Fact Sheet 1.1: Road and Highway Surfaces

The mitigation objective of this Fact Sheet is to reduce damage to the road by moving water off the road surface.

Large amounts of standing and moving water, which are typical with flooding and hurricanes, have the power to damage the surface of a roadway. Increasing the ability of the roadway and the shoulder to withstand the forces of water help mitigate roadway surface erosion. The road surface and the shoulder protect the road base, subbase and subgrade, providing the roadway's stability to support traffic.

Table 1.1.1 summarizes common strategies for reducing the vulnerability of road and highway surfaces to flood and hurricane hazards. The sections below discuss these strategies.

Table 1.1.1. Common Mitigation Solutions

Solutions and Options	***Unpaved Roadway***	***Paved Roadway***
Mitigation Solution: Stabilize Roadway		
Option 1: Resurface Roadway	✓	
Option 2: Reshape Roadway	✓	
Option 3: Construct Shoulder Protection	✓	✓
Option 4: Improve Subgrade Drainage Using Geosynthetic Drainage Systems		✓
Option 5: Improve Subgrade Strength Using Geosynthetics	✓	✓
Mitigation Solution: Reduce Flood Hazard on Roadway		
Option 1: Increase Roadway Elevation	✓	✓
Option 2: Relocate or Reroute Roadways	✓	✓
Option 3: Use Permeable Pavement	✓	✓
Mitigation Solution: Reduce Frost Heave		
Option 1: Improve Drainage	✓	✓
Option 2: Increase Pavement Thickness		✓
Option 3: Stabilize or Improve Subgrade Soils	✓	✓

Mitigation Solution: Stabilize Roadway

Roadway surface damage can be mitigated by increasing the ability of the roadway and shoulder to withstand the forces of water. The following sections present different options to achieve this end.

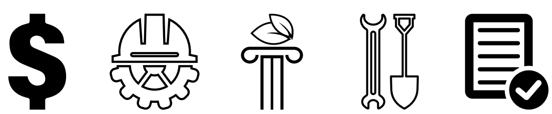
Option 1: Resurface Roadway

Hardening the road surface, repairing the existing road pavement, or reinforcing the paved surface will reduce the damage caused by inundation and debris.

When evaluating this option, keep these considerations in mind:

- Replace damaged, unpaved road surfaces with asphalt or concrete.
- State Department of Transportation manuals can be used to determine which paving materials are best under a given set of conditions.
- Costs could vary widely based on the surfacing material selected. For example, concrete tends to cost more than asphalt up front and uses different paving techniques.
- With paved roadways, consider adding geotextile drainage blankets between the pavement and subbase to strengthen the subgrade.
- To reinforce the subgrade, geotextiles—such as special woven fabrics—can be used and connected to drains. They generally do not drain well.
- Resurfacing may be more effective when completed along with Options 3, 4, or 5, below.

CONSIDERATIONS:



Option 2: Reshape Roadway

Reshape the entire cross-section to make it easier for water to run off the sides of the road. Where space is available, add shoulders if none exist. Slope the roadway from the center line of the road to the outside edge of the shoulder to aid with draining water off the road. Add drainage structures to move water from the road shoulder (Figure 1.1.1).

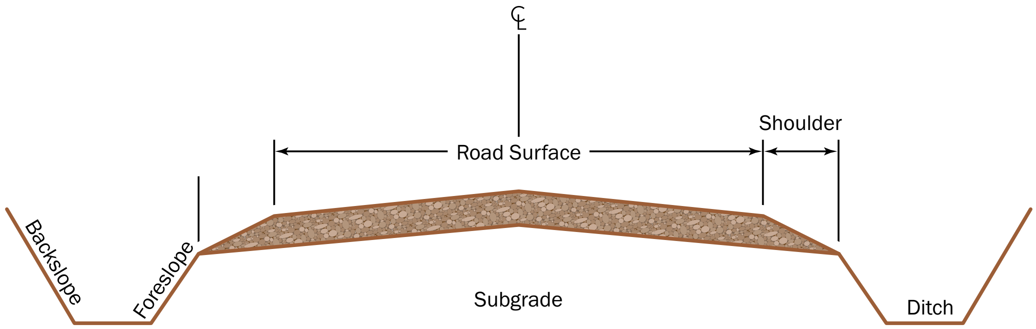
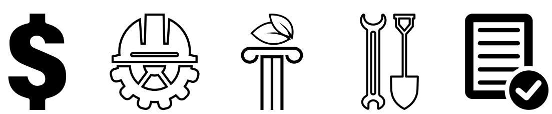


Figure 1.1.1. Reshaping the roadway can improve drainage and decrease flood impacts.

