The challenge of low-cost culvert foundations

The installation of a water-crossing structure on soils with poor bearing capacity can cause numerous issues with road and structure performance and can compromise the ability of the structure to meet fish passage or aquatic habitat protection requirements. A common result is that a culvert may partially or completely sink into the soil as it is driven downward by the weight of the overlying fill. This is often most evident at the centre of a culvert, which leads to a banana-shaped culvert with its ends higher than its centre. This can impede the structure’s ability to provide adequate passage for water, fish, and aquatic species.

In most cases, the selection of foundation-improvement options is made by company or contractor staff and is primarily based on past experience. When installations require large structures with high construction costs, engineering consultants will often be retained to provide geotechnical designs for the structure. However, for smaller, low-cost structures, the installation will typically be performed by company or contractor personnel, who rely primarily on prior experience in dealing with challenging foundations. In these cases, engineering designs will not be complete, so readily accessible information on recommended general construction and design methods is critical to help these personnel achieve the required foundation conditions.

Proposed concepts

In response to requests for low-cost, easy-to-implement foundation improvement options, FPInnovations discussed possible solutions with forest industry members. Following these discussions, FPInnovations compiled the following proposed foundation improvement concepts. These proposals represent concepts that have been implemented or that have been developed and considered, but not known to be implemented.
Proposed concept #1 – Geotextile and compacted gravel base

Possible Application
- A trench is excavated under the location of the pipe until a more stable soil material is reached.
- The trench is then lined with a woven geotextile to act as a separator between the bedding material and the underlying native soil material.
- The bedding material used is a gravel:
  - Bedding provides a proper medium to distribute load.
  - The bedding material should be compacted to a density close to 95% of the modified Proctor.
  - The compaction of the bedding material allows significant increase of the bearing capacity of the foundation.
- The bedding is also used as fill material to bring the culvert foundation up to the required elevation.

Status
- FPInnovations is not aware of any forest companies that have implemented the proposed design.
- FPInnovations has not conducted field testing or monitoring of the proposed design.

Proposed concept #2 – Geogrid with gravel foundation

Possible Application
- Geogrid is a geosynthetic mesh-like product.
- Geogrid is installed under the pipe and extended into the road base.
- Geogrid may act as a “hammock” to help reduce culvert foundation settling.
- Gravel or coarse soil material is placed as a bedding over the geogrid:
  - Bedding provides a proper medium for the culvert to embed and to distribute load.
  - Also used as fill material to bring the culvert foundation up to the required elevation.

Status
- Proposed design has been implemented by some forest companies.
- FPInnovations has not conducted field testing or monitoring of the proposed design.
Proposed concept #3 – Geocell and geotextile

Possible Application

- CGeocell is a honeycomb-shaped cellular confinement system made from high-density polyethylene (HDPE).
- A trench is excavated under the location of the pipe until a more stable soil material is reached.
- The trench is then lined with a woven geotextile to act as a separator between the geocell backfill and the underlying native soil material.
- Geocell is installed on top of the geotextile to provide for increased bearing capacity.
- Before installing the geocell, a gravel material may be placed to bring the culvert foundation up to the required elevation.
- At least 75 mm of gravel refill is then placed on top of the geocell:
  - Gravel refill provides a proper medium for the culvert to embed and to distribute load.
  - Gravel refill serves as a platform for the culvert.

Status

- FPInnovations is not aware of any forest companies that have implemented the proposed design.
- FPInnovations has not conducted field testing or monitoring of the proposed design.

Proposed concept #4 – Large aggregate foundation

Possible Application

- A trench is excavated under the location of the pipe until a more stable soil material is reached.
- Large aggregate is placed into the excavated trench to act as a foundation to improve stability of the soft subgrade soil.
- The aggregate is covered by a woven geotextile to act as a separator between bedding material and the aggregate and soft soil substrate.
- Gravel or coarse material placed as a bedding over the geotextile:
  - Bedding provides a proper medium for the culvert to embed and to distribute load.
  - Also used as fill material to bring the culvert foundation up to the required elevation.

Status

- Proposed design has been implemented by some forest companies.
- FPInnovations has not conducted field testing or monitoring of the proposed design.

THE OBJECTIVE OF THESE PROPOSED CONCEPTS IS TO STIMULATE FURTHER DISCUSSION AND TO IDENTIFY CONCEPTS FOR POSSIBLE FIELD TRIALS.
Proposed concept #5 – Corduroy (single layer) with geotextile and gravel

Possible Application

- Corduroy or logs (as long as possible) are cut and placed into the excavated trench, parallel to the pipe.
- The amount of corduroy must be enough to stabilize the soft subgrade soil.
- The corduroy is covered by a woven geotextile to act as a separator between bedding material and the corduroy and soft soil substrate.
- Gravel or coarse soil material is placed as a bedding over the geotextile:
  - Bedding provides a proper medium for the culvert to embed and to distribute load.
  - Also used as fill material to bring the culvert foundation up to the required elevation.

Status

- Proposed design has been implemented by forest companies as described to FPInnovations
- FPInnovations has not conducted field testing or monitoring of the proposed design.

Proposed concept #6 – Corduroy (2 layers) with geotextile and gravel

Possible Application

- Corduroy or logs (as long as possible) are cut and placed into the excavated trench:
  - The first layer of corduroy is placed perpendicular to the pipe.
  - The second layer of corduroy is placed parallel to the pipe.
- The corduroy is covered by a woven geotextile to act as a separator between the bedding material and the corduroy and soft soil substrate.
- Gravel or coarse soil material placed as a bedding over the geotextile:
  - Bedding provides a proper medium for the culvert to embed and to distribute load.
  - Also used as fill material to bring the culvert foundation up to the required elevation.

Status

- Proposed design has been implemented by some forest companies.
- FPInnovations has not conducted field testing or monitoring of the proposed design.

THE OBJECTIVE OF THESE PROPOSED CONCEPTS IS TO STIMULATE FURTHER DISCUSSION AND TO IDENTIFY CONCEPTS FOR POSSIBLE FIELD TRIALS.
Proposed concept #7 – Corduroy (single layer) with geogrid and gravel foundation

Possible Application

• Corduroy or logs (as long as possible) are cut and placed into the excavated trench, parallel to the pipe.
• The amount of corduroy must be enough to stabilize the subgrade soil.
• The corduroy is then covered by a woven geotextile to act as a separator between the bedding material and the underlying native soil material.
• A geogrid is placed on top of the woven geotextile to provide additional strength and bearing capacity improvement.
• Gravel or coarse soil material is placed as a bedding over the geogrid:
  • Bedding provides a proper medium for the culvert to embed and to distribute load.
  • Also used as fill material to bring the culvert foundation up to the required elevation.

Status

• FPInnovations is not aware of any forest companies that have implemented the proposed design.
• FPInnovations has not conducted field testing or monitoring of the proposed design.

Proposed concept #8 – Log piles and geotextile

Possible Application

• Log piles are driven or pushed into the subsoil:
  • Piles should be driven or pushed until resistance is reached.
• Piles are then covered with a woven geotextile to act as a separator.
• The excavated trench is then backfilled to the required elevation:
  • The final layer, which is gravel, provides a proper medium for the culvert to embed and to distribute load.

Status

• FPInnovations is not aware of any forest companies that have implemented the proposed design.
• FPInnovations has not conducted field testing or monitoring of the proposed design.