

Emergency Landslide Mitigation & Restoration of US Hwy 441 - GRSM

Mounir Abouzakhm, PE
Mohammed Elias, Ph.D., PE
Martin Hatcher, PE
Federal Highway Administration
Eastern Federal Lands Highways Division

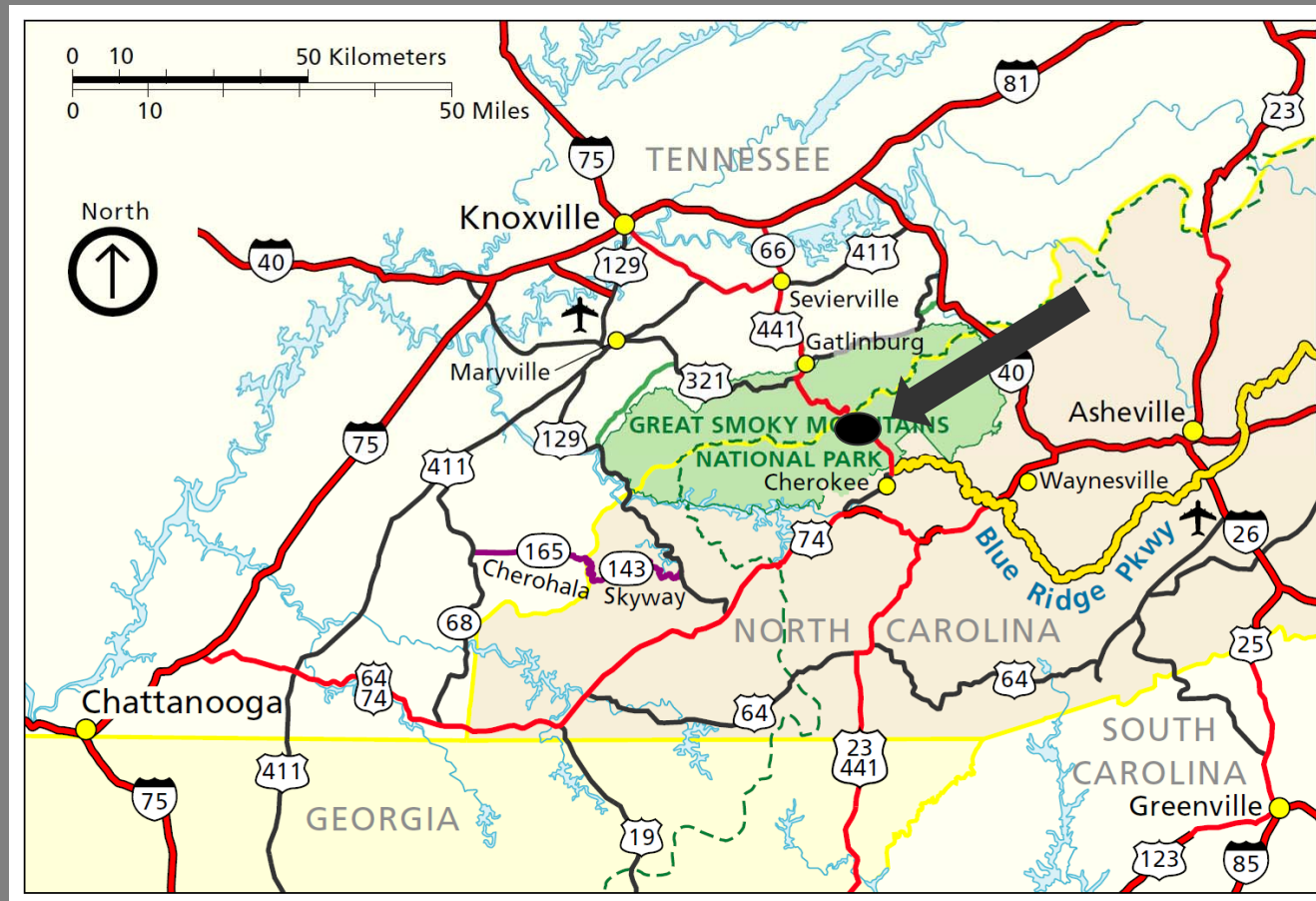


U.S. Department of Transportation
Federal Highway Administration

2016 Geohazard in Transportation Forum

Engineering America's Scenic Highways

Landslide Location



U.S. Department of Transportation
Federal Highway Administration

Scenic road between the towns of Gatlinburg, TN & Cherokee, NC

Engineering America's Scenic Highways

US Hwy 441 Landslide

- **January 16, 2013**
- **Washed away a stretch of 250 feet.**
- **Triggered by heavy rainfall (9")**



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Site Reconnaissance

January 16 - 21, 2013

EFLHD visited the site, completed the survey and initial geotechnical investigation.



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Site Reconnaissance



Abandoned road above the failed slope



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Site Reconnaissance

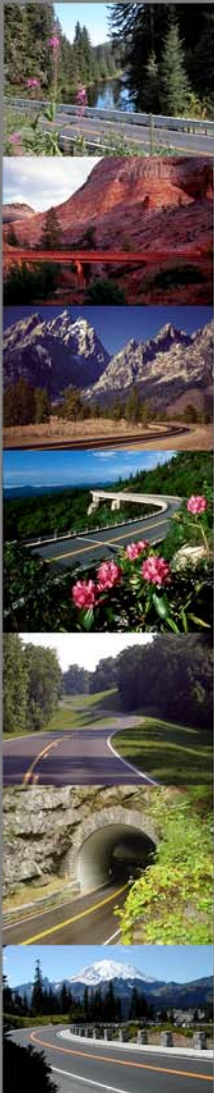


Snow storm following the slope failure



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways



Contracting Methods

