Grade-Separated Trail Crossings
How Do We Get Over There?

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PRESENTATION OVERVIEW

✓ Why grade-separated crossings?
✓ What barriers are we trying to cross?
✓ Decision-making process
✓ At-grade or grad-separated? Go over or under? Where to build it? Etc.
✓ Pedestrian underpass design considerations
✓ Bridge/overpass design considerations
WHY GRADE-SEPARATED CROSSINGS?

✓ Critical links in the bike/ped network: overcome barriers
✓ Provide bike/ped links where at-grade crossings are not possible
✓ Respond to a demand for safe crossings where they didn’t previously exist
✓ Provide direct links where the surrounding transportation system offers limited connectivity
✓ More than just a transportation facility
What are the barriers?

What are we trying to cross?
The decision-making process

✓ At-grade or grade-separated?
✓ Go over or go under?
✓ Where do we build it?
✓ What kind of access can/do we provide?
✓ What are the details?
✓ Can we afford it?
Question 1:
At-grade or grade-separated?

✓ Largely depends on the barrier being crossed
WATERWAYS
RAILROADS
MAJOR ROADS
The main dilemma: Getting across major roads (and to some extent, railroads)
USING A BRIDGE/TUNNEL VS. CROSSING AT-GRADE

✓ User’s decision based on:
  • Bridge/tunnel location relative to desired travel route
  • Availability of alternative crossings
  • Elements precluding/discouraging at-grade crossings
  • Perceived risk of crossing at-grade
  • Distance/time needed to access and cross the bridge/tunnel
USING A BRIDGE/TUNNEL VS. CROSSING AT-GRADE

✓ Institute of Transportation Engineers Study (1998):
  • 70% of peds would use a bridge/tunnel if travel time = at-grade crossing time
  • If bridge/tunnel travel time >50% of at-grade crossing time: Very low use

✓ Washington State DOT Design Manual:
  • Low bridge/tunnel use if walking distance for 85% of peds is ¼-mile of at-grade crossing distance
Question 2:
Go over or go under?

- Drainage, environmental impacts, adjacent property impacts, constructability, user safety and security, etc.
- Vertical ascent/descent necessary to reach bridge/tunnel
Source: Oregon Bicycle and Pedestrian Plan
Question 3: Where do we build it?

✓ Bridge/tunnel proximity to:
  • Surrounding pedestrian/bicycle facilities
  • Logical walking/bicycling routes and destinations
  • Alternative crossing opportunities
Surrounding pedestrian/bicycle facilities

- Good connections to surrounding facilities highly important
- Bridges/tunnels within an overall comprehensive network = potentially higher usage
- Wayfinding critical
Logical walking/bicycling routes; Proximity to destinations

• Should not require out-of-direction travel to/from a logical travel route or desired destination
Bridge

Primary walk/bike route

Alternate crossing
Question 4:
What kind of access can/do we provide?

✓ Depends on:
  • Amount of necessary vertical ascent/descent
  • Available “footprint” space
Bridges/tunnels serving multiple functions

- Visual icons
- Enhance user experience
- Bridges as community gathering places
- Tourism
Question 5:
What are the details?

✓ Pedestrian Underpass
UNDERPASS ISSUES

✓ Feasibility
✓ Success

✓ Critical Issues
  • site constraints
  • constructability
  • structure selection
  • drainage
  • lighting
  • safety
Evaluating the Site

- Utilities
- Right of Way
- Environmental
- Soil Conditions
- Traffic Control
- Drainage
- At what cost?
UTILITIES

- Locate all utilities and coordinate with owners
- Pothole critical utilities
- Asbestos conduits require special treatment
- Avoid costly utility delays
RIGHT OF WAY

- Identify available right of way
- Consider space required for construction
- Talk with property owners early
- Right of way negotiations can take time
SOIL CONDITIONS

- Hire a geotechnical consultant
- Identify groundwater elevations and soil conditions
- Plan for ground water during and after construction
TRAFFIC CONTROL

✓ Consider impacts to traffic during construction

- can the road be closed during construction?
- design speed?
- number of lanes?
- pedestrian and bikes during construction?
TRAFFIC CONTROL

