



The Ohio Department of Transportation Office of Statewide Planning and Research Executive Summary Report

Green Noise Wall Construction and Evaluation

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Problem Statement

Over the years, considerable research has been performed towards effective and practical noise abatement measures. Some of these techniques include traffic management, use of quieter and noise absorbing pavement surfaces, improving land use and planning, and finally the installation of noise barriers. Generally, the most cost effective and efficient noise abatement option is the use of a noise barrier. As a result, numerous guidelines and specifications have been developed for noise barriers to ensure safety, cost effectiveness and substantial noise reduction. These guidelines include information about determining the need for a noise barrier, design and safety considerations, environmental considerations, potential impact, and implementation procedures.

While constructing an effective noise barrier is a priority in areas where traffic noise impacts are substantial, the needs of the residents in that area must be taken into consideration. In order to gather public opinion on whether a community desires and supports the construction of a noise barrier, the Ohio Department of Transportation (ODOT) holds public information meetings, and surveys the affected public to gauge their support for a noise barrier project and to receive feedback about preferences for the design. However, residents and concerned citizens are limited in the options they are presented with for noise barriers. Typical options for noise barrier structures involve the use of concrete or fiberglass. However, no option exists for a “green” noise barrier at this time.

A green noise barrier is a noise barrier that utilizes soil and vegetation to mitigate traffic noise. This type of barrier is expected to offer many benefits when compared to traditional noise barriers. Among these

benefits are: a construction process that is expected to have a lesser impact on the environment; a structure that provides aesthetic beauty to the surrounding area; a structure that can block and absorb a substantial amount of air pollutants from vehicles; and most importantly a structure that offers a competitive noise reduction due to its core that is made of soil and its vegetated surface that can absorb and reflect traffic noise.

In spite of the above-mentioned advantages of green noise barriers, several concerns have been raised regarding their long-term performance and ability to sustain vegetation under adverse weather conditions. Therefore, research is needed to determine whether a green noise barrier is a viable noise mitigation option for Ohio's climate.

Objectives

The primary objective of this study is to determine the feasibility of using a green noise barrier as a traffic noise mitigation option in Ohio. To achieve this objective, this study will be conducted in two phases. The first phase is focused on reviewing available green noise barriers in order to assess their advantages and disadvantages. Key factors to be considered include construction and vegetation costs, ease of construction, structural stability, noise reduction and plant sustainability. This phase also looks into viable plant species through a comprehensive plant study. In addition, it includes constructing a prototype wall in order to evaluate its structural stability and ability to retain moisture. The results of this phase will be analyzed so that recommendations can be made on the construction of a full scale barrier in the second phase. The full scale barrier will be 400 ft in length. A tentative location for this barrier has been selected along the westbound direction of interstate I-70 in Licking County. The first phase will determine the suitability of constructing the full scale barrier in that location.

Based on the previous discussion, the specific objectives of the first phase of this study are:

- Prepare a synthesis of literature review on subjects pertinent to noise barriers.
- Review available green noise barrier products.
- Summarize the experience of state highway agencies with green noise barriers.
- Construct a prototype green noise barrier and monitor its structural stability and ability to retain moisture.
- Compare the noise reduction and cost/benefit ratio of green noise barriers to conventional noise barriers.
- Make recommendations on the construction of the full scale green noise barrier along interstate I-70 in Licking County.

Project Description

This study included a thorough review of available green noise barrier products based on information obtained from the producers and their websites. In addition, it included a questionnaire that was sent out to more than three hundred national and international experts in traffic noise analysis and abatement to document their experience with this type of barriers. Based on the outcome of the literature review and responses to the questionnaire, the Deltalok product was determined to be the most likely product to succeed in Ohio. The Deltalok product is a reinforced earth structure that utilizes geogrid as reinforcement and ecology bags that can sustain vegetation as facing units (Fig. 1). Standard unit connectors are placed between the bag layers to hold the bags in proper position. The space between the bags in each layer is filled with granular material and compacted to form the core of the structure.

A prototype Deltalok wall, measuring 15 ft in length, 9 ft in width and 12 ft in height, was constructed in Covington, Ohio (north of Dayton) to evaluate its structural stability and

ability to retain moisture (Fig. 2). The prototype wall was equipped with various sensors and devices to monitor its earth pressure and deformation characteristics and examine the moisture and temperature distributions within the barrier. The prototype wall was monitored for a period of two months. The data collected from these sensors and the visual inspections allowed for making several recommendations regarding the construction of the Deltalok system and its use as a green noise barrier.

