Research Aids Designs to Prevent Progressive Collapse

— Donald P. Merwin

Federal officials join with PCI and other concrete groups to develop methods to protect against explosive forces

After the World Trade Center towers collapsed on Sept. 11, 2001, the federal government began developing building-code requirements to provide better protection for government buildings against any future attacks. This plan produced two design goals: resisting initial explosions from inside or outside a building and resisting the progressive collapse of a damaged building.

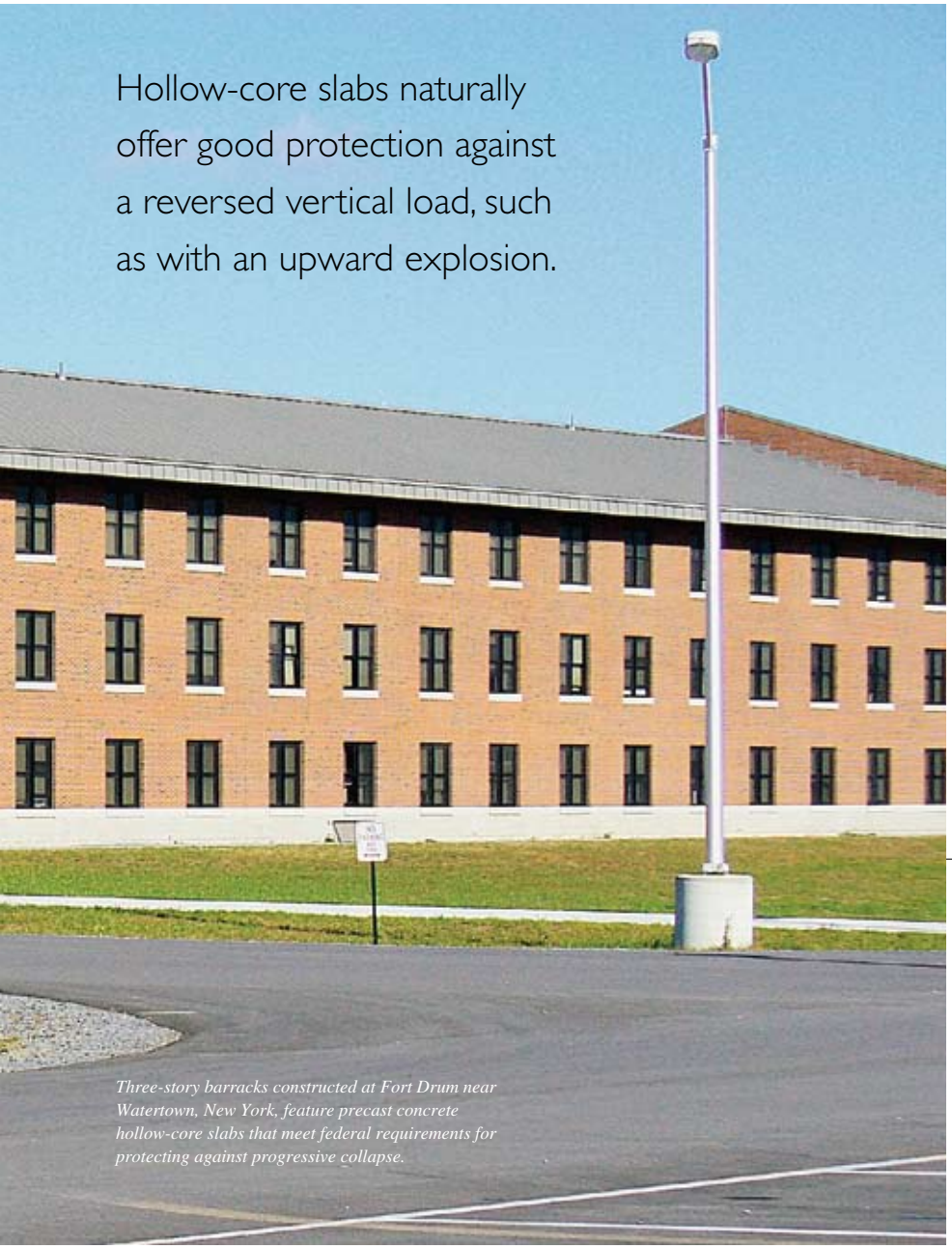
As part of that work, the Precast/Prestressed Concrete Institute (PCI) and other groups, under the organization of the Portland Cement Association (PCA), conducted research to aid in creating new designs. As a result of that research, four barracks were constructed using precast concrete hollow-core slabs at Fort Drum, near Watertown, New York, housing the Army's 10th Mountain Division Aviation Brigade.

The key to minimizing progressive collapse is to create a cantilevered design that does not rely on the outer wall for support, says David Wan, chief engineer for Oldcastle Building Systems of South Bethlehem, New York, which supplied the components.

The first bay of precast concrete slabs was designed as a 10 ft 8 in. backspan with a 10-ft-long cantilever rather than as a 20 ft 8 in. simple span. In the event of a blast in which the end wall (which normally supports the slabs) is destroyed, the precast concrete slabs will cantilever 10 ft from the interior bearing wall and not collapse.

The 8-in.-thick precast concrete hollow-core slabs will continue to be supported by an interior wall 10 ft inside the outer wall. The 10 ft overhang will have almost 3 in. of deflection, Wan says. "But the goal here is prevention of progressive collapse for the safety of individuals, not later serviceability."

