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FALL 2013

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ON THE COVER:
The Howard L. Schrott Center for the Arts, located on the campus of Butler University in Indianapolis, was designed with precast concrete at the forefront. Structural and architectural precast products helped the designer and contractor achieve the desired look and acoustics while also creating many efficiencies that saved time and money.

Cover image compliments of Browning Day Mullins Dierdorf Architects. www.bdmd.com

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The Future of Fly Ash Use in Concrete

Fly ash, the largest industrial waste byproduct, has been beneficially recycled as a partial replacement for portland cement in major U.S. government projects for decades. Why is it currently a controversial issue?

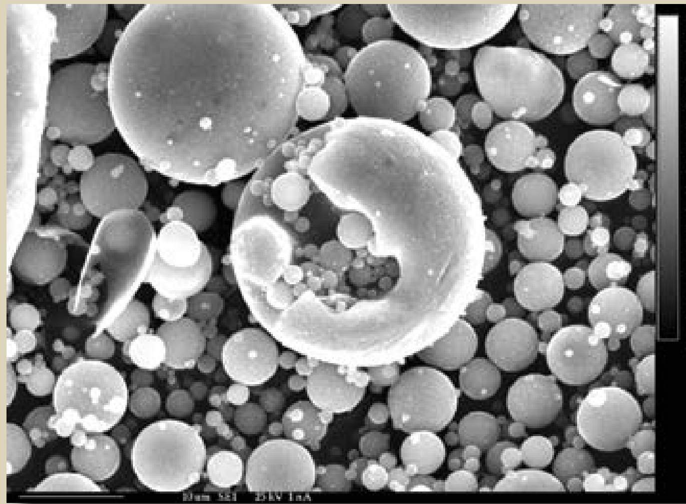
By Sue McCraven

Most people on the street have no idea what fly ash is or how it is used. But for concrete manufacturers, fly ash and the current regulatory controversy spinning around it are a very big deal. After seven decades of beneficial use in concrete structures, the U.S. Environmental Protection Agency (EPA) is currently reassessing the classification, storage, disposal and reuse of fly ash to ensure that it is properly managed to minimize potential harm to human health and the environment.

Structural engineers, infrastructure builders, fossil-fuel power generators, environmental activists and the U.S. Federal Highway Administration (FHWA) are also invested in the ongoing debate over the EPA's recently proposed ruling to reclassify fly ash – after years endorsing its positive contribution to the concrete industry – as a hazardous waste. A balanced discussion of the pros and cons of recycling fly ash (aka coal ash or CCP)[1] in concrete from a global perspective is in order. Let's start with the source of the massive amounts of fly ash: the world's electrical power industry.

What is the main source of electrical power?

The No. 1 source of electrical generation has always been, is today, and likely will continue to be coal.[2] And the burning (combusting) of pulverized coal generates electric power and tons and tons of powdery fly ash residue. Fly ash is captured with electrostatic precipitators, scrubbers or filter fabric baghouses in



power plants, then sluiced to settling basins (wet) prior to disposal or stored in silos (dry) for sale or disposal. In our endless need for power, it makes sense that fly ash has become the earth's largest industrial waste byproduct,[3] but fortunately some of it is diverted for a good purpose. Indeed, certain classes of fly ash are an important component of reinforced concrete, the best composite structural material in the world.

Major role of fly ash in concrete structures

Fly ash is a very fine-particulate material that looks and feels like talcum powder and can be a tan to gray color, depending on its source. It is classified as a pozzolan[4] and with its high silica content is used by concrete producers as a component in the range of 10 to 25% of the cementitious portion of concrete mixtures. Fly ash forms calcium silica hydrate (cementitious material) in addition to that produced by hydration of portland cement.

Worldwide, concrete is used twice as much as all the other building products combined.[5] Concrete is everywhere: in our bridges, roads, buildings, work places and neighborhoods. And underground, concrete foundations support our infrastructure.

Here's where the importance of fly ash in concrete becomes clear: More than 75% of all concrete is made with fly ash. In some states, fly ash is specified for all concrete structures. And the concrete industry is only one of the important entities using this abundant waste material.

Other beneficial uses of fly ash

Fly ash production and its repurposing in various markets are quantified in data from FHWA[6] and EPA[7] (see the sidebar "Fly Ash Reuse"). From these data, we see that the lion's share of recycled fly ash goes into making concrete, and the reason is because fly ash delivers measurable economic and structural benefits. Its worldwide availability, outstanding structural contributions (strength and durability) and relatively economical cost create a constant demand for fly ash in the construction industry.

Several NPCA publications explain fly ash in more technical detail, including its important environmental benefits, its material properties, chemical reactions and guidelines for production.[8] The following is a summary list of fly ash's contribution to concrete:

1. Increases ultimate concrete strength
2. Increases concrete durability
3. Is more economical than portland cement
4. Reduces the heat of hydration (first used in mass concrete construction in the building of Hungry Horse Dam, Montana, 1948)
5. Reduces risk of alkali-silica reaction (ASR)
6. Increases resistance to sulfate attack
7. Reduces concrete bleeding (water loss at the surface after placement)
8. Reduces concrete shrinkage during curing
9. Reduces the amount of water required in mixtures
10. Reduces permeability (increases concrete's resistance to water penetration)
11. Improves workability (microscopic, spherical-shaped particles create a more flowable, easier-to-finish concrete)
12. Lightens the color of concrete
13. Fulfills LEED points (LEED MR 4.1, Reclaimed Materials/Recycled Content) and is routinely specified on many green projects
14. Meets the guidelines of many building codes, design guidelines and standards that encourage fly ash recycling in concrete
15. Meets ASTM standards and test methods (ASTM C618-08, C1240 and C 311-07)[9]
16. Is environmentally beneficial[10]

Left: Fly ash comes from combusted coal, in background, and can be tan to gray in color.

Photo courtesy of HW Headwaters Inc.

Right: Microscopic view of fly ash.

Photo micrograph courtesy of HW Headwaters Inc.

The I-35 bridge near Minneapolis is an example of a large government project that was constructed with fly ash.

Photo credit © Jim Kruger istockphoto.com

Opposition to fly ash

Environmentalists and the EPA are opposed to the wet handling of fly ash (storage of waste CCP slurry in holding ponds) at power plants because of potential violations of The Clean Water Act. A recent report[11] by a coalition of environmental organizations includes this statement from the EPA:

"Coal-fired power plants are the largest source of toxic water pollution in the United States based on toxicity, dumping billions of pounds of pollution into America's rivers, lakes and streams each year.[12] The waste from coal plants, also known as coal combustion waste, includes coal ash and sludge from pollution controls called 'scrubbers' that are notorious for contaminating ground and surface waters with toxic heavy metals and other pollutants."[13]

But it wasn't always this way. Opposition to fly ash is relatively new for the EPA. Prior to 2008, the EPA actually promoted the beneficial use of CCP (including fly ash) in its C2P2 Program, a cooperative partnership with ACAA[14] and USWAG:[15]

"Fly ash is a CCP possessing unique characteristics that allow it to be used ton-for-ton as a substitute for portland cement in making concrete. Through the reuse of fly ash, the GHG emissions associated with the production of portland cement are avoided."

As we'll see, it was an unfortunate event in 2008 that gave the EPA good reason to reassess its position on fly ash.

The best laid plans ...

EPA's sudden change of heart is the result of a massive slurry spill at The Tennessee Valley Authority's (TVA) Kingston plant in 2008. Failure of Kingston's coal ash retention basins resulted in serious local flooding and the pollution of 300 acres including the Clinch and Emory rivers. Consequently, the EPA reassessed its fly ash management position and proposed a new ruling that, for the first time, would regulate waste storage and disposal from coal-fired power generators.