- ◆ **Phase I** – Emergency (letter) contract
- ◆ **Phase II** – Permanent Repair



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways



Phase I Contract

- ◆ Emergency (Letter) Contract
- ◆ Remove debris
- ◆ Establish temporary access roads
- ◆ Place rock base



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways



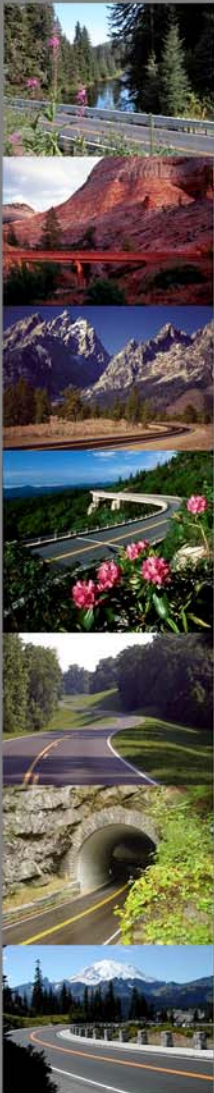
Phase II Contract

- ◆ Permanent Repair
- ◆ Fast and practical design
- ◆ Fast Construction
- ◆ Competent contractor with a proven record of success



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways



Phase II Contract

- ◆ 2 Step Bidding Process
 - Step 1 - Request for Technical Proposals
 - ◆ Released January 28, 2013
 - ◆ 12 contractors submitted proposals
 - ◆ 5 firms found technically acceptable



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways



Phase II Contract

- ◆ 2 Step Bidding Process
 - Step 2 – Advertisement of PS&E
 - ◆ February 7, 2013 Advertisement
 - ◆ February 15, 2013 Bids Opened
 - ◆ February 20, 2013 Project Award



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Phase I – Emergency Contract



January 28, 2013
A letter contract issued to remove slide debris, construct temporary access roads and place base stone to bridge soft soils.



