the sky's concrete the limit
INTRODUCTION

Airports are the gateways to a region and are critical lifelines to their communities’ economic vitality. They allow communities to position themselves competitively as favorable places to live, work, and locate a business. Increased passenger usage, inadequate capacity, and aging infrastructure are the compelling reasons that federal, state, and local entities are investing heavily in airport infrastructure.

Since the very beginning of airport construction, reinforced concrete has proved itself an invaluable material for building airports, from runways to terminals, parking structures to roadways, people movers to hotels.

Airport owners rely on reinforced concrete for its durability and economic advantage. Designers rely on its versatility and strength. Contractors rely on its availability and ease of construction. And the travelling public appreciates its beauty and functionality.

With reinforced concrete, the sky’s the limit as the aviation industry strives to create, expand, and renovate its airside and landside facilities. The Concrete Reinforcing Steel Institute is pleased to present this overview of reinforced concrete’s many diverse airport applications.
Many of the nation’s airports were built in the 1950s and 1960s at the onset of the jet age. In 1960, nearly 58 million passengers enplaned. By 1998 that number had grown to 614 million, and is expected to reach one billion by 2010.

Federal Grant-in-Aid to Airports

The demand for air travel has increased ever since Orville Wright took flight on the 17th of December 1903. By the early 1920’s, the aviation industry was urging the federal government to regulate civil aviation, knowing that airplanes could not reach their full potential without Federal action to improve safety standards.

The first air traffic control towers were commissioned in 1936. Post World War II saw the first federal aid airport aimed exclusively at developing the nation’s civil airports. Federal funding has grown ever since (see graph), and local and private funding has kept pace.

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Endures

Passenger Enplanements

Long-Term Value

Airports are now in serious need of repair and expansion. The Wendell H. Ford Aviation Investment Reform Act for the 21st Century (AIR-21) nearly doubles the federal airport improvement program allocations over previous years, infusing $40 billion over three years into various programs for airport construction and modernization.

Despite this infusion of new funding, airport owners and developers continue to look for best short- and long-term value when planning their projects. Reinforced concrete consistently delivers lower capital cost and higher long-term durability, resulting in lower life-cycle costs overall.

“We clearly need to improve and expand America’s transportation system in a way that not only sustains prosperity, but also improves our quality of life.”

— Rodney E. Slater, U.S. Secretary of Transportation

$ Billions

2000 2001 2002 2003

Proposed Airport Improvement Funds

AIR 21 funding will increase federal aviation spending by nearly 70%.
Runways and Smooth

The need for new runway capacity is among the most politically difficult and budget-straining challenges facing airports today. Many airports looking for alternatives to short-lived asphalt runways have turned to continuously reinforced concrete pavement. It offers greater strength and longevity than other runway materials, with a lower life-cycle cost.

**Strongest Pavement in the World**

Air Force Plant 42 in Palmdale, California is home to ten major aerospace technology and manufacturing corporations that are creating the military aircraft of the future. Plant 42 shares its airfield complex with Department of Airports, City of Los Angeles.

In anticipation of a one-million-pound aircraft being designed and built at Air Force Plant 42, in 1970, engineers chose to design and construct the Palmdale Airport runway with the strongest and thinnest pavement possible: continuously reinforced concrete pavement.

Although a one-million-pound plane (compared to a Boeing 747 at 875,000 pounds) never came to fruition, the newer military aircraft, with extremely high tire pressure and specialized gear configuration, impose intense loads on the runways, much greater than that of current commercial aircraft.

After 30 years of heavy use, Palmdale Airport’s runway is nearly intact. A recent study gives the runway another 25 years of trouble-free operation. Fifty-five years of tremendous performance for a fourteen-inch thick slab with No. 5 reinforcing bars at 6-inches on-center. Using continuously reinforced concrete pavement really paid off.

“Military aircraft are notorious for being pavement destroyers. Despite the heavy loads and continual use, the performance of our CRCP runway has been terrific.”

— Peter Mok, Chief Engineer, Air Force Plant 42
**O’Hare’s True Workhorse**

With nearly 2,500 aircraft operations each day (nearly 900,000 yearly carrying over 72.6 million passengers) Chicago O’Hare International Airport remains the commercial aviation capital of the world.

Chicago’s Midway Airport held the distinction of busiest airport in the world until mid-1962, when all scheduled operations at Midway were transferred to O’Hare. Shortly after, O’Hare built three major new runways and several taxiways, all of continuously reinforced concrete pavement.

CRCP was chosen because of the prospect of significantly lower maintenance. And CRCP proved itself, even under non-stop aircraft landings and departures. Since being overlayed with asphalt in 1994, the CRCP is still serving O’Hare as a super-strong structural support for the new surface layer.