✓ Consider impacts to traffic during construction
TRAFFIC CONTROL

Don’t forget pedestrians, bus stops, etc.
Site challenges have been identified
 ✓ Identify path connection to at-grade facilities (sidewalks, bus stops...)
 ✓ Determine approach grades
   • use ADA and AASTHO Bike Guide Requirements
   • provide 5% max if possible
 ✓ Provide horizontal curves
   • consider sight distance
   • bicycle movements
   • maintenance vehicles
 ✓ Consider ramps and stairs, depending on usage
AASHTO Guide for Development of Bicycle Facilities

- 5 - 6% up to 800 ft
- 7% up to 400 ft
- 8% up to 300 ft
- 9% up to 200 ft
- 10% up to 100 ft
- 11+% up to 50 ft

ADA Guidelines for Outdoor Developed Facilities

- 1:20 (5%) any distance
- 1:12 (8.33%) up to 200 ft
- 1:10 (10%) up to 30 ft
- 1:8 (12.5%) up to 10 ft
LAYOUT DESIGN

✓ Provide alternate routes
Provide alternate routes
STRUCTURE SIZING

- AASTHO: 10-ft vert. clearance
- 8-ft Vert. is typically acceptable
- Horiz. clearance of 14-ft min.
- Consider impacts to utilities and drainage
- Size for flood conveyance if appropriate
- Additional height usually adds more to cost than width
There are plenty of functional examples less than 8’

Provide warnings
STRUCTURE TYPES

Cast-In-Place Concrete

Precast Concrete

Corrugated Steel
CAST-IN-PLACE CONCRETE

Advantages
- can be “customized”
- no joints

Disadvantages
- longer duration of construction
- cost
CAST-IN-PLACE CONCRETE

✓ Fabrication on site takes time
✓ Consider impacts to traffic and control of water
CAST-IN-PLACE CONCRETE

✓ Standard designs are available from many state DOTs
CAST-IN-PLACE CONCRETE
CAST-IN-PLACE CONCRETE

✓ Combined hydraulic structure
CAST-IN-PLACE CONCRETE

☑ Enhanced aesthetic structures
CAST-IN-PLACE CONCRETE

- Controlled Drainage
- Textured Surfacing
- Recessed Lighting
PRECAST CONCRETE

Advantages
- quick installation

Disadvantages
- less flexibility
- joints
- leakage
PRECAST CONCRETE

✓ Three-sided arch structure
PRECAST CONCRETE

- Three-sided arch structure
- Spans up to 35’
PRECAST CONCRETE

- Delivered to the site in 4’ to 8’ sections
- Spans up to 15’
- Base preparation is important
PRECAST CONCRETE

- 3-sided structures used for longer spans
- Spans up to 35’
- Cast-in-place footings required
- Additional Vertical Clearance Required
PRECAST CONCRETE

- Joints
- No control of drainage
- Surface Mounted Lighting
Asphalt paving with curb and gutter
PRECAST CONCRETE

- Textured surfacing
- Recessed lighting
PRECAST CONCRETE

Waterproof joints from the outside
Properly seal and waterproof joints in precast concrete structures

Avoid using in wet locations
CORRUGATED STEEL

✓ Advantages
  - quickest installation
  - least Cost

✓ Disadvantages
  - less flexibility
  - geometric constraints
  - more vertical clearance needed
  - leakage
  - aesthetics
  - service Life
CORRUGATED STEEL

**Underpass**

- **Width:** 1'2" x 1'0" to 20'4" to 17'9"
- **Height:** 6'1" x 4'7" to 20'7" x 13'2"

**Pipe-Arch**

- **Width:** 14' x 14'
- **Height:** 8' x 8'