EPA is currently considering two management options for CCPs. Both options fall under the Resource Conservation and Recovery Act (RCRA). One option would list CCPs (stored in settling basins or slated for landfill disposal) as special wastes subject to regulation under subtitle D of RCRA. In the second proposal – a

Fly Ash Reuse

Fly ash is repurposed in various markets including concrete production. The American Coal Ash Association (ACAA) is the source for EPA's fly ash data. Keep in mind that only about 30 to 35% of total fly ash generation is purchased or diverted for beneficial reuse. Most of the world's supply of fly ash, unfortunately, is destined for already-overburdened landfills.

(FHWA) FLY ASH REUSE CATEGORIES	(FHWA) FLY ASH REUSED/RECYCLED MILLION SHORT TONS	(FHWA) FLY ASH REUSED/RECYCLED %
CEMENT/CONCRETE	**13.40**	**60.9**
FLOWABLE FILL	0.80	3.7
STRUCTURAL FILLS	3.21	14.6
ROAD BASE/SUB-BASE	1.02	4.7
SOIL MODIFICATION	0.74	3.4
MINERAL FILLER	0.11	0.5
MINING APPLICATIONS	0.82	3.7
WASTE STABILIZATION/SOLIDIFICATION	1.44	6.3
AGRICULTURE	0.02	0.1
Miscellaneous/Other*	0.45	2.1
(FHWA) TOTALS	22.00	100
EPA [ACAA source]) 2008 TOTAL U.S. FLY ASH PRODUCTION MILLION SHORT TONS	(EPA) TOTAL FLY ASH REUSE/RECYCLED (ALL CATEGORIES) MILLION SHORT TONS	**(EPA) FLY ASH REUSED/RECYCLED IN CEMENT/CONCRETE MILLION SHORT TONS (%)**
72.5	30.1	**12.6 (42)**
Coal Power Industry Data TOTALS	50+	45% (All uses)

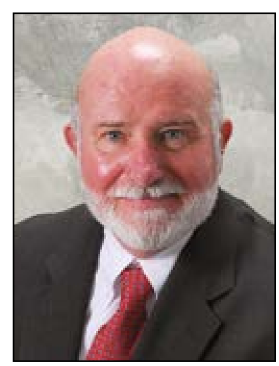
*Roofing and wallboard

ruling that the concrete, power and coal ash industries dread – the EPA would regulate CCPs under subtitle C of RCRA and classify fly ash as a hazardous waste. A long-awaited final ruling is expected in 2014. EPA also proposed a ruling to establish standards for wastewater management at power plants.

Concrete arguments from ACAA

Opposition to listing fly ash as a hazardous waste is based on the economic, environmental and market concerns of producers and associations representing concrete, electric power and CCPs. Thomas H. Adams, executive director of the ACAA, has extensive experience in the concrete industry and is a strong proponent for the continued recycling of fly ash. Adams says, "On Dec. 22, 2008, the EPA decided to re-examine its 1993 and 2000 determinations that coal ash did not warrant management as a hazardous waste for disposal purposes. The mere suggestion that fly ash and other coal combustion products would be viewed as hazardous waste has had a chilling effect on those who have come to recognize the value of fly ash in enhancing concrete durability. A hazardous waste label would create significant issues. This stigma continues to linger with the regulatory uncertainty created by the EPA."

Some federal legislators aren't waiting for the 2014 ruling. House Bill H.R. 2218 would establish minimum federal requirements, administered by states, for the management of fly ash to protect human health and the environment. The bill passed the House in July and was sent to the Senate, where its status is uncertain.

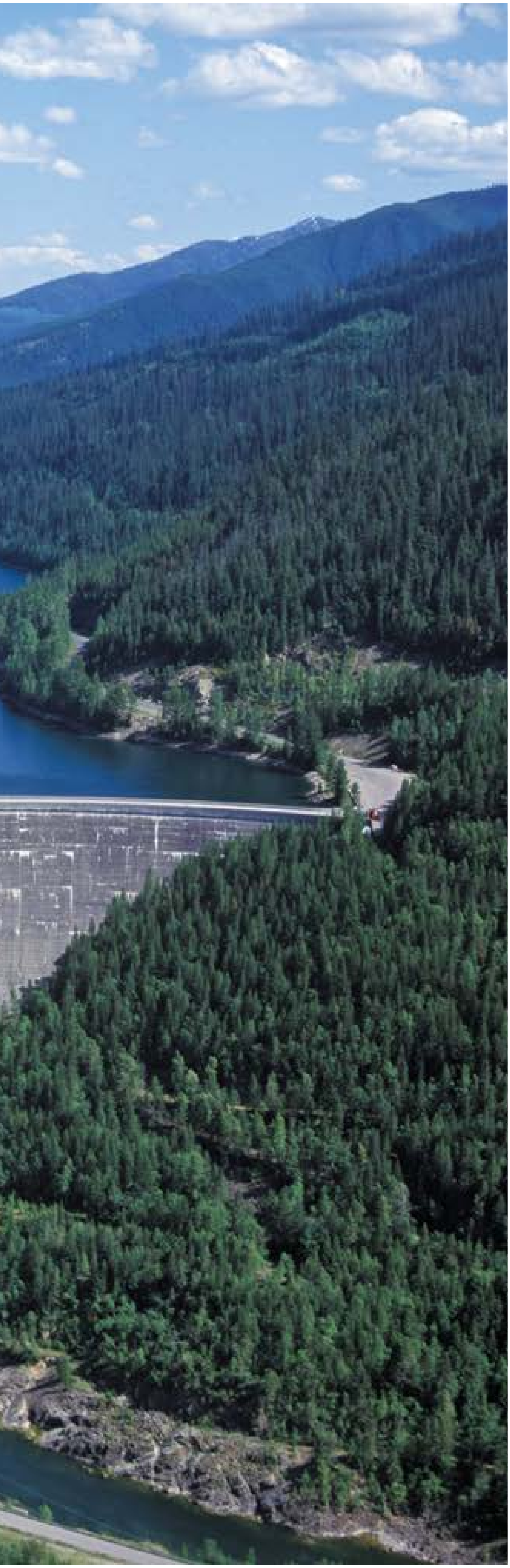


Thomas H. Adams, ACAA PR

What is the future for fly ash?

It should be noted that environmentalists' concerns about potentially toxic water pollution (particularly mercury) have no relevance to the use of fly ash in concrete production. The mercury level in most fly ash is the same as that found in most virgin soils. Further,

The Hungry Horse Dam, started in 1948 and completed in 1953, marked the first significant use of fly ash in concrete.
Photo courtesy of U.S. Bureau of Land Management



if CCPs are high in mercury (mercury has an affinity for carbon), its carbon content would make it unsuitable for concrete. EPA's main concern with fly ash has been certain unlined landfills and specific massive earth fills. Failures of fly ash settling ponds, like the 2008 TVA spill, are extremely rare events, and in any case, only dry fly ash is used in concrete – not wet material in settling ponds. And lastly, the EPA has not indicated any desire to restrict fly ash use in concrete.

After seven decades of reducing the environmental impact of portland cement production and providing a means of recycling industrial waste, fly ash and concrete stand strong together. PS

Sue McCraven, senior NPCA technical consultant and Precast Solutions editor, is a civil and environmental engineer.

(Endnotes)

[1] Coal Combustion Products (CCP) include fly ash, bottom ash and flue gas desulfurization solids. Fly ash is also called CCR (Coal Combustion Residuals).

[2] Coal currently provides 40% of the world's electricity needs. It is the second source of primary energy in the world after oil, and the first source of electricity generation. Since the beginning of the 21st century, coal has been the fastest-growing global energy source. The last decade's growth in coal use has been driven by the economic growth of developing economies, mainly China. Source: www.iea.org/topics/coal

[3] "Coal-fired power plants produce huge amounts of fly ash and generate the world's largest quantity of industrial solid wastes, creating severe waste disposal problems." Recycling of Waste Fly Ash: A Rheological Investigation, by M. Sharma, C. Guria, A. Sarkar and A.K. Pathak. International Journal of Science, Environment & Technology, Vol. 1, No. 4. 2012. p. 285.

