % trucks than arterial roadways; generally a two lane setting with more distance separating noise source and receiver.
  - **United States Route (6 berm locations)** – Similar traffic volume and setting as State Routes though usually a higher % truck traffic and some being a divided, four-lane facility.
  - **Interstate Route (37 berm locations)** – High traffic volume and speed; highest % trucks; greater distance separating noise source and receiver; highest potential difference in elevation between noise source and receiver.
Variables Effecting Small Height Berm Performance

- There are many variables or site conditions that effect the earthen berm’s potential of providing a particular level of noise attenuation.
  - Traffic volume and vehicle mix
  - Distance of berm setback from roadway: Do berms perform better closer to roadway, closer to receptor, or somewhere between?
  - Top of berm shape: Round top, wedge-shape top, and flat top.
  - Different ground cover: Mowed grass, scrub shrub, and wooded.
  - Atmospheric conditions: Wind speed and temperature.
  - Elevation difference among roadway, berm, and receiver: Considers site-specific geometry and elevations at each berm location.
Small Height Earthen Berm Trends

Minor Arterial Roadways

- Average distance from edge of pavement to toe of berm = 19.2 feet
- Average distance from edge of pavement to top of berm = 43.6 feet
- Average distance from edge of pavement to back of berm = 75.8 feet
- Average berm height = 4.2 feet
- Average ODOT measured noise reduction = 8.1 dBA
Small Height Earthen Berm Trends

Principal Arterial Roadways

- Average distance from edge of pavement to toe of berm = 21.7 feet
- Average distance from edge of pavement to top of berm = 46.3 feet
- Average distance from edge of pavement to back of berm = 83.3 feet
- Average berm height = 4.1 feet
- Average ODOT measured noise reduction = 8.0 dBA
Small Height Earthen Berm Trends

State Routes

- Average distance from edge of pavement to toe of berm = 57.4 feet
- Average distance from edge of pavement to top of berm = 87.2 feet
- Average distance from edge of pavement to back of berm = 112.2 feet
- Average berm height = 6.8 feet
- Average ODOT measured noise reduction = 8.9 dBA
Small Height Earthen Berm Trends

**United States Routes**

- Average distance from edge of pavement to toe of berm = 18.8 feet
- Average distance from edge of pavement to top of berm = 45.0 feet
- Average distance from edge of pavement to back of berm = 111.4 feet
- Average berm height = 6.6 feet
- Average ODOT measured noise reduction = 8.7 dBA
Small Height Earthen Berm Trends

Interstate Routes

- Average distance from edge of pavement to toe of berm = 45.7 feet
- Average distance from edge of pavement to top of berm = 78.5 feet
- Average distance from edge of pavement to back of berm = 110.0 feet
- Average berm height = 6.8 feet
- Average ODOT measured noise reduction = 9.8 dBA
Small Height Earthen Berm Trends

Summary of Key Findings:

- Berms with a flat top generally outperform berms with a round top.
- Berms providing the highest sound level reduction, when located closest to the road.
- Berms appear to provide a higher sound level reduction when the roadway and the receiver are at different elevations.
- Receivers situated at a substantially higher elevation than the roadway receive the highest sound level reduction.
- A wooded berm surface provides better sound level reduction than brush/scrub-shrub or grass surfaces.
Small Height Earthen Berm Trends

Summary of Key Findings, continued:

- Berms tend to provide a higher sound level reduction in low percent truck condition (may be due to being situated close to the ground, more effectively reduce automobile tire noise than low frequency truck noise, which can pass over the berm).

- The average reduction from 3’ to 3.5’ tall berms was 5.4 dBA based on 9 berms tested. The average vehicles per hour (VPH) was 1,232.

- The average reduction from 4’ to 5’ tall berms was 9.2 dBA based on 21 berms tested. The average VPH was 3,185 with a range of 300 to 6,600.

- The average reduction from 5’ to 6’ tall berms was 10.7 dBA based on 13 berms tested. The average VPH was 3,300 with a range of 1,200 to 8,900.

- Where the top of a 3’ to 4’ berm matched the elevation of the roadway, the average sound level reduction was 5 dBA based on 3 berms tested.

- Where the top of the small height berm was significantly elevated above the roadway (i.e. >10’), the average reduction was 9.9 dBA based on 14 berms tested. The average height of the berm was 4.2’. The average distance from behind the berm to the edge of pavement was 140’.
Small Height Earthen Berm Trends

Conclusions/Recommendations:

- Small height earthen berms can be a noise abatement measure that can provide substantial noise reduction when utilized under certain conditions. Smaller footprint than presumptive i.e. 10’ berm.

For Arterial Roadways:

- Low height (3’) berms can provide good sound level reduction when located in proximity (≤25’) to the roadway or when the elevation between the roadway and receiver is greater than 3’.
- 5’ high berms can provide a substantial reduction when the berm is located midway between the roadway and receptor and when the roadway and receptor are at the same elevation.

For Interstate Highways:

- Berms 3’ or less in height provide low levels of attenuation and do not perform as well under interstate conditions as they do under arterial roadway conditions.
- 4’ high berms can provide a substantial sound level reduction when they are located close to the source and/or have a difference in elevation of 4’ to 5’ between the roadway and the receiver. Similar to arterial roadway conditions, the taller the berm (≥5’) the higher the level of attenuation.
Acoustical Performance of Small Height Earthen Berms

Possible Steps to Implement

- Perform **Pilot Projects** to test site-specific conditions and berm characteristics. Conduct pilot projects at construction sites with excess soil, where berms can be constructed in close proximity to the roadway or receptors (i.e. address noise complaint areas; reduce noise levels below the FHWA Noise Abatement Criteria, minimize hauling costs), and where noise abatement is needed (adjacent receptors/high sound levels), but noise barriers are determined to not meet criteria.

- Two small height berms already designed!! (LUC-475, FRA/FAI-33)

Risks and Obstacles

- Limited opportunities? Opportunity recognized? Berms have a larger footprint than concrete barriers and right-of-way space is often limited. Potential inability to construct berms at locations/elevations needed to provide necessary attenuation.

- Potential utility or highway lighting conflicts and ecological impacts.

- Potential uncertainties during design if earthen berm construction is feasible.

- Change in ODOT noise culture

- Not visually blocking top half of vehicles (public perception/education issue)
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