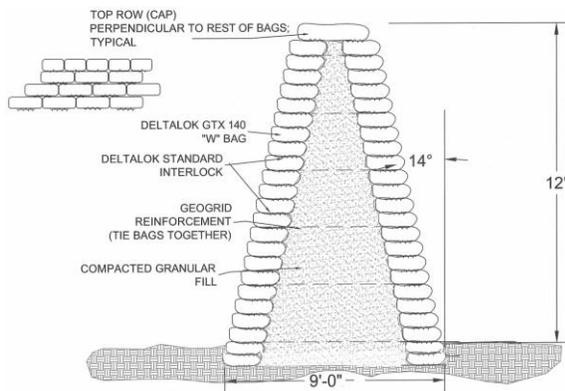


Fig. 1: Deltalok Green Noise Wall.



Fig. 2: Prototype Deltalok Wall.

A laboratory plant study was designed and executed to determine the factors that affect plant survivability on green noise barriers and make recommendations on the vegetation selection. Four different plant mixes were selected for

planting in different sections along the full scale wall to evaluate their adaptability. Mix 1 is a grass mix that ODOT would normally apply through hydroseeding to serve as a control treatment. Mix 2 includes grasses and native prairie forb species. Mixes 3 and 4 are a combination of herbaceous species plus some selected woody species. The woody species are the same for Mix 3 and Mix 4. The difference is that Mix 3 is underlaid with hydroseeded grasses from Mix 1 (seeded at 2/3 the normal seeding rate), while Mix 4 is underlaid with hydroseeded grasses and forbs from Mix 2 (seeded at 2/3 the normal seeding rate). The plant study also addressed the effect of hydroseeding compounds on grass germination and establishment, soil modification, and water needs and supply for the proposed green noise barrier. It was not possible in this phase to evaluate plant establishment and long-term survival in a natural highway environment since this requires constructing a full scale barrier and actually planting it, as planned in the second phase.

A traffic noise analysis study was conducted to investigate the anticipated noise reduction from the proposed full scale green noise barrier. The Federal Highway Administration (FHWA) Traffic Noise Model (TNM) Version 2.5 was used for this purpose. To verify that the TNM model worked accurately at the I-70 site, traffic noise predictions were compared to actual field measurements. With the model verified, the effectiveness of the Deltalok barrier was evaluated by examining the predicted insertion loss calculated by TNM 2.5. Since this program does not contain a Deltalok shaped noise barrier, both a concrete barrier and an earth berm were used in the analysis.

Finally, the cost of the proposed green noise barrier was compared to a traditional concrete barrier with the same length and height. The total cost of the proposed green noise barrier was estimated from the lower of two quotes provided by two local contracts. Meanwhile, the total cost

of the traditional concrete barrier was estimated using ODOT's Summary of Contracts Awarded in 2010 (issued by ODOT Office of Contracts) for Item 606 (Special – Noise Barrier (Absorptive), Over 10 ft to 14 ft Height).

Findings & Conclusions

The following is a summary of the key findings and conclusions based on the research performed under Phase I:

Structural stability:

- The instrumentation plan of the prototype Deltalok wall included an earth pressure cell placed at the center of the prototype wall to measure vertical pressure, four vibrating wire displacement transducers (or crackmeters) mounted on the geogrid at various heights within the wall to measure geogrid deformation, and a number of survey points located on the exterior of the wall to monitor wall deformation.
- The total vertical pressure measured using the earth pressure cell immediately after construction was equal to 5.9 psi, which is less than the estimated at-rest vertical pressure, $\sigma_v = \gamma h$, of 10 psi (assuming a soil unit weight of 120 lb/ft³ and a barrier height of 12 ft). This implied that the vertical load was not uniformly distributed at the base of the wall and the outer portion of the base was carrying a greater portion of the load than the middle. This was attributed to the effect of soil arching, which is not uncommon in soil embankments, and the transfer of the vertical load to the sides of the wall through the geogrid reinforcement. In order to better understand this phenomenon, it is recommended that more pressure cells be used in the second phase of this study.
- The data from the vibrating wire displacement transducers was used to calculate the strain and load in the geogrid.

The maximum geogrid strain occurred 33 inches (2.75 ft) above ground and was equal to 3.4%. This strain corresponded to 621.5 lb/ft load in the geogrid. This load was found to be significantly lower than the long-term and ultimate tensile strengths of the geogrid, which implied that the prototype wall was internally stable in the transverse direction. There is more concern about the internal stability of the prototype wall in the longitudinal direction due to the relatively low of the geogrid in that direction and the short length of the wall. A full scale barrier would have a plane strain response reducing the effects of the longitudinal forces in the geogrid near the middle of the wall. Therefore, additional reinforcement might be needed towards the end of the structure to increase its resistance to longitudinal deformation.