When evaluating this option, keep these considerations in mind:

- Road design may be subject to different requirements, including proper drainage, compaction and surfacing materials.
- When engaging in new construction, consider stabilizing disturbed areas.
- This option may be more effective when completed along with Options 3, 4, or 5, below.

CONSIDERATIONS:



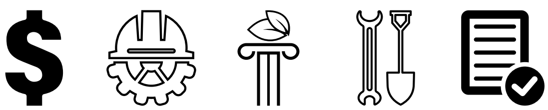
Option 3: Construct Shoulder Protection

Keep the roadway subgrade strong by constructing shoulder protection. When subgrade soils get saturated, they can become weaker, resulting in the road being unable to support traffic loads. Protecting the roadway shoulders can reduce the amount of water that can reach the roadway subgrade, reducing damage to the roadway.

When evaluating this option, keep these considerations in mind:

- Protect unpaved shoulders by adding a layer of clean gravel, crushed stone, or pulverized asphalt.
- If a paved road has gravel shoulders, paving the shoulders or installing a layer of asphalt will reduce the porousness of the shoulder and reduce the material loss from traffic on the shoulder.
- Installing a geosynthetic material on the shoulder slope or constructing retaining walls at the bottom of the shoulder slope can help with stabilization. Geosynthetics used for this purpose should provide both reinforcement and drainage.
- Revegetating the shoulder slope with native plants that have deep root systems will help to stabilize the slope and reduce soil erosion, which helps protect the shoulder from damage.

CONSIDERATIONS:



Option 4: Improve Subgrade Drainage Using Geosynthetic Drainage Systems

Improve roadway strength and durability by using geosynthetic drainage blankets between the pavement section and subbase (Figure 1.1.2).

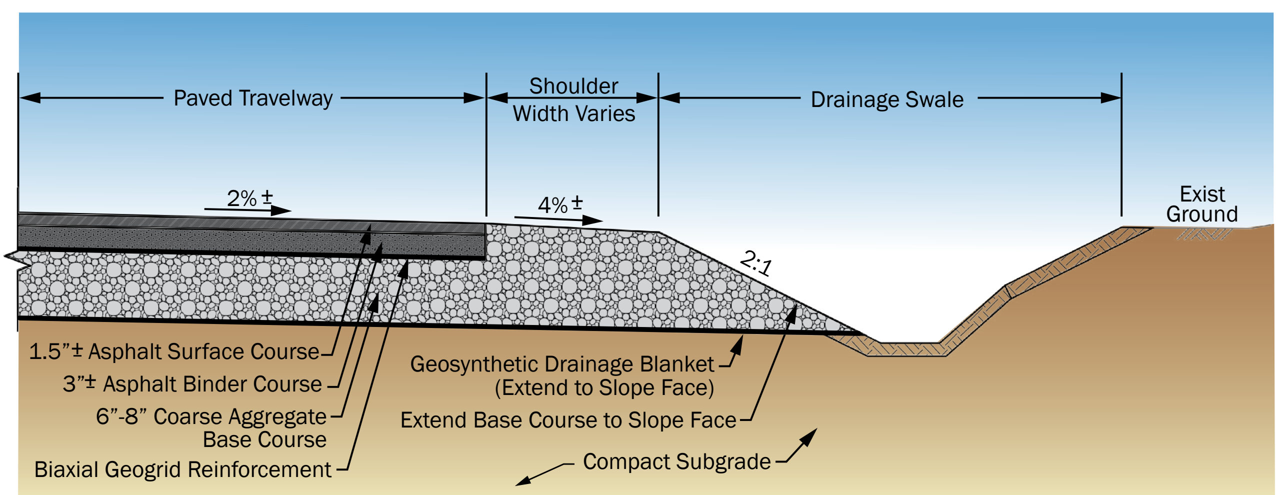


Figure 1.1.2. Geosynthetics can be used to improve drainage and subgrade strength.

