



**Durability • Efficiency • Longevity • Trust**

**Precast Concrete for Underground Infrastructure:  
*Why It Matters***

# Table of Contents

Executive Summary 3

Introduction & Historical Context 4

Benefits of Precast Underground Infrastructure 5

Technical Advantages — Materials, Durability & Watertightness 6

Joint Systems & Sealing Technologies 7

Hydraulic & Structural Performance 8

Installation Efficiency & Safety 9

Life-Cycle Costs, Resilience & Sustainability 9

Design, Specification & Agency Standards 10

Mix Design Examples & Quality Assurance 11

Best Practices & Implementation Considerations 12

Case Studies (with visual examples) 13

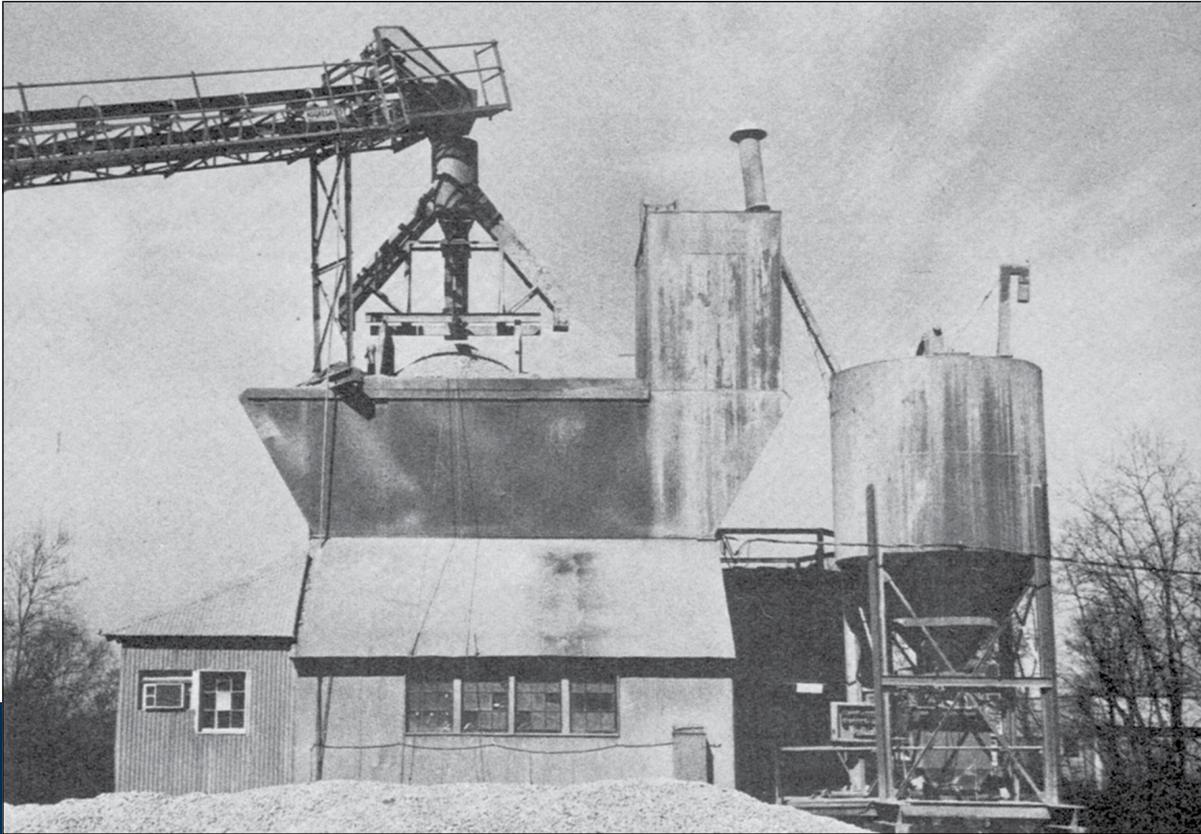
References & Technical Footnotes 14



Modern infrastructure demands reliability, speed, and cost-effective solutions. Precast concrete meets these requirements through controlled production, predictable performance, and exceptional durability. For underground applications such as box culverts, manholes, vaults, and stormwater systems, precast systems reduce installation time, extend service life, and minimize maintenance costs.