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Phase I – Emergency Contract



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Subsurface Conditions

Subsurface conditions exposed during Phase I construction



South side



West side



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Subsurface Conditions

Test pits

Soil borings (24-35 ft)



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Subsurface Conditions



Top Boring

Borings drilled at the top and bottom of failed slope



Bottom Boring



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Subsurface Conditions

Bottom Boring



EL 3230

EL 3225

EL 3195



Cobbles & boulders (fill)

Residual soils/N = 12 to >50 bpf

Auger refusal



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Subsurface Conditions

Top Boring



EL 3290

Sandy SILT-Silty SAND/N= 3 to 8
bpf

EL 3273

EL 3270

Residual soils/N = 25 to >50 bpf

EL 3266

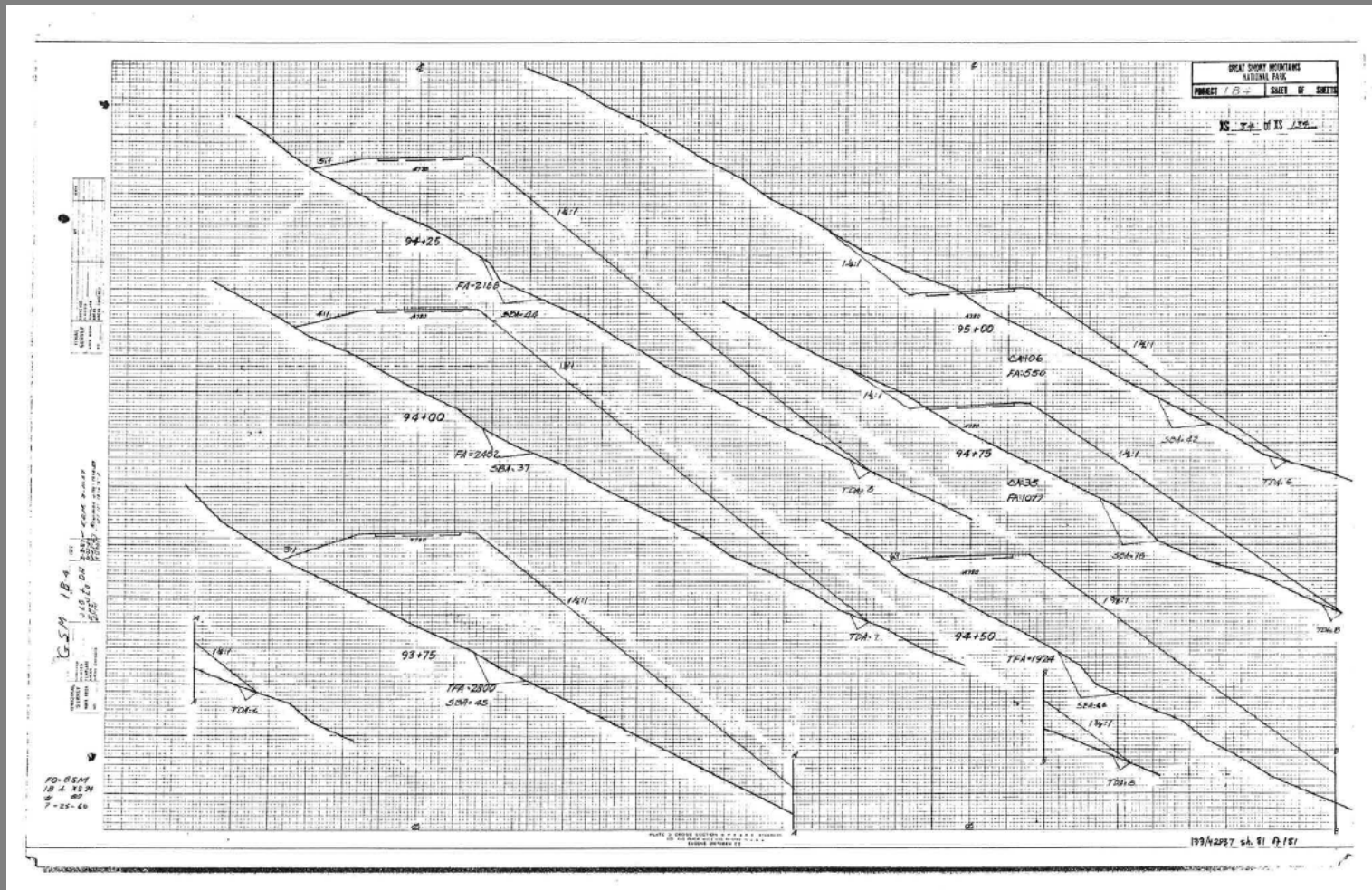
Auger refusal



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Typical as-built plan along NFG