When evaluating this option, keep these considerations in mind:

- Use drainage blankets with free-draining base course material or natural subgrade soils.
- Drainage blankets are especially effective at removing water from the pavement section before it weakens the support of the subgrade.
- Not all geosynthetics promote drainage (e.g., some woven geotextiles do not). If a geosynthetic that is not suitable for drainage is used, it should connect to a drain (Figure 1.1.3).

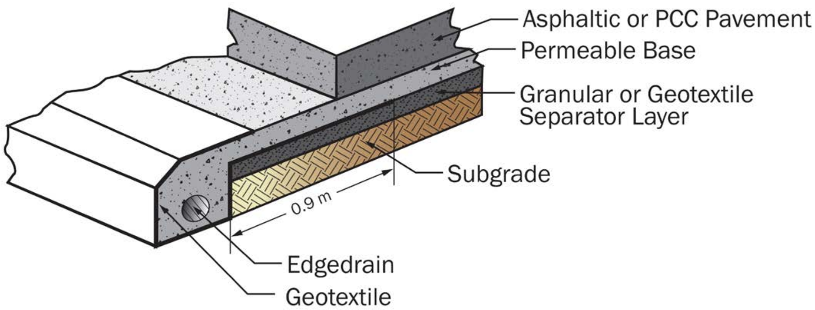
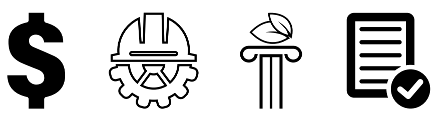


Figure 1.1.3. Geotextiles that do not drain well can be hydraulically connected to a drain.

CONSIDERATIONS:



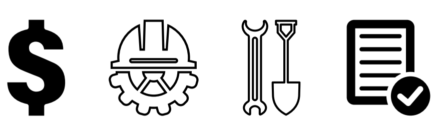
Option 5: Improve Subgrade Strength Using Geosynthetics

If the road is in an area that naturally has poor subgrade soil support (in a swampland, for instance), place a geosynthetic over the subgrade soil and under the road base material to improve roadway strength.

When evaluating this option, keep these considerations in mind:

- The geosynthetic prevents silt and clay soils in the subgrade from mixing with the more granular base courses, destabilizing the subgrade and interfering with drainage.
- Not all geosynthetics reinforce soil strength. Geotextiles that provide separation and reinforcement functions, such as woven geotextiles, may be appropriate for improving subgrade strength. However, they generally do not drain well. If drainage also is desired, they should connect to a drain.

CONSIDERATIONS:



Mitigation Solution: Reduce Flood Hazard on Roadway

Keeping floodwaters off the roadway surface mitigates roadway surface damage. The following sections present different options to achieve this end.

Option 1: Increase Roadway Elevation

To reduce flooding on a roadway and keep the road in service during a flood, consider increasing the roadway elevation. This may be particularly important for access to critical facilities and to maintain open evacuation routes.

When evaluating this option, keep these considerations in mind:

- Elevate often-flooded sections of roadway above the base flood elevation at a minimum. This may require removing the existing pavement, adding enough material to raise the finished roadway surface above flood elevation, and constructing a new pavement section (Figure 1.1.4).
- Elevating the roadway should be combined with measures to protect the embankment slopes.
- If flood levels often are several feet above the roadway surface, elevating the roadway may not be the best option.
- If elevating the roadway on an embankment creates a dam and raises the flood level upstream, elevate the roadway on piles or add a culvert under the roadway.
- Adding material to a floodplain must be reviewed and approved by the local floodplain manager.

