Approximately 35 percent of the bridges in the United States are classified as deficient (The 1993 report of the secretary of transportation to the U.S. Congress)

- structurally deficient (21 percent)
- functionally obsolete (14 percent)

The Federal Highway Administration (FHWA) estimates that the cost to maintain current overall bridge conditions is estimated at $5.2 billion annually.
Portland Cement Types:
- Type I  General Use
- Type II  Moderate sulfate resistance or moderate heat
- Type III  High early strength
- Type IV  Low heat of hydration
- Type V  Sulfate resistant

Problem:
- Low Strength/Weight Ratio
  - Steel: $\frac{30,000 \text{ psi}}{500 \text{ pcf}} = 60$
  - Concrete: $\frac{3,000 \text{ psi}}{150 \text{ pcf}} = 20$

To improve the ratio:
- (a) Lower the density
- (b) Increase the strength

High-Strength Concrete
- HSC: $\frac{10,000 \text{ psi}}{150 \text{ pcf}} = 66$

Light-Weight Aggregate Conc.
- LWAC: $\frac{10,000 \text{ psi}}{100 \text{ pcf}} = 100$
Progress in Concrete Technology

- Lightweight Concrete
- High-Strength Concrete
- High Workability or Flowing Concrete
- Shrinkage Compensating Concrete
- Fiber-Reinforced Concrete
- Concrete Containing polymers
- Heavyweight Concrete
- Mass Concrete
- Roller-Compacted Concrete

Structural Lightweight Concrete

- Definition:
  - 28-day $f'_{c} \geq 2,500$ psi
  - Unit weight: Min: 90 pcf Max: 110 pcf

- Microstructural Properties:
  - Dense, strong transition Zone due to pozzolanic reaction.
  - Strength more influenced by aggregate characteristics than by transition zone.
Structural Lightweight Concrete

- Freeze-Thaw Resistance
- Permeability
- Creep / Drying Shrinkage
- Abrasion / Erosion Resistance
Applications

- Lower overall cost of the structure
- Bridge Decks
- Floor slabs
- Pre-cast concrete elements

Figure 11-3  Structural lightweight concrete wall panels, 16 ft wide and 27 ft high, are light enough to be handled by a small crane. (Photographs courtesy Expanded Shale, Clay, and Slate Institute, Bethesda, Md.)
High-Strength Concrete

- Definition:
  - 28-day $f'_{c} \geq 6,000$ psi (40 MPa)

- Materials and mix proportions:

- Key: POROSITY in 3 phases

<table>
<thead>
<tr>
<th>Water/Cement Ratio</th>
<th>$f'_{c}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>W/C Ratio</td>
<td></td>
</tr>
<tr>
<td>0.38</td>
<td>6,000 psi</td>
</tr>
<tr>
<td>0.36</td>
<td>7,500 psi</td>
</tr>
<tr>
<td>0.34</td>
<td>9,000 psi</td>
</tr>
</tbody>
</table>

- Problem: Mixing, placing, and consolidation

- Use: Water-Reducing Admixture.
High-Strength Concrete

- The Max Size of Aggregate (MSA):
  - Limit to 3/4 inch or Lower
- Incorporate Pozzolanic Material into the Concrete Mixture
- In Portland Cement:
  \[ C_3S + \text{aq.} \xrightarrow{\text{Fast}} C-S-H + CH \]
- In Portland Pozzolan Cement:
  \[ \text{Pozzolan} + CH + \text{aq.} \xrightarrow{\text{Slow}} C-S-H \]
High-Strength Concrete

Applications

- High-Rise Projects
  Construction of RC frames of buildings 30 stories and higher/upper 1/3 conventional RC—reduction in size of the columns in the lower 2/3 of the building

- Bridges
  Reduces the risk of thermal cracking

- Stilling Basin of Dams
  Long-term durability to abrasion-erosion

- Floating Concrete Container Terminals
  (Valdez, AK; Tacoma, WA)
  High durability in seawater

High-Strength Concrete

New Tjorn bridge in Sweden was designed and built in less than 2 years
High-Strength Concrete

No, these are not craters on the moon. This is the result of abrasion-erosion damage to the concrete stilling basin at the Kinzua Dam in Pennsylvania.

High-Strength Concrete

TWO PRUDENTIAL PLAZA
High-Strength Concrete
Concrete Damage Due to Earthquake

Cypress Structure
Oakland, California
October 17, 1989

San Francisco Earthquake - 1989
San Francisco Earthquake - 1989

[Image of damaged structure from the San Francisco Earthquake of 1989]
San Francisco Earthquake - 1989

San Francisco Earthquake - 1989
San Francisco Earthquake - 1989

San Francisco Earthquake - 1989