This whitepaper outlines the technical and economic advantages of precast concrete for underground infrastructure, including material performance, hydraulic design, agency specifications, and life-cycle considerations. It is intended as a technical foundation for engineers, contractors, municipal planners, and regulatory agencies.

# History of Precast Underground Infrastructure

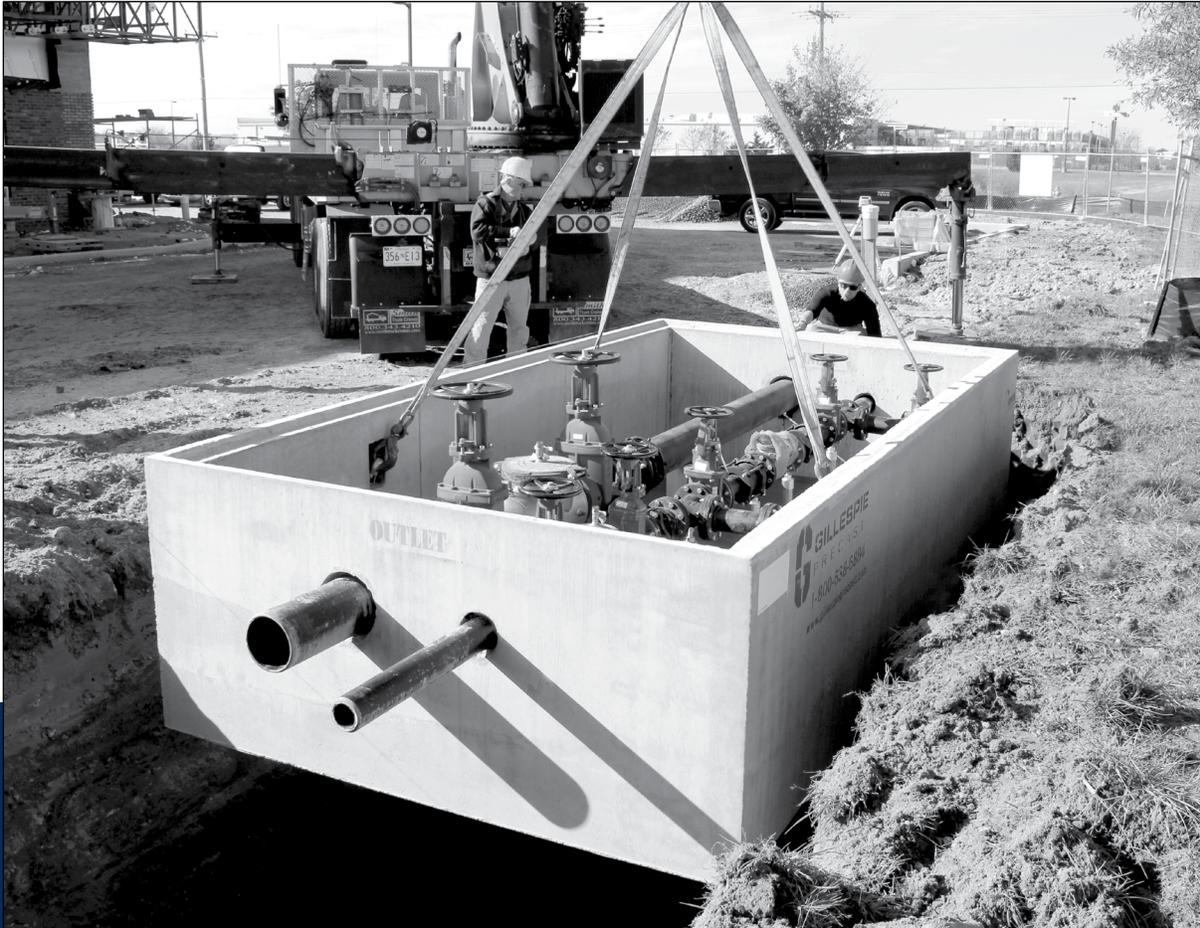


Precast concrete's use in underground infrastructure dates back more than a century. Its rise coincides with the evolution of modern transportation, wastewater treatment, and stormwater management systems. Manufacturing components off-site allows for precise quality control and faster field installation.<sup>6</sup>

## Key Historical Milestones

- Early 1900s: Introduction of factory-made concrete pipe.
- Mid-1900s: Expansion of precast vaults, culverts, and stormwater structures.
- 2000s–Today: Adoption of accelerated construction practices and performance-based specifications across federal and state agencies.