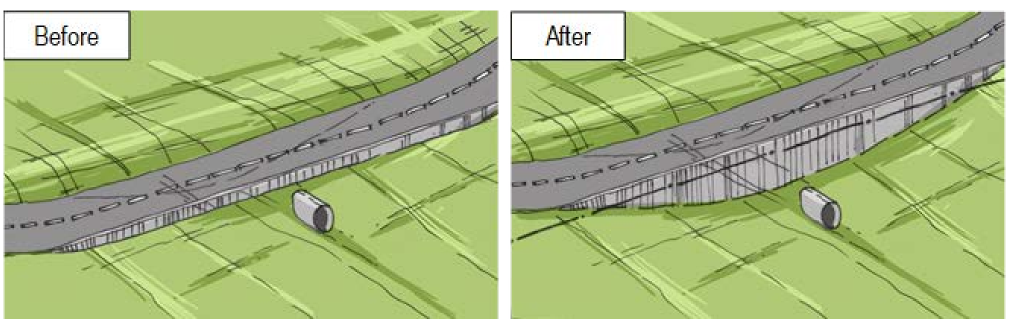
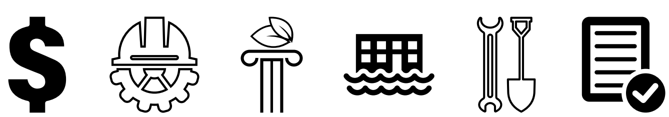


Figure 1.1.4. Increasing the roadway elevation above the base flood elevation

CONSIDERATIONS:



Option 2: Relocate or Reroute Roadway

To reduce flooding on a roadway, consider relocating or rerouting the roadway away from flood-prone areas, areas at risk for landslides, or areas where wave action occurs (Figure 1.1.5).

When evaluating this option, keep these considerations in mind:

- Relocating roadways may be costly.
- This option may be most effective where roads are more-frequently flooded or where a short length of the roadway is flooded.
- The right of way must be available, or land must be acquired to construct a new right of way.
- The relocation might require additional engineering design.
- The relocated roadway must comply with environmental and floodplain management regulations.

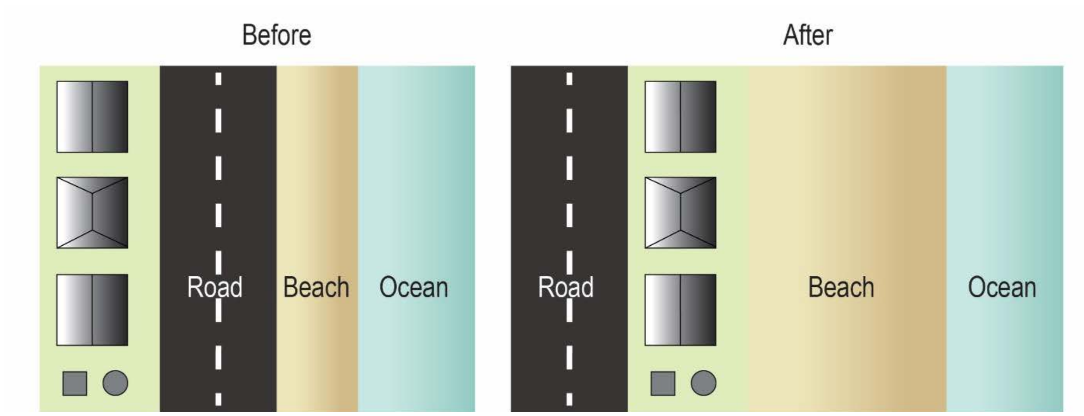
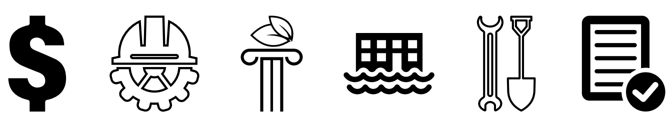


Figure 1.1.5. Relocating the roadway away from the flood source can help protect the road from flooding.

CONSIDERATIONS:



Option 3: Use Permeable Pavement

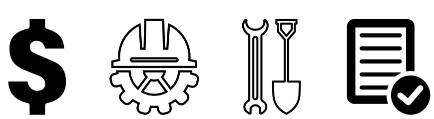
Permeable pavement combines a porous surface, such as permeable concrete, permeable asphalt, or pavers, with an underlying stone layer (Figure 1.1.6). The permeable pavement catches rainfall or runoff and stores it in the stone layer, slowly allowing the water to soak into the soil below the stone layer or releasing it through a drain.