To protect against an interior blast, "the use of a relatively heavy and dense material like hollow-core slabs naturally offers good protection against a reversed vertical load, such as with an upward explosion," Wan adds. The slabs are prestressed, adding four $^1/_2$-in. top strands in addition to the standard six $^1/_2$-in. bottom strands.



Three-story barracks constructed at Fort Drum near Watertown, New York, feature precast concrete hollow-core slabs that meet federal requirements for protecting against progressive collapse.

40 Years of Research

Studies of progressive collapse go back 40 years, to a 1968 gas explosion in a 23-story apartment building in London, U.K. The blast destroyed the load-bearing exterior walls, collapsing that unit and the four apartments above onto that level and then pancaking them all to the ground, destroying all the units beneath. Four people died in that disaster. (For more on that project and other information on progressive collapse, see the article in the Summer 2007 issue of *Ascent*.)

As a result of those disasters, research was conducted in the 1970s by PCA under sponsorship of the U.S. Department of Housing and Urban Development. The research was meant to develop new standards covering structural integrity and progressive-collapse resistance of large-panel buildings. In 1976, PCI published a summary of recommendations that were subsequently adopted by the American Concrete Institute, as part of *Building Code Requirements for Structural Concrete (ACI 318) and Commentary (ACI 318R)*.

FACT SHEET

WSAAF–Barracks Expansion

Location: *Fort Drum, N.Y.*

Owner: *United States Army*

Architect/General Contractor: *Clark Construction Group, Bethesda, Md.*

Precaster: *Oldcastle Building Systems, South Bethlehem, N.Y.*

Components: *Hollow-core slabs, 81,000 sq ft for each building*

‘For economy and speed of construction, and structural requirements, precast was the natural choice for this sort of building.’

The hollow-core slabs could be erected quickly, thanks to the precaster’s ability to continue erection through cold winter weather.

The first bay of precast concrete slabs was designed as a 10 ft 8 in. backspan with a 10-ft cantilever, so if the end wall is destroyed by an external blast, the precast hollow-core slabs will cantilever 10 ft from the interior bearing wall and not collapse.

The code requires that “a structural floor system be designed for gravity and diaphragm loads resulting from lateral loads such as wind and seismic,” Wan explains. “The new Department of Defense design requirements also require that the floor system be designed for potential load reversal or an upward load caused by an internal blast.”

Ned M. Cleland, president of Blue Ridge Design Inc. in Winchester, Virginia, notes that, “In the early development of multistory buildings with large panels, the primary loads that were considered in the design process were gravity and wind. In today’s world the focus is on explosive bombings. Loading problems related to terrorist attacks and bombings have been conceived generally as a vulnerability to progressive collapse.”

Referring to the research conducted for more than 10 years after the London building collapse, Cleland adds, “The primary mechanism to develop an alternative load path for integrity (after an explosion) is the cantilever behavior of the wall assembly.”

Experiments on precast, prestressed concrete insulated sandwich wall panel assemblies were conducted early last year at the U.S. Air Force Research Lab in Panama City, Florida. They were said to have “performed well,” according to a government spokesman. Results continue to be analyzed at Lehigh University in Bethlehem, Pennsylvania, and at the University of Alabama at Birmingham.

The studies were assessed in greater detail in the November-December 2007 issue of *PCI Journal*, where it was recommended that experiments be conducted on floor assemblies to provide “validation of double-tee, hollow-core, and other precast concrete horizontal panels to facilitate effective blast-resistant design of precast concrete systems.”

“That recommendation was to be expected,” Wan notes. “On any new subject such as progressive collapse, engineers would want to have that happen. We do a lot of seismic and wind studies, but we don’t get an explosion to study every day.”

Economy, Speed Cited

Precast concrete wins plaudits from the contractor on the first two of the four barracks to be constructed at Fort Drum, each of which used about 81,000 sq ft. “For economy and speed of construction, and structural requirements, precast was the natural choice for this sort of building,” says Steve Maslen, project executive for Clark Construction Group in Bethesda, Maryland.

“Previously constructed barracks at Fort Drum were all two stories, extending from a hub with two long wings, and they weren’t subject to blast rules,” Maslen explains. “But once the design added a third story, as we did with these new barracks, the force-protection rules applied, and we went to the cantilever method.”

“The design team on this project showed that precast, prestressed concrete hollow-core slabs can be successfully integrated with other building materials, such as steel and masonry, to meet new Department of Defense anti-terrorism requirements,” says Wan. “The use of a precast-plank floor system also met tough budget limits and a fast-track construction schedule.” The masonry and precast concrete work were completed in January and February of 2006 in upstate New York, where the winter can be harsh on construction activity, he notes.

More Opportunities Arise

Recently, the U.S. Army announced plans to increase its size by 74,000 soldiers by 2010, a move that Wan views as an opportunity for more precast structures to be built. “I feel we have a competitive, economical product that will meet progressive collapse requirements.”

The Army’s plans call for basing new combat brigades (about 3,500 soldiers each) at Fort Bliss, Texas; Fort Carson, Colorado; Fort Stewart, Georgia; Schofield Barracks, Hawaii; Fort Leonard Wood, Missouri; Fort Lewis, Washington; and Fort Polk, Louisiana, plus moving two brigades to Fort Irwin, California, and to Fort Drum from other bases. The cost of building the 743 military construction projects is estimated at $66.4 billion. The projects include 69,000 new barracks spaces.

The cantilever method of construction offers a good solution not only for the construction of barracks but also for hotels and condominiums, Wan says. “Any multifamily or multistory structure will find advantages.” ■

For more information on these or other projects, visit www.pci.org/ascent.