[4] A pozzolan is a siliceous and aluminous material made up of very finely divided particles; when pozzolans are mixed with lime and water, they react to form a strong cementitious product, essentially slow-hardening cement.

[5] Source of statistics: www.ecosmartconcrete.com

[6] Source: FHWA Fly Ash Facts for Engineers, April 2011.

[7] www.epa.gov/epawaste/conserve/tools/warm/pdfs/Fly_Ash.pdf

[8] "Using Fly Ash in Concrete" by Arnie Rosenberg, May/June 2010 Precast Inc.; "Ultrafine Fly Ash" by K. Foody, May/June 2010, Precast Inc.; "Fly Ash: A Hazardous Material?" by C. Goguen, P.E., LEED AP, Precast Inc., July/Aug 2010; "If You Use Fly Ash in Your Mix, You Need to Read This!" NPCA Staff, Oct/Nov 2010, Precast Inc.

[9] ASTM C618, "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete"; ASTM C1240, "Standard Specification for Silica Fume Used in Cementitious Mixtures"; and ASTM C311, "Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete"

[10] By replacing cement, fly ash reduces energy and greenhouse gas emissions from cement clinker production and significantly reduces industrial waste destined for landfills.

[11] "Closing the Floodgates: How the Coal Industry is Poisoning our Water and How We Can Stop It," authored by a coalition of environmental organizations, July 2013.

[12] EPA, Environmental Assessment for the Proposed Effluent Limitation Guidelines and Standards for the Steam Electric Power Generating Point Source Category 3-13 (April 2013) [hereinafter, EA].

[13] EA 3-34, 3-38.

[14] The American Coal Ash Association www.acaa-usa.org

[15] Utility Water Act Group

Precast Concrete's Resistance to High-Velocity Projectiles

History continues to teach harsh lessons about deadly high winds, and now there is a way to seek shelter from the storm.

By Evan Gurley

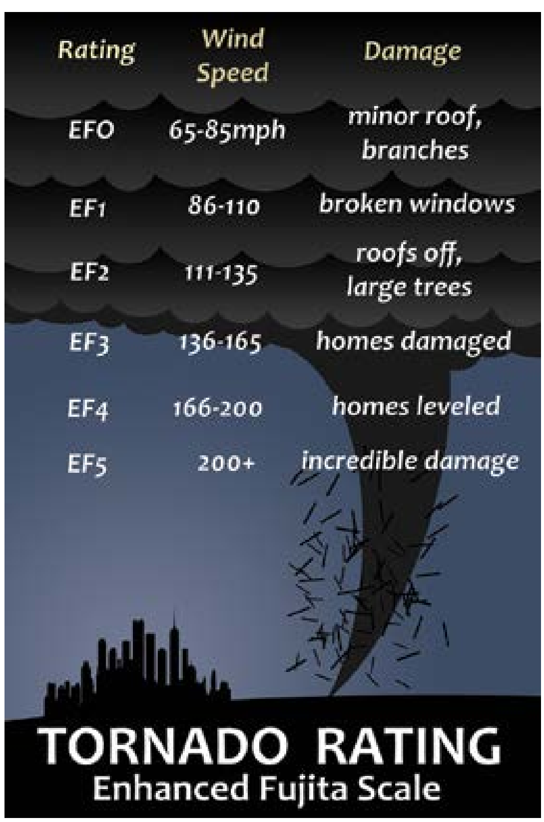


Figure 1. The severity of a tornado is categorized by the Enhanced Fujita Scale (EF scale).

Every year, natural disasters involving extreme wind events take aim at residential areas. Tornados, hurricanes and tropical storms strike with lethal force. For North America, some years are far worse than others.

2011 was an unusually active and deadly year for tornados across the United States, with a total of 1,691 of the angry funnel clouds reported across the country – the second most in history! Two years ago, an EF-5 tornado hit the city of Joplin, Mo., leaving 157 people dead. The Joplin tornado was the deadliest single tornado since modern recordkeeping began in 1950.[1]

Are tornados growing in strength?

When we look at the storms that made headlines in 2012, the tornado that hit Henryville, Ind., on March 2 stands out. Packing winds of 175 mph, it struck the small town of 2,000 residents, killing 11 and nearly wiping out all the buildings and aboveground structures.

The National Weather Service (NWS) office in Norman, Okla., announced that a tornado slammed into

The destructive power of a tornado causes windborne missiles that cause even greater damage to other buildings.

© Philcold | Dreamstime.com

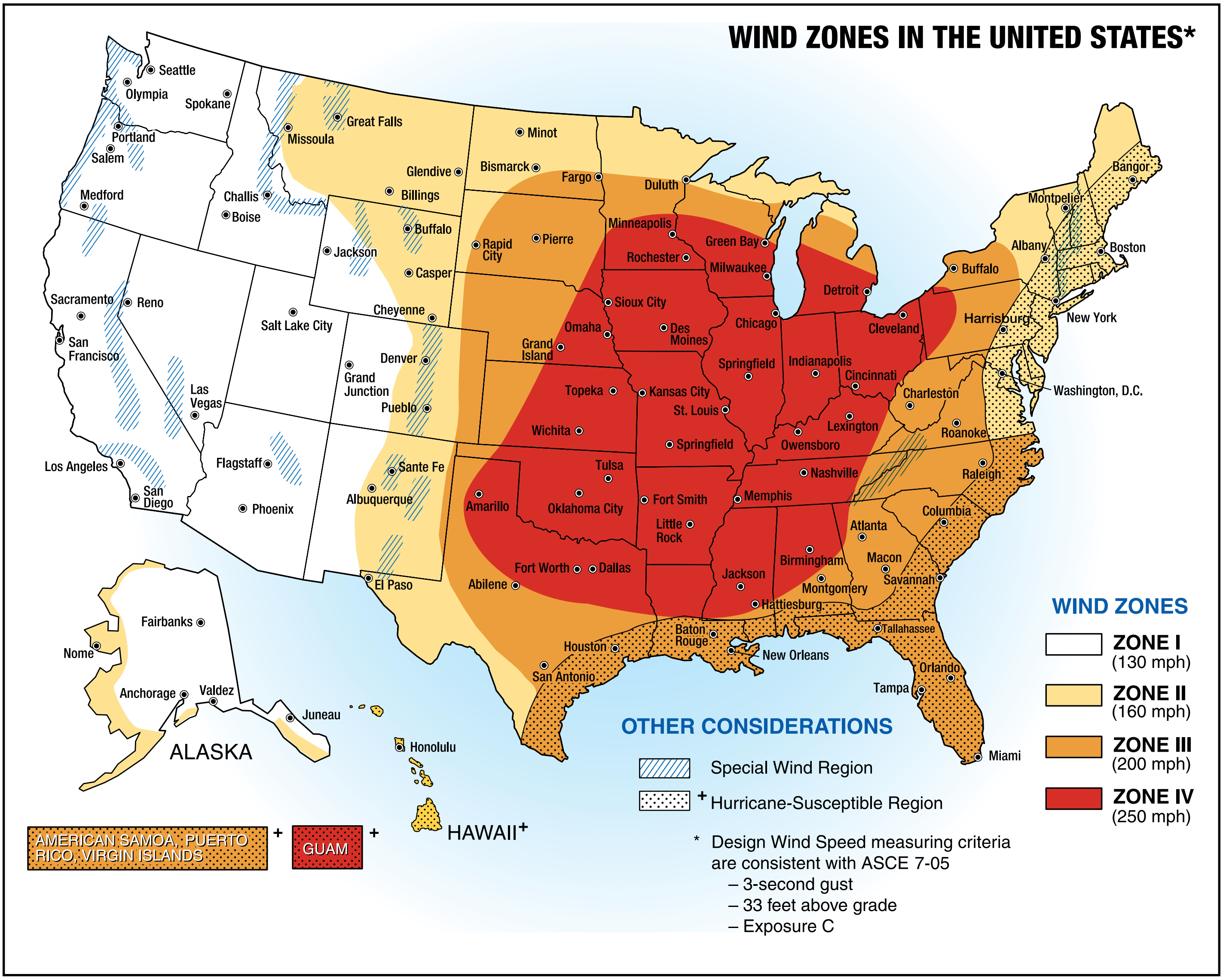


Figure 2: Wind Zones in the United States

(Resource: Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business)

El Reno, Okla., on May 31, 2013, and was responsible for killing 20 people including three storm chasers. It was the widest tornado ever recorded in the United States at 2.6 miles wide.