When evaluating this option, keep these considerations in mind:

- Permeable pavement typically is most suitable for parking lots, roads with low traffic volumes, sidewalks and driveways. Some types also may be suitable for highway shoulders.
- Permeable pavement can filter some pollutants contained in runoff water.
- By controlling the rate of runoff, permeable pavement can help reduce the required size of regional best management practices.
- The thickness of the aggregate base may vary depending on the quantity of rainfall a location typically receives or is expected to receive. Locations with greater rainfall require thicker aggregate bases.
- During winter in cold climates, permeable pavements may resist frost heave better than traditional pavements.
- Maintain permeable pavement regularly to prevent clogging. Maintenance practices may differ from those of traditional pavement; follow manufacturers’ instructions for maintenance.
    - In cold climates in winter, less road salt generally is needed than for traditional pavements over the winter season. However, salt application may result in poor performance of concrete porous pavement systems.
    - Sand cannot be used for winter maintenance.

Figure 1.1.6. Permeable pavement includes pavers, permeable concrete, and permeable asphalt (USGS, 2018).

CONSIDERATIONS:



Mitigation Solution: Reduce Frost Heave

Damage from floods to infrastructure, particularly transportation infrastructure, can worsen in the Spring when freeze-thaw cycles coincide with thaw-related flooding. These freeze-thaw cycles often lead to “frost heaves,” where areas of the ground surface appear to push up, resulting in cracking of pavements, misalignments of culverts and other associated damage.

Option 1: Improve Drainage

When roads thaw, layers nearest to the ground surface thaw first, while material deeper in the ground remains frozen. This results in water becoming trapped near the ground surface. If temperatures drop below freezing, this trapped water re-freezes and can cause heaving.

USE FREELY DRAINING SOIL

Under normal freezing conditions, little to no heaving occurs in clean, free-draining sands, gravels, crushed rock and similar granular materials (FHWA, 2017). The large void spaces allow water to travel freely and freeze without forming the ice lenses responsible for frost heaves.

When evaluating this option, keep these considerations in mind:

- Identify frost-susceptible areas:
    - Where frost heaves have been observed
    - Where subgrade soils are likely to include inorganic soils having more than 3% of fine grains
    - Where the water table is within 3 meters (10 feet) of the pavement surface
    - Where water is likely to accumulate beneath the roadway but above the frost depth
- Remove the frost-susceptible soils and replace with freely draining material having less than 3% of fine grains.
- “Rock caps” can help drainage while also providing additional structural stability (Figure 1.1.7). They are made of crushed rock material and may be placed on top of a geotextile where there are fine subgrade soils (Pavement Interactive, 2020).

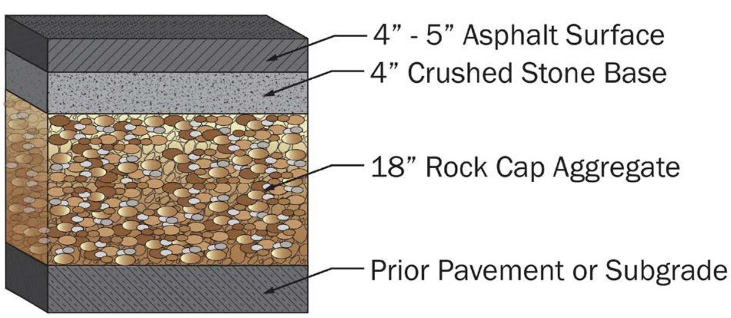


Figure 1.1.7. “Rock caps” can improve both drainage and structural stability of roads susceptible to frost heaves (Yu and Beck, 2009).

INSTALL DRAINAGE

Draining water away from the upper layers of soil beneath the road surface can help to reduce frost heaves.