**Structural Shape Geometry**

<table>
<thead>
<tr>
<th>Shape</th>
<th>Span x Rise</th>
<th>Common Name</th>
<th>Trade Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrel</td>
<td>2' to 20'</td>
<td>Corrugated</td>
<td>X MATERIAL</td>
</tr>
<tr>
<td>Vertical Ellipse</td>
<td>12' x 15'</td>
<td>Corrugated</td>
<td>X MATERIAL</td>
</tr>
<tr>
<td>Underpass</td>
<td>12' x 17'</td>
<td>Corrugated</td>
<td>X MATERIAL</td>
</tr>
<tr>
<td>Pan-Arch</td>
<td>12' x 14'</td>
<td>Corrugated</td>
<td>X MATERIAL</td>
</tr>
<tr>
<td>Horizontal Ellipse</td>
<td>7' x 3'5&quot;</td>
<td>Corrugated</td>
<td>X MATERIAL</td>
</tr>
<tr>
<td>Arch Single Radius</td>
<td>4' x 5'2&quot;</td>
<td>Corrugated</td>
<td>X MATERIAL</td>
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<tr>
<td>Low Profile Arch</td>
<td>3'2&quot; x 1'6&quot;</td>
<td>Corrugated</td>
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</tr>
<tr>
<td>High Profile Arch</td>
<td>3'2&quot; x 1'6&quot;</td>
<td>Corrugated</td>
<td>X MATERIAL</td>
</tr>
<tr>
<td>Pan-Arch</td>
<td>3'2&quot; x 4'8&quot;</td>
<td>Corrugated</td>
<td>X MATERIAL</td>
</tr>
<tr>
<td>Pier</td>
<td>27' x 35'</td>
<td>Corrugated</td>
<td>X MATERIAL</td>
</tr>
<tr>
<td>Horizontal Ellipse</td>
<td>17' x 32'</td>
<td>Corrugated</td>
<td>X MATERIAL</td>
</tr>
<tr>
<td>Box Culvert</td>
<td>8' x 24'</td>
<td>Corrugated</td>
<td>X MATERIAL</td>
</tr>
</tbody>
</table>

* Longer span sizes are available up to 30 ft. spans. Call your local Sales Engineer for more information.
CORRUGATED STEEL

Assembled on site and lifted in place
CORRUGATED STEEL

✓ Circular pipe
CORRUGATED STEEL

✓ Concrete collar required

✓ Vertical arch “underpass” shape
CORRUGATED STEEL

✓ Three-sided arch
CORRUGATED STEEL

Surface mounted lighting
WALL TYPES

- Cast-In-Place Concrete
- Mechanically Stabilized Earth
- Gravity Wall
WALL TYPES

- **Cast-In-Place Concrete**
  - $H = 20\text{'}+$

- **Mechanically Stabilized Earth**
  - $H = 20\text{'}+$
  - Reinforcing Needed

- **Rock Gravity Wall**
  - $H = 4\text{'}-5\text{'}$
  - Multiple Tears
✓ Consider constructability issues
DRAINAGE

- Underpasses are low and dark
  - drainage is critical
- Avoid cross-path drainage
- Collect drainage before entering underpass
- Consider icing issues
DRAINAGE

🔹 Direct water away from path
🔹 Control water, keep it from crossing path
🔹 Locate inlets at low points, off travel way
DRAINAGE

Controlling water contains debris
Better to direct drainage away from path rather than to the center.
Better to control drainage and catch it outside the structure.
Standing water and debris reduces user value
DRAINAGE

✓ Must provide drainage outfall
DRAINAGE

- Outfall location water surface must be below inlet elevation
- Consider back-flow conditions and flood wall heights
DRAINAGE
Lift station design
Provide access to lift station and control panel
Avoid Drainage Mistakes!
LIGHTING

✅ Natural and artificial lighting
✅ Balance interior and exterior light
✅ Provide approach lighting
✅ Vandal resistance & maintenance
LIGHTING

Various levels of vandal resistance and aesthetics available
Lighting is most critical in long structures.

☑ Bright interior color helps.
Lighting

- Skylights
  - provide natural light
  - brighten long underpasses
  - Median required
LIGHTING

✓ Provide approach lighting
SAFETY CONSIDERATIONS

✓ Safety Concerns
  • collisions / user conflicts
  • wipe-outs

✓ Safety Solutions
  • channelize / separate users
  • provide adequate visibility
  • control speeds
  • control water / ice / debris
  • provide slope protection (railings and barriers)

✓ CONSIDER THESE THROUGHOUT THE DESIGN
SAFEY CONSIDERATIONS

✓ Provide warnings and channelization
SAFETY CONSIDERATIONS

- Center striping
Island channelization to improve user separation
SAFETY CONSIDERATIONS