NWS confirmed that the El Reno tornado, which was originally classified as an EF-3 tornado (See Figure 1), was reclassified as an EF-5 tornado. It generated wind speeds of 296 mph and left a 16.2-mile-long swath of destruction, making it one of the strongest tornados ever recorded.

Some communities, homes and businesses are equipped with shelters, basements or rooms designed to withstand the forces and high-velocity projectiles associated with extreme wind events. However, many communities and individuals do not have these resources available and remain at risk. Precast concrete, as a building component, can help provide protection and peace of mind for families and communities when these dangerous storms approach.

A home or business "built to code" is no panacea

Based on 60 years of tornado history and more than 150 years of hurricane history, the United States has been divided into four Wind Zones that geographically reflect the number and strength of extreme wind events. Figure 2 shows these four zones, where Zone IV experiences the highest frequency and strength of high-wind events.

Your home or place of business is most likely built in accordance with local building codes that require buildings to withstand a "design" wind event. In most tornado-prone regions, the building code design wind event is a storm with 90 mph winds. For hurricane-prone regions, the code for design wind events ranges from 90 mph to 150 mph.

A home or building designed and constructed to code does not mean that your home or office building can withstand wind from every event. An intense tornado

or extreme hurricane can pack winds much greater than local code requirements.

"Near-absolute protection" requires safe rooms

Extensive testing by Texas Tech University[2] and other wind engineering research facilities shows that walls, ceilings and doors commonly used in building construction to meet minimum building code requirements for standard building construction cannot withstand the impact of projectiles carried by extreme winds. Most homes, even new ones constructed according to current building codes, do not provide adequate protection for occupants seeking safety from tornados. Only specially designed and constructed safe rooms, which are built above the minimum code requirements as defined by the Federal Emergency Management Agency (FEMA) offer life-safety occupant protection during a tornado or strong hurricane.

Having a safe room in your home, business or community can help provide "near-absolute protection"[3] for you, your family, employees and visitors from injury or death caused by extreme winds.

FEMA safe room guidelines are the Gold Standard

To ensure that safe rooms are structurally sound and will provide near-absolute protection from devastating storms, FEMA has developed design, construction and operation criteria (FEMA 320 and FEMA 361) for architects, engineers, building officials, local officials, emergency managers and prospective safe room owner/operators. FEMA 320 outlines the design criteria for the development of residential safe rooms (16 persons or less) located in basements, garages, interior rooms and standalone structures (buried or exposed). FEMA 361 contains the design criteria for construction and operation for both community (greater than 16-person capacity) and residential safe rooms.

Using the FEMA guidelines as a pre-standard, design and construction professionals, led by the International Code Council (ICC) and the National Storm

An above-ground community shelter manufactured to comply with NSSA standards assures protection from injury or death during storms.
Photo courtesy of Vaughn Concrete Products Inc. (vaughnconcreteproducts.com)

Fig. 4 (Top). 2" x 6" missile penetrating a refrigerator, Midwest tornados of May 3, 1999.

Fig. 5 (Bottom). Palm tree pierced by plywood missile, Hurricane Andrew

Shelter Association (NSSA), have joined forces to produce the first ICC/NSSA Standard for the Design and Construction of Storm Shelters (ICC-500). Precasters who manufacture safe rooms meeting this standard are able to assure prospective owners and occupants that precast concrete safe rooms will provide life-safety protection (see Figure 3). While fully supporting this effort, FEMA has continued to promote its 320 and 361 guidelines to communities and individuals seeking further guidance on best practices.

Typical residential buildings are no match for windborne missiles

When a tornado or hurricane starts ripping apart structures and buildings, the wind field associated with that storm becomes filled with flying debris. Once airborne, these objects become dangerous projectiles, or "windborne missiles." When wind speeds are extreme, debris missiles are propelled with enough force to penetrate or perforate windows, walls or roofs. For example, a standard 2x4 weighing 15 lbs, when powered by a 250-mph wind, can have a horizontal speed of 100 mph! At this speed, it can penetrate most common residential building materials (See Figures 4 and 5).

Numerous instances show that during extreme winds, building failures occur even on the far peripheries of a storm's path. These failures can generate projectiles of various sizes, perhaps whole roofs, that could damage other structures. This means that just one weak building can produce windborne missiles, which could damage other buildings that otherwise would have suffered little or no damage.

When an urban area is stuck by an extreme wind event, the projectile load carried in the debris cloud represents a substantially increased hazard compared with an equivalent tornado in an open, rural setting. In addition to increasing a tornado's damage potential, it is well known that being hit by a projectile is among the three major causes of causalities in tornados (the other fatalities occur when people become airborne or are crushed within collapsing structures).

The precast advantage: university projectile impact tests

FEMA has long recognized that precast concrete safe rooms provide effective protection against the most dangerous storms. Precast concrete inherently possesses the vital characteristics, such as strength, penetration resistance and durability, required to withstand the hazards of violent weather. Precast concrete's superior structural characteristics make it one of the most preferred construction materials for safe rooms.

Texas Tech University, a leader in wind engineering research, conducted debris impact tests on various nonproprietary materials to determine how these different building products are affected by high-speed debris impact, simulating the conditions in an extreme wind event.

The test setup included a pneumatic cannon that can accelerate a timber plank to a speed of 150 mph (See Figure 6). The pneumatic cannon can also simulate other types of debris, such as lumber, fence posts, bricks,

Figure 6: Debris impact cannon, Texas Tech University

PVC pipe and steel conduit. A 15-lb 2x4 traveling at 100 mph is equivalent to the weight and speed of debris in a 250-mph tornado – the maximum wind speed of 99% of tornados.[4]

Building materials that were tested included concrete masonry unit (CMU) wall sections, reinforced concrete, plywood-and-metal combinations and doors. Tests of reinforced concrete slabs, compared with the other building materials, clearly showed that concrete excelled and incurred no damage in nearly every scenario. Even when a 4-in.-thick concrete test specimen (reinforced with No. 3 rebar, 6 in. OC) was hit with a 2x4 plank traveling at 140 mph, no damage was reported; in fact, the missile was reduced to splinters. Under the same conditions, other building elements did not fare nearly as well. In addition to the Texas Tech University tests, numerous industry tests confirm that precast concrete's strength and durability offer unmatched resistance to windborne projectiles during tornados and hurricanes. Precast concrete safe rooms can be manufactured to exacting specifications by most precast concrete producers. To find out more, visit precast.org. PS

Evan Gurley is a technical services engineer with NPCA.

References
A Summary Report on "Debris Impact Testing at Texas Tech University," prepared by the Wind Science and Engineering Research Center, Texas Tech University, Lubbock, Texas. June 2003.

(Endnotes)

1 The May 21, 2001, tornado is ranked as the 7th deadliest in U.S. history.

2 A Summary Report on "Debris Impact Testing at Texas Tech University," prepared by the Wind Science and Engineering Research Center, Texas Tech University, Lubbock, Texas. June 2003 : (www.depts.ttu.edu/nwi/research/DebrisImpact/index.php)

3 "Near-absolute protection" as defined by FEMA means that, based on current knowledge of tornados and hurricanes, the occupants of a safe room built according to FEMA guidelines will have a very high probability of being protected from injury or death.