When evaluating this option, keep these considerations in mind:

- Install deep drains that maintain the water table below the level of the freezing zone.
- Install a capillary barrier to prevent moisture rise in the freezing zone.
  - Capillary barriers are either an open-graded gravel layer between two layers of geotextiles or a horizontal geocomposite drain (FHWA, 2017) (Figure 1.1.8).
  - Capillary barriers should be installed by removing the frost-prone soils to a depth below the frost line to reduce frost heave damage to the road surface. The frost-susceptible soil can be replaced and compacted above the capillary drain to the road surface elevation.
  - The capillary barrier must be hydraulically connected to a drain.

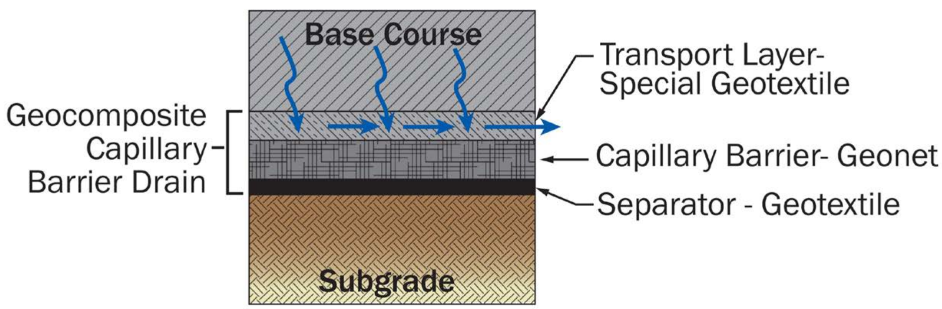
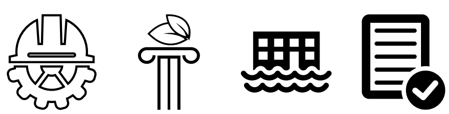


Figure 1.1.8. A capillary barrier can help prevent surfaces from frost heaving (Roberson et al., 2006).

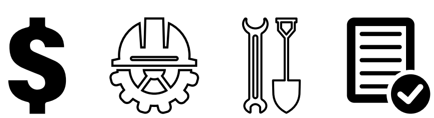
CONSIDERATIONS:



Option 2: Increase Pavement Thickness

In locations where frost heaves occur, road pavement thickness can be increased to help offset the reduction in subgrade strength during the Spring freeze-thaw period (FHWA, 2017). A general rule of thumb is that the pavement thickness should be at least one-half the depth of frost-prone soils.

CONSIDERATIONS:



Option 3: Stabilize or Improve Subgrade Soils

Stabilize weak soils by using an admixture to improve strength and decrease or remove passages through which moisture can pass.

When evaluating this option, keep these considerations in mind:

- Mix cementing agents such as Portland cement, lime fly-ash, lime, or bitumen with the weak subgrade soils to bond soil particles together.
- Inject polymers, such as polyurethane, into the subgrade soils (Figure 1.1.9).
  - 5/8-inch holes are drilled through the road surface.
  - The polymer is injected into the soils and flows through the void spaces, expanding to fill the holes.
  - As the polymer expands, it creates a layer of insulation that reduces heat loss and prevents the occurrence of localized freezing.

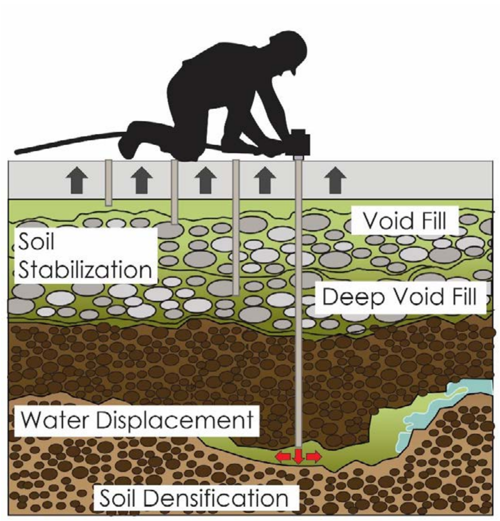
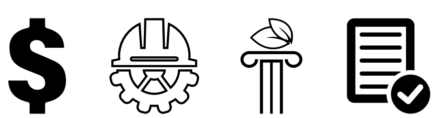


Figure 1.1.9. Improve subgrade soils by injecting a polymer into the soil to fill voids (Source: Fakhar and Asmaniza, 2016).