## Benefits of Precast Underground Infrastructure



### Precast systems offer:

- Factory-controlled quality — ensuring uniform material properties.
- Accelerated construction — minimizing site disruption and weather delays.
- Long service life — 50 to 100 years with proper design.
- Watertight performance — proven jointing systems reduce infiltration/exfiltration.
- Reduced total cost of ownership — lower maintenance and user-delay costs.

## Technical Advantages



## Materials, Durability & Watertightness

### Controlled Production

Precast elements are manufactured in NPCA or PCI-certified facilities. Temperature, curing cycles, reinforcement placement, and dimensional tolerances are closely monitored.<sup>3</sup> These controls:

- Increase compressive strength.
- Lower permeability.
- Provide consistent fit for joints and connections.

### Durability

High-quality precast concrete offers:

- Excellent resistance to freeze-thaw cycles.<sup>6</sup>
- High abrasion resistance.
- Protection of steel reinforcement through concrete alkalinity.

### Service Life Expectations

Precast structures often achieve design service lives of 75–100 years when manufactured to specification and installed correctly.<sup>1</sup>

# Joint Systems & Sealing Technologies

Watertightness is a critical performance parameter for underground infrastructure. Precast systems use standardized and tested joints.

## Typical Joint Types

- Tongue-and-Groove with Gasket — common for manholes and vaults.
- Butt Joint with External Wrap — used for stormwater and sanitary structures.
- Rubber Gasket Joints (ASTM C443) — standard for watertight pipe connections.

## Testing and Standards

- ASTM C443 — Rubber gasket joints.
- ASTM C478 — Precast manhole sections.
- ASTM C990 — External joint wraps.
- Watertightness testing often includes hydrostatic or vacuum pressure tests to verify infiltration limits.<sup>4</sup>



# Hydraulic & Structural Performance

## Hydraulic Efficiency

Smooth factory finishes reduce friction losses, improving flow and capacity. This is critical in stormwater culverts and detention structures.

- Precast box culverts meet FHWA HDS design standards.<sup>2</sup>
- Reduced head loss compared to corrugated or rough materials.

## Structural Performance

- Designed to withstand earth loads, live loads (AASHTO HL-93), and buoyancy.<sup>5</sup>
- Controlled reinforcement placement ensures uniform stress distribution.
- Integral joints help maintain structural integrity over long service life.



## Life-Cycle Costs, Resilience & Sustainability

While initial unit costs may be similar to cast-in-place or alternate materials, total cost of ownership favors precast:

- Fewer repairs and lower infiltration maintenance.
- Faster installations reduce user-delay costs.
- Longer service life extends replacement cycles.
- Reusable forms and efficient batching lower environmental impact.

Many state DOTs and municipalities have documented savings over a 30–50 year analysis period.<sup>1</sup>

## Installation Efficiency & Safety

### Installation Advantages

- No on-site forming or extended cure time.
- Crane-set elements reduce labor hours.
- Faster restoration of traffic and site access.

### Safety Benefits

- Reduced confined space exposure.
- Lower risk of cold joints and site-cast defects.
- Simplified quality assurance (inspection at plant rather than field).

### Typical Installation Rate

- Precast box culverts: up to 80 linear feet/day (depending on crew and conditions).
- Manholes and vaults: typically installed in one shift.