U.S. Department of Transportation
Federal Highway Administration

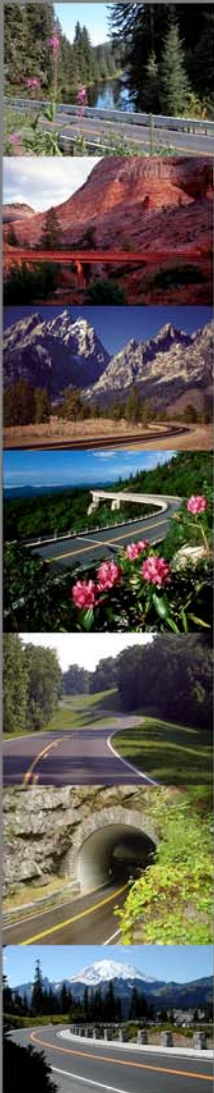
Engineering America's Scenic Highways

What triggered the failure?



U.S. Department of Transportation
Federal Highway Administration

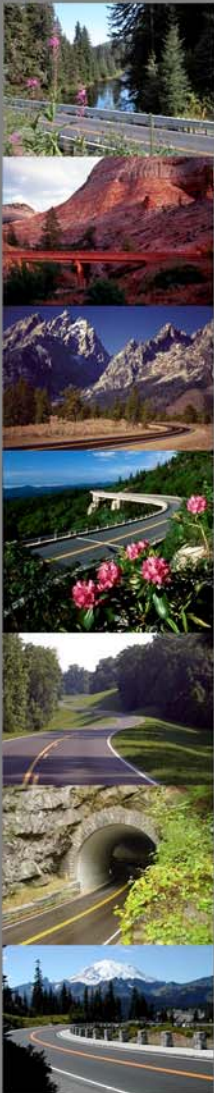
Engineering America's Scenic Highways



What triggered the failure

- ◆ Heavy rain (9")
- ◆ Steep slope
- ◆ Presence of springs and surfaced runoffs
- ◆ Failure of the subdrainage system

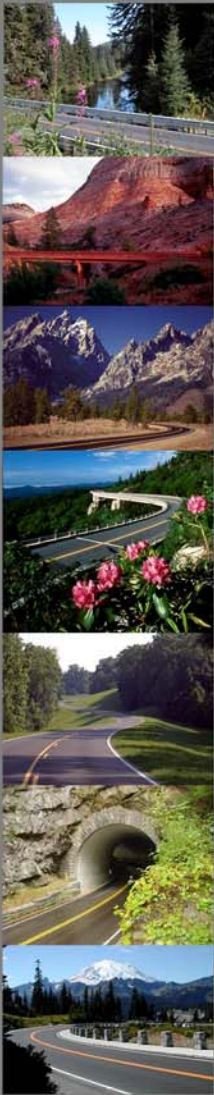




Design Analysis

- ◆ Reinforced Soil Slope (RSS)
 - Layers of geogrid and granular backfill
- ◆ Drainage System
 - Subsurface Drainage
 - Surface Runoff





RSS Advantages

- ◆ Fast-track construction
- ◆ Simple
- ◆ Offers flexible design and construction
- ◆ Cost effective
- ◆ Integrates well with the park landscape