4 90% of tornados have wind speeds ≤ 150 mph.

Casting Call

Precast concrete is at the top of the bill for a new performing arts center at Butler University.

By Kirk Stelsel

Since 1855, Butler University existed in relative obscurity as a small liberal arts school in Indianapolis. That all changed after its basketball team made recent back-to-back runs to the national championship game and put Butler on the national radar.

Despite the elevated profile, though, Butler remains rooted in its liberal arts background, and no liberal arts campus is complete without a home for the performing arts. The newly completed Howard L. Schrott Center for Arts is the *pièce de résistance* of Butler's performing arts complex. And although it made ample use of many materials to achieve the right looks and acoustics, precast concrete took the leading role.

A 450-seat auditorium for music and theater lies at the heart of the multipurpose performance hall, which is used primarily as a teaching facility for the Jordan College of the Arts and its disciplines of arts administration, dance, music and theater.

▲ *The use of architectural precast concrete panels in combination with ashlar limestone created a visual identity for the Schrott Center for the Arts at Butler University that matches the rest of campus.*

Photo courtesy of Browning Day Mullins Dierdorf Architects (www.bdmd.com)

Throughout construction, structural and architectural precast products were used to save time and money while also achieving the desired look and performance.

Photos courtesy of Shiel Sexton (www.shielsexton.com)

Local architectural firm Browning Day Mullins Dierdorf (BDMD) designed the building with both structural and architectural precast concrete in mind.

The firm soon discovered that there are as many differences as similarities in the specific needs of performing arts and their audiences. "This is especially true as it relates to the goal of being acoustically excellent. What works for music does not work for theater," said Tim Ritchotte, R.A., architect/associate at BDMD. "But the problem is even more subtle than that. The acoustical needs of choral music are different than that of the full orchestra, just as lyric theater requires a different environment than spoken drama."

The mass of the precast panels keeps the performance sounds in and the sounds of the world out. An inner cube of insulated, architecturally finished

structural precast forms the taller stage house and audience chamber, and architectural precast wall panels form the exterior wall around the perimeter support spaces, including the lobby and back-of-house areas, explained Ritchotte. "There were around 64 different structural precast panels, with a majority having a 52½-ft panel height. This includes three horizontally spanning panels, which form the header of the 56-ft-wide proscenium opening," he said. "There were also four precast structural columns, which were architecturally finished due to their prominence in the lobby."

More than 70 architectural precast panel units, most over 45 ft high, had intricate bevels and pilasters that would have been more difficult to do with a high-end building material such as limestone. "Butler's campus is populated mostly with limestone-clad buildings, but it became clear to us that the funding would not provide a budget for limestone cladding," Ritchotte said. "Having used precast in designs elsewhere on campus, BDMD looked at precast for this building, working closely with the construction manager to understand the benefits in terms of system cost and constructability."

For Shiel Sexton, the construction manager on the project, the benefits of precast were clear. Gregory L. Carr, general superintendent of Shiel Sexton, is no stranger to the use of precast concrete on projects and cited cost savings, a more rapid schedule for enclosing the building and aesthetics among the top benefits.

"Precast installs quickly, and after it's installed you have a finished product," said Carr. "The precast supported steel – in many cases we welded roof or floor beams to an embedded plate in the precast. Also, the architectural panels were insulated with internal foam, which was very cost effective. Our structural panels were fire rated, so we didn't need to cover them with drywall to achieve a fire rating."

Carr explained that the structural precast panels were also designed to be architectural panels above the roofline. "This was great, because we achieved two designs in one panel and was a real time saver," he said.

Both Ritchotte and Carr were pleased with the finished product. The color, texture, scale and detail of the panels all help the building fit in with the surrounding architecture while also "redefining the front door of the campus," according to Ritchotte, who fully expects the precast to continue to perform well.

Precast concrete is proudly on display inside and out at the newly completed Schrott Center for the Arts at Butler University.

Photo courtesy of Browning Day Mullins Dierdorf Architects (www.bdmd.com)

Inside the performance hall, acoustics was the No. 1 priority and the mass of precast panels helps keep performance sounds in and outside noises out.
Photo courtesy of Browning Day Mullins Dierdorf Architects (www.bdmd.com)

The Schrott Center for the Arts and its precast concrete facade are center stage at the east entrance to Butler University's campus.
NPCA photo

For Carr, looks and performance made precast the perfect building material. "The decorative architectural precast was used on 90% of the building's exterior," he said. "It was accented with random-pattern ashlar limestone and metal panels at the canopies and looks beautiful!"

Ritchotte added that precast concrete was chosen for a number of reasons for the Schrott Center. "The vertical scale of a performance hall wall lends itself to a panelized system, and mass is a crucial physical property in the surrounding noise isolation assemblies of a performance hall," he said. "In addition to the aforementioned noise isolation benefit, both the structural and architectural precast provided a beautifully and consistently finished exterior cladding. The precast is proudly on display, from both inside and out." PS

Kirk Stelsel is NPCA's director of Communication.

This is one of a series of articles highlighting precast solutions for resilient construction in post-disaster rebuilding.

Advantages & Load Tests:

Lighter, Stronger Precast Concrete Floor System

In the wake of Superstorm Sandy, FEMA's new flood zone and insurance guidelines demand superior and sustainable rebuilding materials.

By Mohamed Mahgoub, Ph.D., P.E.

Photos courtesy of Northeast Precast LLC (www.northeastprecast.com)

There is a great need for a durable precast concrete floor structure that is lighter, stronger and more energy efficient, and one that can be manufactured in variable sizes. Nowhere is this need greater than in areas devastated by storms, particularly in New Jersey's rebuilding efforts after Superstorm Sandy. A new concrete floor plank system offers many advantages for post-disaster rebuilding efforts. Test results (see the sidebar "Load Testing of Precast Concrete Plank") compare the system's greater strength and durability compared with other building materials.

A LOOK AT TRADITIONAL AND NEW PRECAST FLOOR SYSTEMS

Traditional hollowcore precast concrete floor panels used in residential and multi-story buildings have been the go-to product for many years, and with good reason. Hollowcore floor systems have many advantages that have made them the backbone of sustainable, durable precast concrete building components. To help reduce flooring weight for transportation, erection and foundation loading, hollowcore precast concrete planks are cast with continuous circular voids running through the panel's length. For added strength, prestressing strands are cast into the panels during production. With its top and bottom longitudinal flanges, hollowcore is an exceptionally strong structural component that is used to span large areas between building columns and walls.

Some of the advantages of the newly developed floor system include:

1. Decreased panel weight (almost half the weight of traditional systems) allows smaller column or wall sections to safely carry the floor loading.
2. Smaller and lighter columns and walls help to minimize the building's foundation dimensions, or project footprint, and thus reduce project costs.
3. Reduced seismic design load requirements are possible with less weight.
4. More efficient transport and job-site delivery are possible with lighter panel weights. Because the pieces are easier to tilt on the truck, more space is available so more product can be delivered per shipment to the job site (see Figure 1).
5. Design flexibility and construction efficiency are increased because planks can be manufactured in various widths.

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Figure 1. New insulated precast concrete floor planks are set in place at the Boardwalk Casino in Sea Isle City, a gaming and condominium business on the Jersey Shore. Rebuilding work after Superstorm Sandy is taking place in very congested and costly developments along New Jersey's Atlantic beachfront. Seven large floor slabs, each about 8 ft x 25 ft, can be transported per truck, which is a huge advantage because more product is quickly delivered, ready to install. Efficient delivery means fewer project delays and lost time caused by idle crews waiting for one truck to maneuver out of a clogged site to make room for the next truckload to move into place. For this structure, the SLL = 100 psf and SDL = 20 psf. Note the 4-in.-thick end blocks resting on the bearing walls. End blocks extend the full width and depth of the floor planks.