CONSIDERATIONS:



REFERENCES:

Detailed technical information on road and highway surface mitigation methods, considerations, and general design practices can be found in these publications:

Concrete Network.com. 2020. Frost Heave and Foundations. Available at: https://www.concretenetwork.com/concrete/frost_protected_shallow_footings/frost_actions_and_foundations.htm

Concrete Stabilization Technologies, Inc. 2020. Frost Heave Mitigation. Available at: https://cststabilization.com/frost-heave-mitigation/

Edgar, T., C. Potter, and R. Mathis. 2015. "Frost Heave Mitigation Using Polymer Injection and Frost Depth Prediction." 16th International Conference on Cold Regions Engineering. Available at: https://ascelibrary.org/doi/10.1061/9780784479315.037.

Fakhar, A. and A. Asmaniza. 2016. "Road Maintenance Experience Using Polyurethane (PU) Foam Injection System and Geogrete Soil Stabilization as Ground Rehabilitation." IOP Conference Series: Materials Science and Engineering, Vol. 136. Available at: https://iopscience.iop.org/article/10.1088/1757-899X/136/1/012004

Federal Emergency Management Agency (FEMA). 2001. *Flood Hazard Mitigation Handbook for Public Faciliti*es. Available at: https://www.hsdl.org/?abstract&did=34754#:~:text=This%20Flood%20Hazard%20Mitigation%20Handbook,and%20mitigation%20ideas%20for%20local

FEMA. 2005. *Hurricane Mitigation: A Handbook for Public Faciliti*es. Available at: https://www.hsdl.org/?abstract&did=34831

FEMA. 2010. FEMA B-797, Hazard Mitigation Field Book, Roadways. Available at: https://www.fema.gov/sites/default/files/2020-07/b797_hazmit_handbook.pdf

Federal Highway Administration (FHWA). 1995, revised 1998. Geosynthetic Design and Construction Guidelines, FHWA-HI-95-038. Available at: https://www.fhwa.dot.gov/engineering/geotech/pubs/011431.pdf

FHWA. 2015. Gravel Roads Construction & Maintenance Guide. Available at: https://www.fhwa.dot.gov/construction/pubs/ots15002.pdf

FHWA. 2017. Geotechnical Aspects of Pavements Reference Manual, Chapter 7.0 Design Details and Construction Conditions Requiring Special Design Attention. Available at: https://www.fhwa.dot.gov/engineering/geotech/pubs/05037/

FHWA. 2020. Department of Transportation Master Site to All State Standard Drawings. Available at: https://flh.fhwa.dot.gov/resources/standard/state.htm

Pavement Interactive. 2020. Reference Desk: Frost Action Mitigation. Available at: https://pavementinteractive.org/reference-desk/design/design-parameters/frost-action-mitigation/

Roberson, R., et al. 2006. NCHRP Report No. 113 Geocomposite Capillary Barrier Drain (GCBD) for Limiting Moisture Changes in Pavements. Available at: http://onlinepubs.trb.org/onlinepubs/archive/studies/idea/finalreports/highway/NCHRP113_Final_Report.pdf

Stitchdiary. December 12, 2018. "5 Facts You Need to Know About Geotextiles." Available at: https://medium.com/@stitchdiary/5-facts-you-need-to-know-about-geotextiles-46984cce506e

U.S. Geological Survey. 2018. Scientific Investigations Report 2018-5037 Hydraulic, Water-Quality, and Temperature Performance of Three Types of Permeable Pavement under High Sediment Loading Conditions. Available at: https://pubs.usgs.gov/sir/2018/5037/sir20185037.pdf

Yu, X., and R. Beck. 2009. FHWA Report No. OH-2009/4 The Performance and Economic Benefits of Thick Granular Base for Flexible Pavement Design in Ohio. Available at: http://worldcat.org/arcviewer/2/OHI/2009/08/18/H1250610088170/viewer/file1.pdf