“CRCP served Chicago O’Hare very well with no major rehabilitation for over 35 years of heavy use.”

— Stephen Shulus, P.E., Chief Airport Engineer
Chicago O’Hare International Airport
Reinforced concrete allows architects and engineers freedom of creativity to produce stunning landmark designs for airport terminals. From breathtaking overhangs to graceful curves evoking the elegance of flight, the most expressive architectural forms can be cost-effectively achieved with easily molded reinforced concrete.

**Gateway to the Skies**

With more than 36 million passenger enplanes and deplanes yearly, Sky Harbor International is the nation’s fifth busiest airport. Central to a major expansion to handle this and more traffic was Barry M. Goldwater Terminal.

Passengers approaching the airport by car encounter a dramatic concrete façade dominated by helical ramps that access the parking garage. Each ramp consists of a 21-foot-wide post-tensioned concrete slab cantilevered from a two-foot-thick, cast-in-place concrete circular core wall.

"Concrete had always been central to the airport’s overall design, so it was a natural, aesthetically pleasing choice for blending the new with the old. And we achieved our other objectives: fast construction, low maintenance, and high durability.”

— David Hensley
Airport Development Engineer
City of Phoenix Aviation Department

In an interesting departure from typical post-and-beam construction, Y-shaped columns form a structurally integrated continuous support for a dual-level roadway system and the parking levels above and add a distinctive, flight-oriented metaphor to the facade.

Inside the parking levels, a unique method helped to reduce restraint forces and cracking in the post-tensioned decks. In the “soft column” technique, the bottom one foot of each perimeter support column was left partially uncast, with its reinforcing steel acting as a hinge to allow creep and shrinkage of the massive 100,000-square-foot deck slabs above. Ninety days after post-tensioning, the bottoms of the soft columns were filled with concrete grout for a crack-free finish.
**Spacious Structures**

Surrounded by crystal-blue lakes and a golf-course-like setting, Orlando International is often referred to as “The World’s Most Beautiful Airport.”

The new Landmark Terminal has used that setting to great advantage. But the extraordinary size and complexity of this expansion project required some imaginative structural solutions.

Covering 1.2 million square feet, the four-level terminal employs a reinforced concrete two-way space frame system to support a seven-story parking garage and a hotel. The focal point is an 85-foot-high, 240-foot by 120-foot atrium that includes a 25,000 square-foot skylight.

Mild reinforcing steel within the cast-in-place concrete waffle slab afforded the strength needed to avoid shear walls and the visual obstruction of columns in the vast open space of the atrium.

“Our goal was to eliminate as many columns as possible. We didn’t want our passengers to see the structural gymnastics behind the scenes.”

— Walter Taylor, KBJ Architects, Inc.

Orlando International Airport  
Landslide Terminal  
Orlando, Florida  
Owner: Greater Orlando Aviation Authority  
Architect: KBJ Architects, Inc.  
Engineer: Kun-Young Chiu & Associates, Inc.  
Contractor: Great Southwest Corporation
Airport infrastructure is no longer the unsung and invisible hero. Airport owners want durable structures with low life-cycle costs. They also want structures that reflect aviation’s grandeur and innovation. Reinforced concrete provides both.

**The Future Takes Off**

At 321 feet, the John F. Kennedy International Airport air traffic control tower is one of the tallest in North America. The striking white reinforced concrete shaft was designed to FAA’s stringent requirements for rigidity and reduced sway caused by the Atlantic Ocean’s severe coastal winds.

The FAA cab and a sophisticated radar unit sit atop 1,620 yards of cast-in-place reinforced concrete. JFK’s new control tower provides improved observation and state-of-the-art electronic equipment to monitor and guide over 343,000 aircraft movements each year.

Epoxy-coated reinforcing bars were used in the structure’s outer layers to prevent rust staining on the pristine white concrete exterior surfaces. Uncoated interior reinforcing bars ground the tower’s lightning protection system.

“JFK’s new tower symbolizes the start of the multi-billion dollar expansion that will take our airport well into the 21st century.”

— Frank Lombardi, P.E., Chief Engineer
Port Authority of New York and New Jersey
Cool Functionality

Reinforced concrete has been the predominant construction material at SeaTac since its beginning. SeaTac’s new twin cooling towers, constructed of conventionally reinforced concrete, are consistent with the airport’s simple and subtly organic style.

Although the cooling towers serve a highly functional purpose, to create chilled water for the airport’s air conditioning system, they also create an artistic visual statement to passers-by.

Water falling through the ceramic cooling media is funnelled toward the outside of the structure, making a 20-foot waterfall that is fully visible from Deplane Drive. The 6,500 gallon-per-minute flow then hits a sloped concrete slab and pours out again as a pair of 12-foot waterfalls into an oval concrete basin below.