Figure 2. LEED points are gained through the energy efficiency and long-term energy savings provided by 3.5 in. of white EPS insulation covering the bottom of the panels, shown in the photo above. Similar to double-T beams, the longitudinal prestressed concrete stems, spaced 2 ft on center, provide added load-carrying capacity. The stem depth varies from 6 in. to 16 in., and stem width can range from 2 in. to 15 in., depending on the design loads.

6. The new panel system costs less and is more efficiently produced than traditional precast concrete floor systems.
7. It offers increased resistance to flood and seismic forces.
8. Thin topping means the deck may be as thin as 1 in.
9. Successful load testing for several types of loading (distributed and concentrated) showed good system performance results.
10. Energy efficiency of insulated precast planks reduces heat loss and energy bills in commercial and residential construction, which may help contribute to project LEED points (see Figure 2)
11. Greater tensile loads are carried by the incorporation of prestressed strands in the stems and mild reinforcing in the deck.

A closer look at the new floor system

Here are some of the design and installation details of the precast concrete planks:

Stems: The floor panel is comprised of a topping (or deck) supported by a number of parallel, longitudinal concrete stems that extend along the length of the panel. The concrete stems extending between the end blocks are spaced 2 ft on center. Each stem has a depth of 6 in. to 16 in. and a width of 2 in. to 15 in., depending on design loads.

End blocks: Two transverse end blocks support the deck. Located at plank ends, the concrete blocks have a minimum thickness of 2 in. End blocks are formed with (and protrude from) the deck and run along the panel's width.

Bearing surface: Made of solid concrete, the blocks form a continuous bearing surface for mounting the floor panels on top of wall members, and these blocks subsequently support the walls for the next level (see Figure 3).

Storage and transportation: The end blocks also prove useful for stacking, storage and transportation.

Post-tensioning: Each end block has an opening along the panel width for post-tensioning after the floor is installed on the bearing walls. Post-tensioning helps to distribute wind, seismic or any other lateral forces on the bearing walls.

Insulation: A 1-in. to 3.5-in. thickness of molded expanded polystyrene insulation can be attached to the panel bottom. Insulation extends around the stems, the bottom portion of the deck, and the inside portion of the end blocks between the stems. Insulation provides important thermal resistance and noise dampening for building occupants.

Metal wall stud: A metal wall stud, attached to the insulation at the bottom of each stem, can be used for attaching drywall or other finish materials. An optional lightweight, nonstructural leveling coat may be applied to the top deck.

Installation: Each building level's floor is formed with a number of precast concrete panels set side by side. Panels are mechanically connected along their lengths. These connectors are welded together once the panels are installed.

Connections and voids: Connectors help distribute wind, seismic or any other lateral forces to the floor panels. Vertical holes or channels may be manufactured per specification or cut in the field for plumbing, electrical conduit or any other utility runs. Field-cut utility openings are easily accommodated for construction change orders.

Mohamed Mahgoub, Ph. D., P.E.

Figure 3. Taken during rebuilding of the WKR residence in Cape May, N.J., this photo shows one side of the floor panels mounted on top of an insulated precast bearing wall system. This structure is located in the FEMA surge zone, which experienced devastating destruction from Superstorm Sandy.

Figure 4. Rebuilding efforts near this marina in Cape May, N.J., are able to continue during inclement weather with no stoppage of work or project delays typical of traditional construction methods. This photo shows the raked finish on the new insulated precast concrete floor plank system. Strong, resilient and sustainable precast concrete wall and floor systems are built with open lower levels to allow storm surge water to flow through in compliance with new FEMA Flood Zone Guidance.

Rebuilding with a stronger floor system

This new floor system is currently being used in rebuilding work along the Jersey Shore, which took a direct hit from Superstorm Sandy in October 2012. With many coastal areas of the Atlantic Coast incurring the greatest damage from the record-breaking hurricane's destructive force, rebuilding efforts must consider the most resilient building materials for sustainability, public safety and flood insurance (see Figure 4). Strong precast concrete walls and advanced floor systems provide a dry, warm, damp-resistant and exceptionally energy-efficient structure for family and commercial residents.

Recent changes to FEMA's flood zoning and insurance guidelines make it clear that we can no longer afford to rebuild with the inferior building materials of the past. PS

Mohamed Mahgoub, Ph.D., P.E., is assistant professor and Concrete Industry Management (CIM) program director at the New Jersey Institute of Technology, and an industry expert in bridge rehabilitation, inspection, rating, design and analysis. Dr. Mahgoub may be reached at mahgoub@njit.edu.

Load Testing of Precast Concrete Plank

Testing was performed in July 2012 to analyze the performance of a new floor plank system under maximum loading.

After each increment of weight was applied, deflection was measured again, the plank was inspected at mid-span for cracks, and the strands were checked at the end of the plank for slippage. The load was increased incrementally until there was a point load of 10.8 kips at mid-span, in addition to the 52 ft-kip load initially applied. At this point, the panel had deflected more than 8 in., with the last weight increase having increased the deflection by 3 in.

Please visit precast.org/floorplank for the complete test procedures and results to compare the system's greater strength and durability with other building materials. Test results are provided courtesy of Peter Gorgas, E.I.T., of Northeast Precast LLC in Millville, N.J.

The Jack of all Building Materials

With its extraordinary versatility, concrete is continuously the ace in the hole for the construction industry.

By Mason Nichols

Few would question concrete as a key component of the world's infrastructure. Twice as much concrete is used globally than plastic, aluminum, steel and wood combined. This statistic alone proves the major role concrete plays in meeting our everyday needs.[1]

However, what many fail to realize is that technology and concrete go hand in hand. Research on methods to make concrete even more versatile than it already is has allowed it to be used in a nearly endless array of projects and designs. The question thus becomes: Just how versatile of a building material is concrete, exactly? The following examples showcase ongoing concrete advancements, ranging from rapid repairs on roadways to research into "living" buildings.

Precast concrete pavement systems

DOTs, contractors and engineers are increasingly turning to precast concrete pavement systems (PCPSs) as the go-to solution for road repairs that must be made quickly, efficiently and with minimal traffic disruption. Designed for an expansive variety of roadway applications, including intersections, horizontal curves and more, PCPSs are cast and cured off site before any roadwork begins, dramatically reducing the need for traffic mitigation by shortening construction time and allowing the repaired road to reopen immediately upon installation.[2] While the slabs can be installed at anytime throughout the day, they are typically installed at night during non-peak hours, reducing risk to workers and lessening delays for drivers.

In Syracuse, N.Y., precast pavement slabs were used for just this purpose in August. Two bridge decks required quick repairs to be made in time for the New York State Fair, scheduled to open just under a month after construction began. A PCPS solution was chosen for the job precisely because of its ability to significantly reduce project duration, according to NYSDOT.[3]

Tough talk

While concrete possesses a well-established legacy of strength[4], researchers are always attempting to make one of the world's strongest materials even stronger.