✓ Don’t encourage conflicts
✓ Enhance sight lines with mirrors
SAFETY CONSIDERATIONS

- Provide warnings
SAFETY CONSIDERATIONS

✓ Control user movements
Delineate edges
SAFETY CONSIDERATIONS

☑ Control speed
SAFETY CONSIDERATIONS

✓ Consider visibility
ESTIMATING UNDERPASS COST

- Underpass Structure $100-$200 / SF .................. 14’x100’=$140k - $280k
- Temporary Traffic Control ........................................ $50k - $200k
- Concrete Path $4 - $8 / SF ................................. 10’x600’=$24k - $48k
- Drainage ................................................................. $5k - $50k
- Lighting ................................................................. $5k - $25k
- Pavement Restoration $2 - $4 / SF ...................... 100’x75’ = $15k - $30k
- Railings $50 -$200 / LF ........................................... x100’ = $5k - $20k
- Retaining Walls $20 - $60 / SF ............................. 15’x100’ = $30k - $90k
- Landscape .............................................................
- Utilities ...............................................................
- Right of Way .......................................................
Question 6:
What are the details?

✓ Pedestrian Overpass
PURPOSE OF BRIDGE

✓ Functional
  • aesthetics don’t matter
  • low cost is everything

✓ Statement
  • gateway
  • community icon
  • cost doesn’t matter

On a system of Functional Bridges try to include a Statement Bridge every now and then!!!
BRIDGE NOMENCLATURE

Pedestrian Bridge - Alternate 4
Three-Span Bow String
Combination Truss
TRAFFIC BRIDGE ISSUES

✓ Critical Issues
  • bridge selection
  • ramp length & configuration

✓ Other Issues
  • constructability
  • railings
  • lighting
RIVER BRIDGE ISSUES

✓ Critical Issues
  • bridge selection
  • river impact
  • constructability

✓ Other Issues
  • railings
  • lighting
DESIGN LOADS

- Dead Load ~ Structure Self Weight
- Pedestrian Load
  - 85 psf AASHTO
  - reduce per span length (65 psf min)
- Vehicle Load
  - maintenance (10,000 lb typical)
  - emergency (54,000 lb)
  - Snow Cat (6,000 lb)
  - equestrian
- Snow, Wind, Thermal & Earthquake
CLEARANCES

✓ Vertical
  • Street & Highway ~ AASHTO ~ 16.5’
  • Railroad ~ AREMA ~ 25.0’
  • River
    • Local ~ 2’ min. over 100-year event
    • DOT ~ F = 0.89*Q^{0.3} + 0.26*V^2

✓ Horizontal
  • Approach width plus 2’ recommended
  • Approach width plus 0’ common
BRIDGE TYPES

- **Girder**
  - Short Spans
  - 5’ to 100’

- **Truss**
  - Medium Spans
  - 20’ to 150’

- **Arch**
  - Medium Spans
  - 50’ to 300’

- **Cable Stay**
  - Long Spans
  - 100’ to 300’

- **Suspension**
  - Long Spans
  - 200’ to 500’
SUPERSTRUCTURE COSTS

Span Length vs. Cost

- $100
- $200
- $300
- $400
- $500

0 Piers

0 100 200 300
BRIDGE AESTHETICS

✓ Integral to Bridge Structure
  • truss
  • arch
  • cable Stay
  • suspension

✓ Add-on aesthetics
  • railings
  • pilasters at abutments
  • veneers

Try to make the bridge crossing and viewing experience memorable!!!
GIRDER BRIDGE

✓ **Material Types**
  - steel
  - concrete
  - timber

✓ **Advantages**
  - many fabrication & construction options
  - unique identity with railing
  - cost ~ $75 - $150 / sf

✓ **Disadvantages**
  - girder depth & vertical clearance
STEEL
STEEL
TIMBER
TRUSS BRIDGE

✓ Material Types
  • steel
  • timber
  • fiberglass (FRP)

✓ Advantages
  • fitting aesthetics
  • railing integral with structure
  • easy construction
  • installs quickly
  • cost ~ $75 - $150 / sf