- The total vertical settlement in the prototype wall was found to be 4.98 inches (or about one layer of Deltalok bags) after two months. The prototype wall is expected to continue to settle. Therefore, it is recommended to construct the barrier using a minimum of two additional layers of Deltalok bags to compensate for the effect of settlement on the reduction in acoustic performance of the Deltalok wall. To accommodate the increase in barrier height, a layer of geogrid should be used every three rows of Deltalok bags rather than four to better resist the tensile forces within the structure.
- The previous results suggested that the proposed green noise barrier will be structurally stable in the short term. However, additional evaluations are needed to determine its long-term stability.

Temperature and moisture distributions:

- The prototype Deltalok wall was instrumented with eight temperature and eight moisture sensors to monitor the

temperature and moisture distributions within the barrier.

- Higher temperatures were noticed on the south side than on the north side. This was expected because the south side received direct sunlight, which raised the temperature of the soil within the Deltalok bags during the day. Additionally, the south side saw more fluctuation in temperature than the north side. The increases in temperature were lost quickly at night, causing the noticeable fluctuations.
- By comparing the temperature readings on the same side, it was noticed that the temperature at the top of the barrier was greater than the temperature on the lower parts of the barrier. This was true for sensors on both the north and south sides. This variation was caused by the bottom of the barrier being in contact with the ground, which reduced its temperature. Meanwhile, the top of the barrier was exposed to direct sunlight, which increased its temperature. Since this data was collected in the months of April and May, wind did not significantly impact the temperature distribution within the barrier. However, it is expected that the top of the barrier will have a lower temperature in the winter months because it is exposed to wind and does not have a large mass to retain heat. In contrast, the top of the barrier is expected to be warmer in the summer months because of the exposure to sun.
- The prototype wall was watered using a soaker hose until reaching the water holding capacity. The soaker hose was then turned off and the moisture content was monitored. A 30 to 40% reduction in moisture content was observed within one week after the removal of the soaker hose.
- The previous results indicated that the proposed full scale green noise barrier will be susceptible to wide variations in temperature and moisture on its north and south sides and along its height. These

variations should be taken into consideration in choosing the plant mixes for the Deltalok noise barrier.

- The previous results also indicated that the proposed green noise barrier may not be able to retain enough moisture to sustain vegetation. This loss in moisture was observed for all locations within the barrier.

Vegetation:

- The vegetation survivability on the proposed green noise barrier will be affected by several factors including moisture availability, exposure to sunlight, soil composition (pH and nutrients), salt sensitivity, and time of planting.
- Water availability will be critical for the success of vegetation. This will be particularly the case during the initial growing season. The Deltalok structure has a relatively small footprint that may not allow enough rain water to infiltrate into the barrier. Furthermore, it has steep faces that may not allow moisture to be retained within the structure. Therefore, it will not be possible to achieve proper establishment without irrigation and irrigation will be needed if dry periods occur or persist after establishment. The irrigation system must provide adequate moisture to all locations on the wall, be as automatic as possible, and be constructed of high quality materials that do not require time consuming maintenance.
- The research team consulted with Columbus Irrigation Company and TORO Micro-Irrigation, supplier to the Columbus Irrigation Company, regarding the irrigation of the Deltalok green noise barrier. It was determined that a drip irrigation system would be the most adequate in providing sufficient moisture to the barrier. The proposed irrigation system consists of 20 drip lines that will be installed at different heights within the barrier during construction to account for differing volumes of soil and

potential water movement from top to bottom by gravity. It was also determined that a water well is needed at the proposed barrier site to compensate for the lack of a nearby water source. This well will include a steel casing, submersible pump and pressure tank. Standard maintenance will be required, but in this situation the tank must be drained at the end of each season and the pump primed each spring. Maintenance will also be required to monitor and program the drip irrigation control system at the beginning of each growing season. For safety and security, the pressure tank should probably be enclosed in a small structure at the site.

- The soil pile that was identified near the green noise wall test site for use in the Deltalok bags was evaluated to ensure that it contained the necessary soil nutrients. Soil samples were taken from the soil pile and tested for pH, Lime Test Index, available phosphorus (P), exchangeable potassium (K), calcium (Ca), magnesium (Mg), and cation exchange capacity (CEC). The chemical test results revealed a soil pH well within the range of tolerance for the selected plant mixes and sufficient amounts of nutrients for the selected plant mixes. However, to account for plant uptake and maintain a desirable reservoir of nutrients, it is recommended to modify the soil/sand mix in the Deltalok bags by adding 2.7 lbs of 0-11-46 and 0.5 lbs of 46-0-0 fertilizers per 100 ft³ of top soil.
- Planting, whether accomplished by hydroseeding or live planting, must be scheduled at a time when optimum growth conditions for establishment prevail. The best time will be determined by time of wall construction, favorable environmental conditions (likely mid spring or early fall), and availability of plant propagules at the scheduled planting time.
- A laboratory study was conducted to evaluate the effect of hydroseeding slurry components on seed germination and

establishment of native grass and forb species that might be used on the green noise wall. This study revealed that standard slurry compounds are safe to use with the native prairie species. Therefore, no changes are needed to the standard hydroseeding procedure currently used by ODOT.