Jason Weiss, Ph.D., civil engineering professor at Purdue University, has been hard at work for nearly a decade enhancing concrete's durability through the process of internal curing. Traditionally, concrete is cured by adding water at the surface level. Weiss' method mixes things up by providing water pockets inside the concrete to enhance the material's durability.[5]

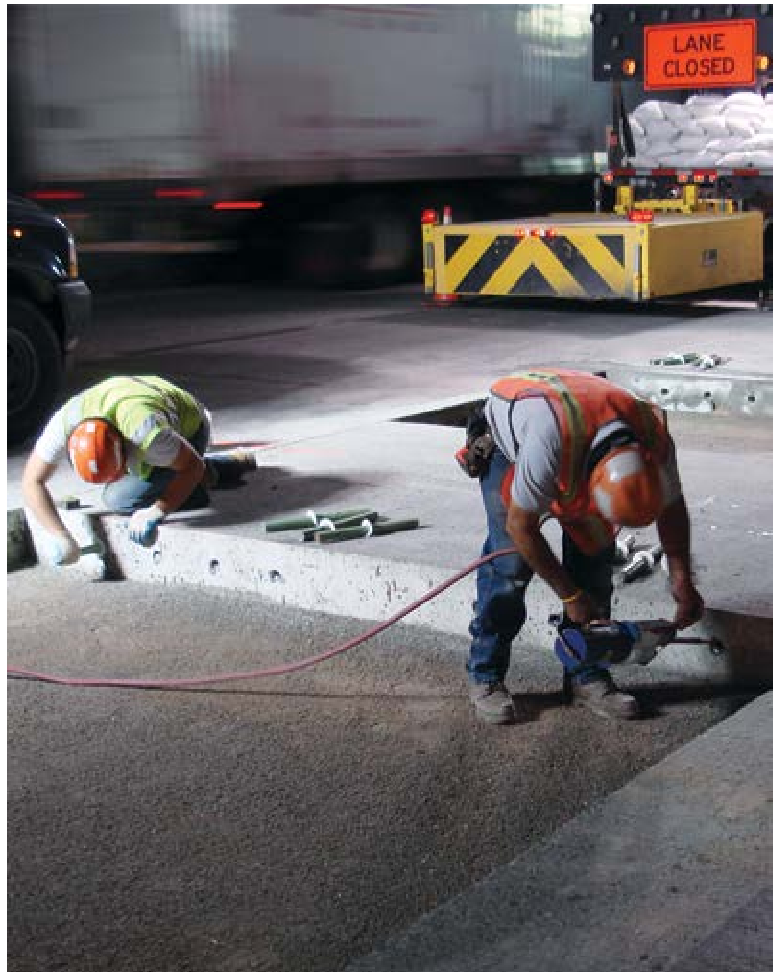
The internally cured concrete has already proven its mettle in Utah, where two bridges were built: one with traditionally cured concrete and one with Weiss' internally cured alternate. Engineers found the internally cured bridge to be 20 times less likely to crack than its counterpart.

Living, breathing concrete

With the construction industry continuing to focus on sustainability, researchers at the Universitat Politècnica de Catalunya (UPC) in Barcelona, Spain, are putting a whole new spin on the term "green building."

The Structural Technology Group at UPC has developed a biological concrete that functions as a "living facade," supporting the growth of lichens, mosses and other microorganisms. Currently, vertical garden systems – designed to achieve the same effect – require complex supporting structures. However, UPC's biological concrete allows for organisms to grow directly on the surface, achieving a striking aesthetic effect while also allowing for several environmental advantages.[6]

Researchers hope to succeed in accelerating the growth of organisms on the biological concrete so that surfaces acquire an attractive facade in less than a year.



Precast concrete pavement systems are cast and cured before roadwork begins, ready to install, significantly reducing project duration.

Versatility in perspective

Concrete is the most used building material on earth, but has revealed itself to be a quick-change artist as well, capable of meeting the needs of seemingly any project. Innovations in the design and use of concrete will continue to allow for the overall enhancement of the precast concrete industry, opening up possibilities for producers now and into the future. PS

Mason Nichols is NPCA's communication coordinator.

(Endnotes)

1 www.sustainableconcrete.org/?q=node/42

2 For more information on PCPSs and to watch a video of PCPS installation, visit precast.org/pavement.

3 www.syracuse.com/news/index.ssf/2013/07/i-81_to_close_temporarily_in_syracuse_starting_next_friday.html

4 Earlier this year, the Bureau of Reclamation's Materials Engineering and Research Lab employed a 5-million-lb press to break a concrete cylinder 6 ft high and 3 ft in diameter. The concrete cylinder withstood pressure up to 4.4 million lbs before finally giving way. View the video at www.youtube.com/watch?v=bu3Oq910PPc

5 www.purdue.edu/newsroom/releases/2013/Q1/indiana-using-new-concrete-to-increase-bridge-life-span.html

6 www.upc.edu/saladepremsa/al-dia/mes-noticies/researchers-at-the-upc-develop-a-biological-concrete-for-constructing-201cliving201d-facades-with-lichens-mosses-and-other-microorganisms/?search-term=concrete

The 28-Day Myt

Breaking the misconception about breaking concrete test cylinders.

By Eric Barger

Throughout the construction industry, the common belief is that concrete takes 28 days to cure and reach 100% of its strength. This evolved from a misunderstanding of what curing actually means. Some regulators characterize concrete as "green" if it has not cured for a certain time frame, not realizing this leads to unnecessary delays and higher project costs. An evaluation of the concepts of measured compressive strength and curing is in order to shed light on the mystery that surrounds the 28-day myth.

Specifying concrete strength is normally done with a minimum compressive strength (psi) at a certain age (days). Specified concrete compressive strength is the minimum compressive strength at which the concrete should fail in standard tests of 28-day-old concrete cylinders. A typical concrete compressive strength specification requires 4,000 to 5,000 psi at 28 days. Some go a step further and mandate that concrete products cannot be installed or used until 28 days after the date of manufacture. This, mistakenly, has given concrete a reputation among some specifiers as being weak or inferior if it has not cured for the full 28 days.

An arbitrary timeframe

The 28-day period is an arbitrary specimen age – though chosen for many good reasons – for testing the compressive strength of concrete. Specification writing authorities chose 28 days as the standard specimen age to establish consistency for testing procedures throughout the industry.[1] Such an arbitrary time frame, however, is not relevant to all mix designs. It is estimated that concrete reaches 75% of this 28-day compressive strength in seven days,[2] and its strength will remain stable or even increase over time.

A specific ratio can be determined for each specific mix design and curing process to fine-tune this arbitrary age so that the mix design dictates the 28-day compressive strength. Some mix designs reach 5,000 psi of compressive strength in seven days – or even in 24 hours. However, the faster concrete reaches the minimum design compressive strength, the greater the cost of the concrete.

Strength measurement protocol

Measuring the compressive strength of concrete is achieved by taking a sample of concrete at the time of placement. Cylinders, measuring 12 in. high by 6 in. in diameter, or 8 in. by 4 in., are compressed by a break machine that exerts increasing force upon the cylinder until it structurally fractures. When a failure occurs (commonly referred to as a "break"), the compressive strength is measured by dividing the force (lb) measured at the time the cylinder fails by the load-bearing surface area (sq in.) of the concrete sample. At the time of the break, the sample's age is generally noted for quality assurance purposes. Therefore, to meet the typical concrete compressive strength specification as previously noted, the break results should calculate to at least 5,000 psi at 28 days.

When a specification has performance criteria of 5,000 psi at 28 days, for example, governing authorities will want a test record (two individual cylinder breaks at 28 days) to ensure conformance with the specification. Fortunately, more than two cylinders are typically collected for testing. Through research and empirical data collection, projection of a 28-day strength from a three- or seven-day test break is easy to perform and results in an estimated strength very close to that measured at 28 days. With the accuracy of this early estimation, if a problem arises, it can be reviewed much sooner than 28 days.

Why curing is misunderstood

Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration.[3] This would refer to a great many processes that are used to cure concrete, including steam curing, moist curing, air curing and more. It is immediately apparent that the phrase "curing" can have different meanings to different people. Strength and age associations behind the word "curing" are overwhelmingly misunderstood.

Digging deeper into the curing process, hydration is the chemical process that allows concrete to go from a plastic state to a hardened state while gaining strength over time. Hydration occurs at a faster rate

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Compressive strength is measured by dividing the force (lb) measured at the time the cylinder fails by the load-bearing surface area (sq in.) of the concrete sample.
Photo courtesy of C.R. Barger & Sons Inc.

in the early stages after concrete placement and slows down after a month or so goes by. Many cement pastes will cease hydration before one year, and some may continue to hydrate over the course of several years.[4] Because of the variable length of the hydration process, the phrase "green concrete" is a purely subjective characterization.