## Design, Specification & Agency Standards



U.S. Department  
of Transportation

**Federal Highway  
Administration**

### Key guidance documents:

- NPCA Quality Control Manual -  
<https://precast.org/qcmanual/>
- PCI Design Handbook<sup>3</sup> -  
<https://www.pci-central.org/designerresources>
- FHWA Precast/Prefabricated Bridge Elements & Systems guidelines -  
<https://prltap.org/eng/wp-content/uploads/2025/09/Prefabricated-Bridge-Elements-Systems-PBES.pdf>
- ASTM C478, C890, C1433, C1577: structural and dimensional standards -  
<https://webstore.ansi.org/sdo/astm>
- AASHTO LRFD Bridge Design Specifications: load rating and design<sup>5</sup> -  
<https://aashtojournal.transportation.org/aashto-issues-10th-lrfd-bridge-design-spec-edition/>

# Mix Design Examples & Quality Assurance



## Typical Mix Design (General)

- Compressive strength: 5,000–6,000 psi (target)
- w/cm ratio:  $\leq 0.40$
- Cementitious: Portland + SCMs (e.g., fly ash, slag)
- Air content: 5–7% (for freeze-thaw resistance)
- Reinforcement: ASTM A615 or epoxy-coated bar, or GFRP where specified

## QA/QC Protocols

- Compressive strength testing per ASTM C39.
- Air and slump tests per ASTM C231 / C143.
- Dimensional tolerance checks per ASTM standards.<sup>4</sup>
- Joint gasket inspection and hydrostatic tests as required.

# Best Practices & Implementation Considerations

- Early coordination of logistics (crane capacity, truck access, panel weights).
- Design for durability: specify exposure class, cover depth, SCMs as needed.
- Use certified plants (NPCA or PCI).
- Standardize joint systems across project phases to simplify inspection.
- Include life-cycle cost analysis during planning to evaluate long-term savings.<sup>2</sup>



## Case Studies

### **Case Study 1: Effects of Inlet Geometry on Hydraulic Performance of Box Culverts** (Report No. FHWA-HRT-06-138)

Source: Federal Highway Administration (FHWA)

Link: <https://www.fhwa.dot.gov/publications/research/infrastructure/hydraulics/06138/chapt1.cfm>

Summary:

- Investigates hydraulic performance of precast box culverts under varying inlet geometries.
- Includes laboratory and field testing to determine flow efficiency, head loss, and scour risk.
- Provides data that supports precast design decisions for municipal stormwater and highway drainage systems.
- Highlights improved hydraulic efficiency and long-term performance of precast culverts.

### **Case Study 2: Precast Bent System for High Seismic Regions (FHWA, FHWA-HIF-13-037)**

Source: Federal Highway Administration (FHWA)

Link: [https://www.fhwa.dot.gov/hfl/partnerships/precast\\_bridge/hif13037/hif13037.pdf](https://www.fhwa.dot.gov/hfl/partnerships/precast_bridge/hif13037/hif13037.pdf)

Summary:

- Focuses on precast bent and superstructure systems for bridges in high seismic zones.
- Shows how precast systems reduce site labor, enhance quality control, and shorten project schedules.
- Validates precast use for durable, high-performance infrastructure components.

### **Case Study 3: Precast Concrete Pavement Technology Implementation** (FHWA, FHWA-HIF-19-013)

Source: Federal Highway Administration (FHWA)

Link: [https://www.fhwa.dot.gov/hfl/partnerships/precast\\_bridge/hif13037/hif13037.pdf](https://www.fhwa.dot.gov/hfl/partnerships/precast_bridge/hif13037/hif13037.pdf)

Summary:

- Examines deployment of precast concrete pavement (PCP) across multiple U.S. states.
- Highlights accelerated installation, reducing lane closures and traffic disruption compared to cast-in-place methods.
- Documents performance, durability, and life-cycle benefits of precast elements in roadway infrastructure.
- Supports long-term savings and operational efficiency for DOT projects.



## References & Technical Footnotes

1. NPCA — Lifecycle and durability guidance.
2. FHWA PBES and culvert manuals.
3. PCI Certification and MNL manuals.
4. ASTM standards C443, C478, C990, etc.
5. AASHTO LRFD Bridge Design Specifications.
6. Goodfellow, Concrete for Underground Structures.
7. NPCA Case Study Index: <https://precast.org/case-studies/>
8. FHWA Innovative Infrastructure Projects: <https://www.fhwa.dot.gov/innovation/>
9. PCI Bridge Case Studies: [https://www.pci.org/PCI/Design\\_Resources/Project\\_Profiles.aspx](https://www.pci.org/PCI/Design_Resources/Project_Profiles.aspx)



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