These dramatic waterfalls furnish 7,000 tons of cooling capacity, dropping the water temperature 10 to 15 degrees before it enters the air conditioning units located nearby. The circulating air from these units cools the entire airport, ultimately cooling the airplanes as they sit at the gate.
Nearly every major airport today uses parking structures to bring its car-driving passengers as close to the terminal as possible. And most parking structures are built with reinforced concrete, an ideal material, providing versatility for creating ramps and decks, and durability for low initial cost and less long-term maintenance.

Filling a Critical Need

Nevada’s population has increased more than 66 percent over the past decade, more than any state in the nation. To keep pace with this tremendous expansion, Las Vegas’s McCarran International Airport is proactively renovating, reconfiguring and expanding its facilities.

A new nine-level parking structure is filling the critical need for short-term parking capacity for airport visitors and employees. Operational flexibility is the key to the garage’s success. A complex variety of dedicated ramps and roadways flow into and through the garage, including a helical ramp that accesses two floors.

Utilizing the local workforce was a compelling reason to use cast-in-place concrete, in lieu of precast, to construct the parking structure. Las Vegas-based concrete and reinforcing steel suppliers, testing laboratories, contractors, and laborers together build the garage.

Controlling the rate of concrete cure in Las Vegas’s intense heat was one of the biggest construction challenges. Soaker hoses, sprinklers, and burlap and plastic covers all allowed concrete to properly cure.

“With cast-in-place concrete, we can eliminate many of the shear walls that would be necessary with pre-cast concrete construction. Cast-in-place also allows us to build a big open deck with high ceilings. People feel more comfortable in an open structure.”

— Dick Kenney, P.E., Vice President, Walker Parking Consultants
Full Operability

San Francisco International Airport’s new International Terminal provides a world-class welcome to an expected 12 million passengers each year. Two new cast-in-place reinforced concrete garages, one on each side of the central airport roadway, provide over 3,000 short-term parking spaces close to the new International Terminal.

Cost effectiveness, combined with superior seismic performance, was the main design criteria. The airport designated the South Parking Garage as a “critical structure,” to remain fully operational with only repairable structural damage after a major earthquake.

SFIA, adjacent to the San Francisco Bay, sits on very soft soil, known to amplify seismic ground motion. Hundreds of 16-inch-square concrete piles 80 to 100 feet long were used to support the garages. The heavily reinforced piles use a sophisticated low-permeability, high-strength concrete mix.

High-ductility reinforced concrete shear walls with state-of-the-art reinforcing details are strategically placed throughout both garages. Circular ramps at the west end of each permit the use of flat concrete slab floor diaphragms, which double as seismic structural elements.

“Starting from the foundation up, cast-in-place concrete lends itself well to our facilities. Structurally, it can be designed to withstand severe seismic shaking and liquefaction. And concrete is readily available and cost effective.”

— Ivar Sataro, Project Manager
Bureau of Design and Construction
San Francisco Airport Commission

San Francisco International Airport
North and South Parking Garages
San Francisco, California
Owner: City and County of San Francisco
Architect: MBT Architecture and ED2 International
Engineer: Degenkolb and Forell/Elsesser
Contractor: Tudor Saliba
Streamlining vehicular arrival into and departure out of an airport eases a passenger’s journey and expands the airport’s capacity. Because of its strength, durability, and cost effectiveness, “concrete” is nearly synonymous with bridges throughout the aviation world. And concrete pavement that is continuously reinforced with steel is gaining in popularity as airport owners recognize its superiority over other pavement materials.

Superior Pavement

Houston’s Hardy and Sam Houston Toll Roads have carried well over a billion patrons into and around Houston since the first segment opened in 1987. The latest addition to the toll road system is a 1.2-mile connector from Hardy Toll Road to Bush Intercontinental Airport.

All 83 miles of Harris County’s toll road system are paved with continuously reinforced concrete pavement. CRCP provides superior performance. That’s why the Texas Department of Transportation, Harris County Toll Road Authority, and other forward-thinking transportation departments around the country routinely use CRCP to replace aging pavement or to build new.

Harris County adopted the Texas Department of Transportation’s pavement design standards: 12-inches thick with No. 6 longitudinal reinforcing bars at 6-inch spacing.

This reinforcing creates a pavement that is considerably stronger than any other. Combining greater durability, longer life expectancy, and minimal maintenance requirements, CRCP provides the best long-term value for airport needs.

Elegant Enplane

Savannah International Airport’s Enplane Drive Bridge creates an airport entrance as stately and inviting as the long tree-lined roads leading to Georgia’s antebellum homes. Yet the bridge supports over 600,000 enplaning passengers a year, bringing vehicles directly to the door of terminal’s second floor ticketing area.