With so much variation in hydration time, waiting for completion of the hydration process before testing the compressive strength of concrete would be impractical. In determining a more practical age for testing concrete strength, the 28-day myth began. So, while curing does help the hydration process, "28 days" is not an inclusive rule dictating a specific time to produce minimum compressive strengths. Simply stated, as the concrete cures and hydration takes place, the concrete gets stronger – and hydration may continue long after the minimum required compressive strength is reached.

Curing is a process, not a measure of strength

A specified compressive strength may be for any strength at any age of concrete. There is nothing wrong with specifying 5,000-psi compressive strength at one, seven, 11, 14 or 56 days. It all depends on the mix design, circumstances and project requirements. The American Concrete Institute recognizes 28 days or "the test age designated for determination of the specified compressive strength."[5] Therefore, when a specifier calls for 5,000 psi concrete at 28 days, this tells the concrete producer to select a mix design that will attain a minimum of 5,000 psi 28 days after manufacture.

In precast concrete manufacturing, however, very early attainment of specified strengths – reaching the minimum required compressive strength much sooner than 28 days – is the norm. It is extremely rare for a specifier to require a specific cure time. Rather, specifications might state that installation prior to 28 days is acceptable, provided that two cylinder breaks prove the minimum required compressive strength has already been reached. With a select mix design, concrete could easily reach its minimum required compressive strength one day after it is manufactured and therefore be specification-compliant for installation.

The main thing to remember is that curing is a process and not a measure of concrete strength. The 28-day stipulation provides a consistent industry-wide basis for comparing the compressive strength of concrete products. The 28-day time frame is not directly related to whether or not a specific product meets strength requirements for a particular application. As long as the minimum compressive strength is met before the product is put in service, the time frame to reach the minimum compressive strength should not be relevant. PS

Eric Barger is vice president of C.R. Barger & Sons Inc., Lenoir City, Tenn., a family-owned business spanning five generations. Eric is a civil engineer but admits that he learned all he knows by growing up in a precast plant and listening to his father's motivational speeches. Contact him at: eric@bargerandsons.com.


Eric Barger

(Endnotes)
1 Cement & Concrete FAQs, Portland Cement Association (PCA); www.cement.org/basics/concretebasics_faqs.asp

2 Kosmatka, S.H., Panarese, W.C., Allen, G.E. and Cumming, S. Design and Control of Concrete Mixtures, PCA, Skokie, Ill. 2002.

3 "Curing of Concrete," April 2006; www.concrete.net.au/publications/pdf/Curing06.pdf

4 "Overview of the Concrete Hydration Process," Section 5.1; www.iti.northwestern.edu/cement/monograph/Monograph5_1.html

5 Building Code Requirements for Structural Concrete and Commentary (ACI 318-11), ACI, Farmington Hills, Mich.

Surviving the Storm

When extreme weather strikes, the difference between life and death comes down to the built environment around us. Are we ready?

By Kirk Stelsel

If you feel like you've heard more about deadly, destructive weather events recently, it's because you have. According to a January statement from the National Aeronautics and Space Administration (NASA), we should "get ready for more extreme weather and increasingly serious impacts on health, the economy and the environment." As the cost of lives and rebuilding efforts due to these storms continues to mount, the media, lawmakers and the general public have taken increasing notice with each passing event.

The cover of June 3 issue of *Time* simply stated "16 minutes." That's the amount of time the residents of Moore, Okla., had to find a safe place to hunker down between the first warning and touchdown of a devastating EF-5 tornado. Among the survival stories was that of a mother who secured her children in an interior closet only to discover it would not be sufficient for the storm that was bearing down on her family. With minutes to spare, she found safe haven in the storm shelter of a neighbor and emerged to find her house leveled.

While the ability of weather authorities to provide earlier and more accurate warnings can help save lives, no amount of "take cover" or evacuation orders solves the core issue: the ability of the community to withstand and rebound from a major weather event. That is rooted in decisions made long before the first menacing cloud or drop of rain begins to appear.

With communities from coast to coast at risk of some form of extreme weather, resilient building materials that can save lives and emerge intact from extreme weather are rising to prominence if for no other reason than the cost is simply too great to ignore them.

Precast strong

Following Superstorm Sandy, coastal New Jersey residents returned to what they once called home to find a water-ravaged landscape. The iconic boardwalk was destroyed, as were the businesses that depended on its tourists. More than 300,000 homes were damaged or destroyed. Devastation was rampant. One home, though, featured in the Spring 2013 issue of *Precast Solutions,* stood tall in the face of the storm's fury. It survived because it was built with survival in mind. The materials and design were chosen not for cost savings, but for longevity. The house was made of precast concrete.

After an EF-5 tornado tore through Joplin, Mo., it left a sea of destruction in its wake. Yet an image used by the media showed a hospital that provided a critical barrier and protected the lives of patients and employees by standing up to the deadly winds and debris. It, too, was constructed of precast concrete.

In 2011, after a particularly bad stretch of weather caused more than 342 deaths – mostly due to tornados – an NPCA member in Mississippi was interviewed by the local news about his precast concrete storm shelter rated for winds up to 250 mph. His phone started ringing off the hook with inquiries about the product.

Precast concrete has proven to be a building material that can stand up to extreme weather. It's why many NPCA members manufacturing storm shelters are also National Storm Shelter Association (NSSA) Producer Members. An NSSA member manufactures structures to preset standards and meet the ICC 500 code. It's also why precast structures are often the only ones left standing after a tornado or hurricane. But decisions on

resilient building materials must be made during the building or rebuilding process in order to save lives and money down the road.

Planning ahead

The storms aren't going away, but the mindset of government officials, city planners and homeowners is beginning to shift. Following the tragedy in Moore, schools in high-risk areas for tornados have taken action by retrofitting existing structures and building new ones with storm shelters. Walker Valley High School in Ohio recently added a precast concrete safe room during an expansion. In Missouri, Hollister High School incorporated a secondary gym and weight room into a 6,400-sq-ft safe room constructed of precast concrete. Starting in 2015, all schools with 50 or more occupants and located in areas with design wind speeds of 250 mph will be required to have storm shelters that meet ICC 500 requirements by the International Building Code.

Perhaps just as critical as protecting citizens is protecting the emergency services in a community that will help those in need after a storm. If the police, fire department or EMS cannot respond, or if the hospital can't treat victims, there's little help for those in need.

In the Caribbean, the U.S. Coast Guard (USCG) stands at the ready for those in peril on the sea. But to be effective, the station itself needs to be able to withstand storms. A new hangar in the Bahamas is designed with exactly that need in mind. By utilizing an engineered precast concrete system from Oldcastle Precast, the USCG built a first-of-its-kind hanger that can withstand Category-5 storms. The structure replaces a steel hangar leveled in 2008 by Hurricane Ike. High-strength, 6,000-psi precast concrete was used for the walls, doors and all other structural components of the 20,000-sq-ft structure. In addition to the hangar, the development includes a HAZMAT storage building and a residential structure.

Take action

Precast concrete plants manufacture a wide variety of products that provide everyone from homeowners to city planners with peace of mind. Whether it's small storm shelters, infrastructure or above-ground building products, the quality, strength and durability of precast concrete is unmatched.

To find an NPCA member in your area, visit precast.org and click on the "Find Precast Products Now" button at the top of the page. PS

Kirk Stelsel is NPCA's director of Communication.

A U.S. Coast Guard hangar, constructed of precast concrete including its doors, is a first-of-its-kind hangar that can withstand Category 5 storms in the Caribbean.
Photo courtesy of Oldcastle Precast (oldcastleprecast.com)