U.S. Department of Transportation
Federal Highway Administration

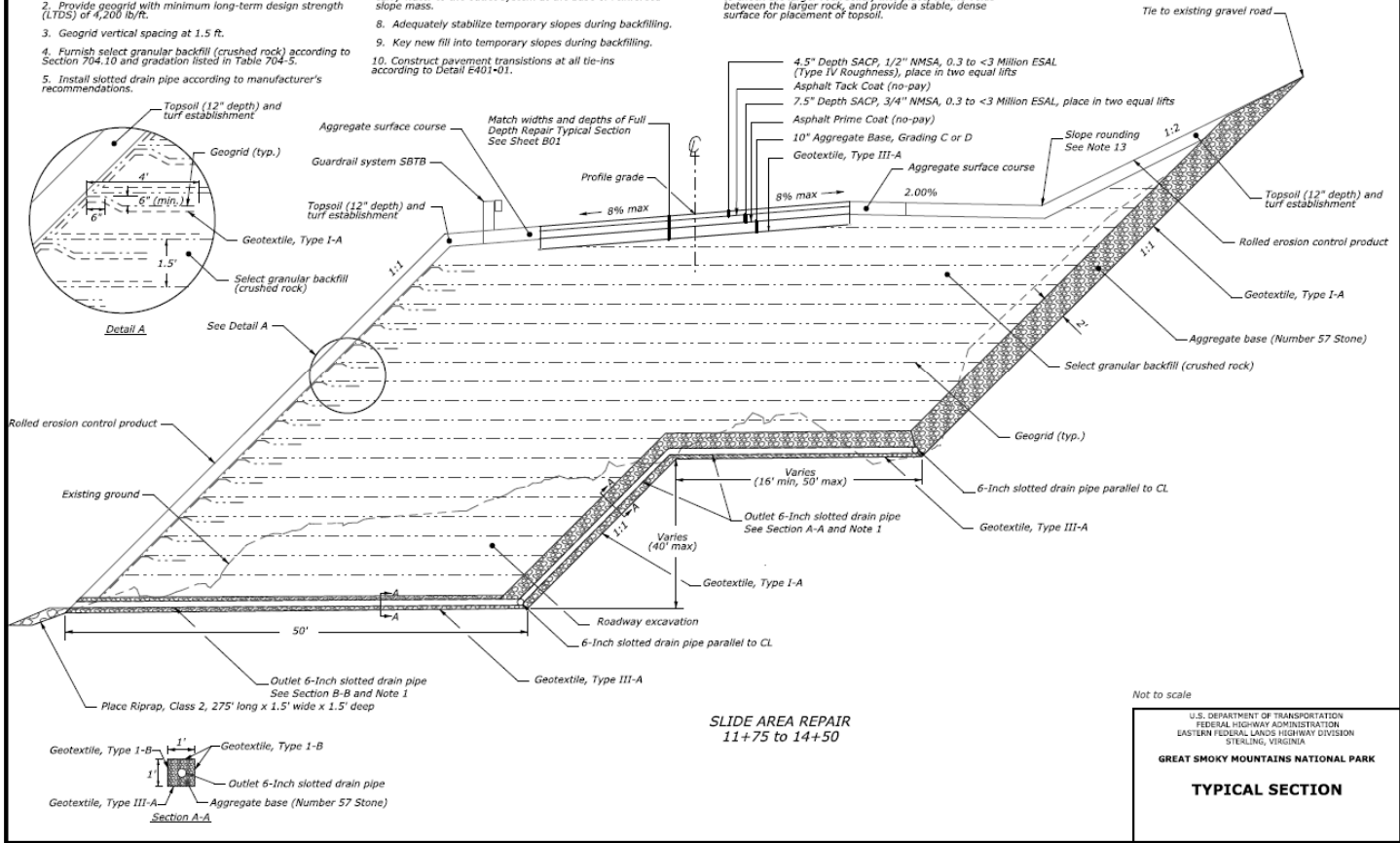
Engineering America's Scenic Highways

RSS Typical Cross-section

Notes:

1. Install outlet 6-inch slotted drain pipe to provide positive drainage (min 2% grade) at maximum spacing of 10 ft and at low points as approved by CO. Cover the end of the outlet pipe with screen according to Section 605.03. Hold the screen securely in place with standard coupling bands or as approved by CO.
2. Provide geogrid with minimum long-term design strength (LTDS) of 4,200 lb/ft.
3. Geogrid vertical spacing at 1.5 ft.
4. Furnish select granular backfill (crushed rock) according to Section 704.10 and gradation listed in Table 704-5.
5. Install slotted drain pipe according to manufacturer's recommendations.
6. Bench the back slope to accommodate reinforcement length required.
7. Provide drainage blanket on benches sufficient to collect subsurface drainage and maintain ground water level at or below the level of the benching system. The system shall carry water to the outlet system at the base of reinforced slope mass.
8. Adequately stabilize temporary slopes during backfilling.
9. Key new fill into temporary slopes during backfilling.
10. Construct pavement transitions at all tie-ins according to Detail E401-01.
11. Place topsoil and establish turf at all disturbed areas except travel lanes and shoulders in accordance with Section 624 and 625. Place aggregate surface course on shoulders and establish turf in accordance with Section 301 and 625.
12. Use spalls smaller than the minimum rock size to check the larger rock solidly into place, fill the voids between the larger rock, and provide a stable, dense surface for placement of topsoil.

FHWR NO.	FPS NO.	REG	STATE	PROJECT	SHEET NO.
200833	1117	SE	NC	PSA-GRSM 1820	B02



Phase II- RSS Construction



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Phase II Construction



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Phase II Construction



Engineering America's Scenic Highways



Lessons Learned

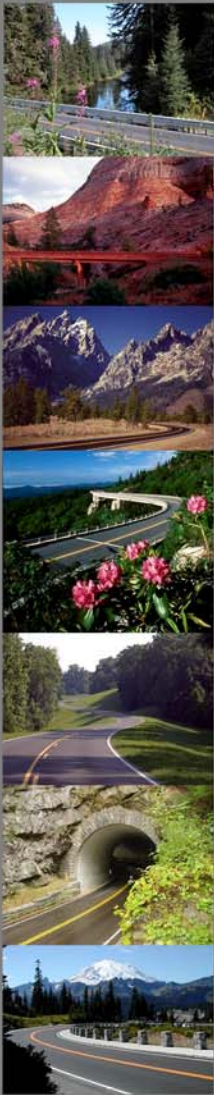
- ◆ Work with the community and respond to their needs
- ◆ Incentives can be a powerful tool
- ◆ Use of crushed stone/select granular material (SGM)



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

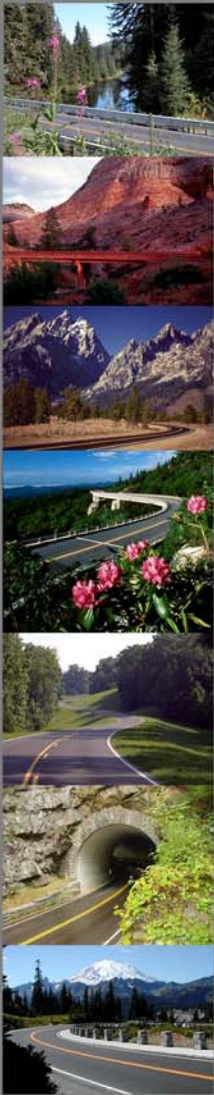
Respond to the community needs



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

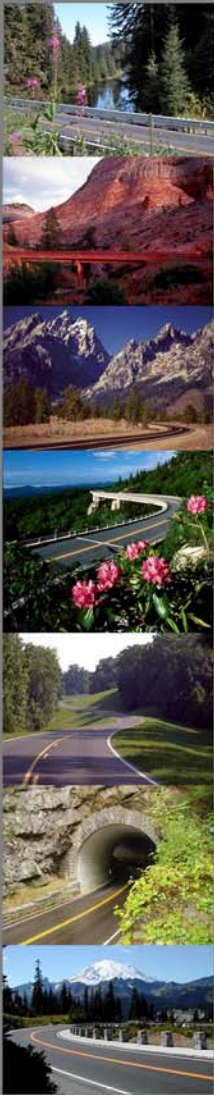
Incentives



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Use of Crushed Stone/SGM



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways

Highway 441 Landslide 90 DAYS – Landslide to Repair



U.S. Department of Transportation
Federal Highway Administration

Engineering America's Scenic Highways