The superstructure is a continuous, multi-celled, cast-in-place concrete box structure with reinforced concrete planter boxes cast into the front side of the bridge. The flowers and foliage in the planter are visible to drivers through an open barrier composed of concrete posts and metal railing.

Below, all bridge columns line up with the key design elements of the terminal, resulting in various bridge span lengths ranging from 30 to 100 feet. The closed box structure of uniform depth creates a continuous underside of the bridge, hiding water lines, electrical conduits, and drainpipes within the box.

The box structures are supported by an integral concrete cap on a single column pier. Caps were cast inside the box structure, creating a complex, congested grid of reinforcing bars. By using CADD drawings supplied by the designer, the rebar fabricator accurately and efficiently developed the bar list and details, ultimately saving the project time and money.

“Our continuously reinforced concrete pavement is performing as we anticipated with absolutely no problems.”

— Clenton Wilson
Engineering/Maintenance Department
Harris County Toll Road Authority

Hardy Toll Road Airport Connector
Houston, Texas
Owner: Harris County Toll Road Authority
and City of Houston Department of Aviation
Engineer: Ratheon Infrastructure
Contractor: Champagne-Webber, Inc.
“Separating enplaning and deplaning passengers into two levels creates better traffic flow. But aesthetics are also important. We wanted our lower-level passengers to look up and see a clean, uncluttered ceiling. No exposed girders or utilities. Our concrete bridge is low maintenance and it looks good. We’re very pleased.”

— Clyde Martin
Director of Planning and Engineering
Savannah Airport Commission

Savannah International Airport
Enplane Drive Bridge
Savannah, Georgia
Owner: Savannah Airport Commission
Architect: KBJ Architects, Inc.
Engineer: URS Corporation
Contractor: Dunn Construction Company, Inc.
People mover systems create operational flexibility by allowing fast, ready movement between satellite concourses and main terminals. The infrastructure for nearly every airport people mover system in the world — elevated structures, bridges, tunnels, platforms, and guideways — is built with reinforced concrete. There is simply no other material that matches concrete’s strength, durability, and versatility.

Moving Many People
When Hartsfield Atlanta International Airport’s people mover opened for operation in September 1979, 6 two-car trains served 12 stations. Today, 9 four-car trains operate on a 3.5-mile pinched loop track, pulling into the 14 stations approximately every two minutes and carrying passengers back and forth between the terminal and six concourses.

Hartsfield Atlanta’s people mover carries more passengers than any other automated people mover system in the world, averaging over 1.3 million passengers per week, 68 million total in 1999.

Reliability and durability are critical. While the system operators work diligently to keep the trains in good mechanical working order, solid, trouble-free infrastructure is also important.

And in the 21 years of operation, there have been no major repairs needed to the concrete infrastructure, despite high groundwater pressure on the tunnel walls. No spalling, no cracking, and no loss of traction. Airport operators continue to appreciate concrete’s durability and low maintenance for years.

“High quality initial construction and staying on top of minor maintenance has resulted in our people mover infrastructure performing extremely well.”

— Steve Yates, Manager of People Mover Operations
Hartsfield Atlanta International Airport
Department of Aviation
Concrete’s Smooth Ride

Denver International Airport’s automated ground transportation system (AGTS) is every bit as efficient as the new airport is stunningly beautiful. The AGTS is housed in two parallel tunnels, each nearly a mile long, connecting the terminal with concourses A, B, and C.

In 1998, nearly 37 million passengers passed through the airport, and over half used the AGTS. Because there is no pedestrian access to concourses B and C, the AGTS runs 24 hours per day, seven days a week.

The AGTS tunnels were constructed with a precast floor slab founded on reinforced concrete drilled shafts, leaving a 2-foot space between the ground and the tunnel bottom to account for extreme soil expansion. The walls and roof were then cast-in-place. Running beams were also cast-in-place, and attached to the tunnel floor with dowels and bars.

The AGTS’s concrete running surface was cast-in-place and broom-finished for traction, creating a ride free of jerks and bumps. Concrete provides the foundation for a reliable and extremely smooth ride.

“Our passengers and employees rely heavily on the AGTS to get around the airport. The concrete tunnels and train infrastructure have performed very well with absolutely no major problems.”

— Hana Rocek, P.E., Assistant Deputy Manager, Denver International Airport
Reinforced concrete is an integral and invaluable part of America’s airports. Since 1924, the Concrete Reinforcing Steel Institute has fostered the continued growth of reinforced concrete as an economical, durable, aesthetically pleasing, and extremely versatile airport construction material.

Thanks to the Portland Cement Association for providing historical photographs.