✓ Disadvantages
  • lead time
  • “common” look
TRUSS BRIDGE
TRUSS BRIDGE
TRUSS BRIDGE
ARCH BRIDGE

✓ Material types
  - steel
  - concrete
  - timber

✓ Advantages
  - graceful aesthetics
  - low below trail profile

✓ Disadvantages
  - cost ~ $150 - $300 / sf
ARCH BRIDGE
ARCH BRIDGE
CABLE STAY BRIDGE

✓ Material Types
  • steel
  • timber
  • concrete

✓ Advantages
  • aesthetics
  • long span
  • low profile

✓ Disadvantages
  • cost ~ $400 - $500 / sf
  • few contractors
CABLE STAY BRIDGE
CABLE STAY BRIDGE
Material Types
- steel
- concrete
- timber

Advantages
- long river crossings
- graceful aesthetics
- inaccessible pier locations

Disadvantages
- few contractors
- cost ~ $400 - $500 / sf
SUSPENSION BRIDGE
SUSPENSION BRIDGE
APPROACH RAMPS

✓ Use ADA Guidelines
✓ Long Ramps Due to Vertical Clearances
  • 370’ at 5%
  • 225’ at 8.33%
✓ Significant “Overlooked” Cost
APPROACH RAMPS
ABUTMENTS & PIERS

✔ Types
• footings
• piles*
• caissons*
• helical/screw

✔ Cost
• abutment ~ $5,000 to $15,000
• pier ~ $5,000 to $25,000

✔ Requires soils investigation & utility locates

* Preferred when scour is possible
BENEFIT OF PIERS

Span Length vs. Cost

0 Piers
1 Pier
2 Piers
IMPACT TO RIVER

- Regulatory Requirements
- Freeboard & Bridge Depth
- Approach Embankments
IMPACT TO RIVER

- Number of Piers
- Scour Protection
- Construction
- Wetland Impact
- Mitigation
BRIDGE RAILINGS

✓ Urban & High Risk Areas *
  • IBC-based
  • 42” high
  • 4” sphere to 34”, 8” sphere above 34”

✓ Highway Overpass
  • 2” sphere to 7’-10”

* USFS Trail Bridge Catalogue
BRIDGE RAILINGS
BRIDGE RAILINGS

✓ Rural & Moderate Risk Areas *
  • AASHTO-based
  • 42” for peds & 54” for bikes + equestrian
  • 6” sphere to 27”, 8” sphere above 27”

* USFS Trail Bridge Catalogue
BRIDGE RAILINGS
BRIDGE RAILINGS
BRIDGE RAILINGS

✓ Remote & Low Risk Areas *
  • OSHA-based
  • 42” for peds & 54” for bikes + equestrian
  • 15” between 2”x4” wood rails and 19” between steel rails

* USFS Trail Bridge Catalogue
BRIDGE LIGHTING

- Functional = Safe
- Architectural
- Human scale
- Vandal resistant
- Maintenance

LED use is revolutionizing lighting!!!
BRIDGE LIGHTING
BRIDGE LIGHTING
BRIDGE LIGHTING
BRIDGE LIGHTING
## UNDERPASS VS. BRIDGE

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<tr>
<th>CATEGORY</th>
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<th>OVERPASS</th>
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<tbody>
<tr>
<td>Safety</td>
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<tr>
<td>Convenience</td>
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<td>User Experience</td>
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<td>Resident Impact</td>
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<td>Aesthetics</td>
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<tr>
<td>Constructability</td>
<td><strong>Red</strong></td>
<td><strong>Neutral</strong></td>
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<tr>
<td>Cost</td>
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### Legend
- **Clear** Advantage
- **Neutral**
- **Clear Disadvantage**

*Image and text credit: Alta Planning + Design*
COST CONSIDERATIONS

- Grading & Drainage
- Utility Relocation
- Traffic Control
- Retaining Walls
- Main Structure
- Secondary Structure
- Railings
- Street or River Repair
- Path Concrete
- Landscaping
- Right-of-way

Costs add up quickly.

Don’t get caught short.
✓ Is crossing at-grade or separated
✓ Do you go over or under
✓ What is the best location
✓ How is it accessed
✓ Figure out the details
✓ Make sure you budget enough $$$
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