- Another experiment was conducted in the greenhouse to determine early establishment success of seeds inside the Deltalok bags. Mini bags were filled with a typical sand/soil mix and saturated with water. A mix containing water, colloidal tackifier and seeds was applied. Seeds of several species, representing a range of size, shape, and morphology, were used. Bags with soil and seed attached were watered by an automated irrigation system in the greenhouse. Germination success was evaluated on regular basis based on seed germination and root penetration of the bag. This experiment revealed that while grass seeds were able to penetrate the Deltalok bags, none of the forbs emerged through the bag due to blockage by the fabric. Therefore, it was concluded that the forb mixes should be hydroseeded on the outside of the bag to ensure successful emergence.

Traffic noise reduction:

- The proposed Deltalok noise barrier is expected to have noise reduction properties as good as or better than a traditional concrete barrier. Using the TNM model, the predicted noise reduction at a location 50 ft away from the center of the proposed full scale barrier was 8.9 dBA assuming a concrete barrier and 9.0 dBA assuming an earth berm. Both values are higher than ODOT's noise barrier design requirement of 8.0 dBA for front row receptors. Therefore, the Deltalok green noise barrier should provide sufficient noise reduction at the proposed barrier site.

Cost:

- The total estimated cost of constructing the proposed green noise barrier was \$321,000. This figure included the cost of the Deltalok bags delivered to the job site filled and stacked on pallets, mobilization and site preparation, barrier materials and construction, a drip irrigation system, a water well, initial vegetation, and vegetation maintenance (including plant replacement as needed) for two growing seasons.
- The estimated cost of the proposed green noise barrier (\$321,000) was higher than a traditional concrete barrier (\$148,560). This was not unexpected given the relatively short length of the proposed barrier and the fact that the Deltalok system has never been used as a green noise barrier in Ohio. If successful, the cost of Deltalok system is expected to decrease in the future as contractors become more familiar with this product. Nevertheless, it is expected to be higher than a traditional concrete barrier due to the added costs from vegetation.

Implementation Recommendations

This study revealed that although important questions have been answered regarding the use of the Deltalok system in Ohio, additional research is needed to clearly identify the advantages and limitations of this product as a noise mitigation option. Based on the research conducted under Phase I, it is believed that the Deltalok system will be structurally stable and capable of producing the desired noise reduction. However, it was not possible in this phase to evaluate plant establishment and long-term survival in a natural highway environment since this requires constructing a full scale barrier and actually planting it, as planned in Phase II. Proceeding with the Phase II will also enable the research team to evaluate the long-term performance of the Deltalok system and

accurately assess the maintenance needs of this type of noise barriers in Ohio.

Based on the results of Phase I, the following recommendations are made to ensure the success of vegetation on the proposed full scale barrier:

- Plant the proposed green noise barrier in the mid spring or early fall because of the favorable environmental conditions during these periods.
- Install a drip irrigation system covering the whole height of the barrier to compensate for varying water infiltration levels and potential water movement from top to bottom by gravity.
- Add 2.7 lbs of 0-11-46 and 0.5 lbs of 46-0-0 fertilizers per 100 ft³ of top soil used in the Deltalok bags to account for plant uptake of phosphorus, potassium and nitrogen, and maintain a desirable reservoir of these nutrients.
- Apply forb seed mixes by hydroseeding on the outside of the Deltalok bags. The grass seed mixes could be mixed with the soil inside the Deltalok bags or applied on the outside of the Deltalok bags through hydroseeding.

It is also recommended to construct the full scale green noise barrier using a minimum of two additional layers of Deltalok bags to compensate for the effect of settlement on the reduction in acoustic performance of the barrier. The settlement of the Deltalok structure could be minimized through the use of additional layers of geogrid and by ensuring proper compaction of backfill materials during the construction of the structure. It is recommended to use a layer of geogrid every three rows of Deltalok bags instead of four.

If successful, the Deltalok green noise barrier will provide an environmentally friendly green alternative to traditional concrete barriers that are currently being used in Ohio. While this product

may not be suitable for all locations due to its high initial and maintenance costs, it might be a good option for locations that are considered unique or have a special interest by the community. Examples of such locations include historic properties, schools, local and state parks, and other natural settings. The benefits

associated with a green noise wall for these communities cannot be quantified for inclusion in any cost comparison. Funding for such projects could be covered in-part by the affected residents or communities that have a strong desire for a green alternative to traditional concrete barriers.