

# ENR

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## SEISMIC DESIGN

# High-Strength Rebar Called Revolutionary

In Seattle skyscraper, material's first use for concrete confinement boosts constructibility

**A**fter years of struggling to improve constructibility of tall concrete frames in high seismic zones, a solution is in the works—code-approved use of high-strength reinforcing steel for seismic confinement of high-strength concrete. But one structural engineer in the Northwest is jumping ahead of the code

change, which could take two more years. Last month, Cary Kopczynski got the green light to use the material in Escala, a 31-story residential condominium in Seattle. He says it is the first such use of 100-ksi rebar in North America and perhaps the world.

“This will revolutionize high-rise concrete building construction in seismic zones,” says Kopczynski, president of the structural firm bearing his name in Bellevue, Wash.

The patented, 100-ksi rebar offers corrosion resistance and higher strength than the industry standard, 60-ksi steel (see p. 2). Made by MMFX Technologies

Corp., Irvine, Calif., the material has been used for several years in mat foundations and bridge decks, but not for seismic confinement (ENR 12/2/02 p. 14).

The rebar reduces the amount of seismic confinement steel in columns and shear-wall boundary elements by 40%, compared to 60-ksi rebar. That in turn reduces rebar congestion, long the bane of designers and contractors, because it slows construction and can affect quality.

But current codes do not allow use of the material. “Cary’s office worked this both ways, by also going in for a permit based on the code,” says David Glassman, Escala’s



▲ Coming. Escala’s concrete frame first to get 100-ksi bars.

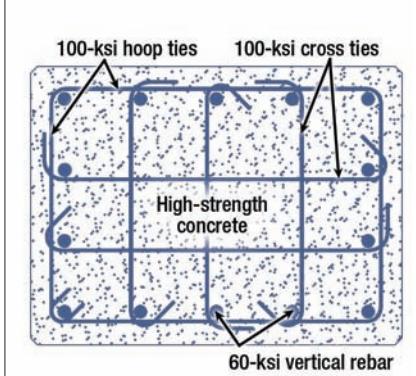


▲ Shear Wall. Boundary elements are simpler.

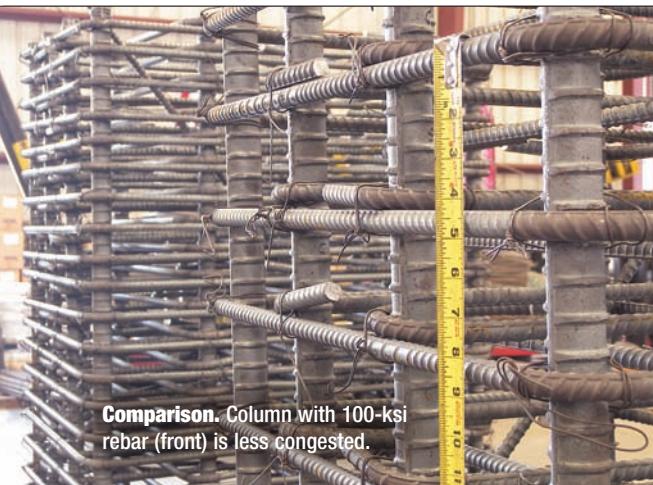
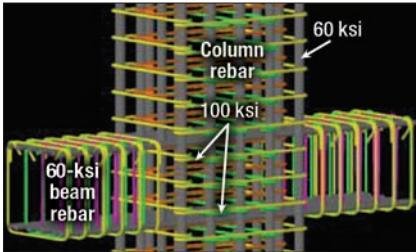
project manager for Mulvanny G2 Architecture, Bellevue. The project also was bid two ways, with 100-ksi and 60-ksi rebar.

It was a prudent approach. “We turned them down a couple times,” says Steven Pfeiffer, engineering and technical codes manager in Seattle’s Dept. of Planning and Development. “We were hesitant because it wasn’t in the code, but Cary was pretty persistent,” he adds.

The city gave its formal approval on July 23 but not before making the engi-



◀ **Fewer Ties.** 100-ksi horizontal rebar in high-strength concrete columns (top left) increases rebar spacing, reduces rebar diameter and simplifies beam connection (middle).



**Comparison.** Column with 100-ksi rebar (front) is less congested.

neer jump through several hoops. Kopczynski had to build a case that included documentation from concrete experts. A letter describing a pending code-change proposal was sent from Jack Moehle, the chair of the American Concrete Institute's seismic subcommittee. The group, along with the ACI's code committee, had recently approved the model code change, currently out for ballot. In addition, Pfeiffer had Kopczynski craft a letter that put the engineer of record on record, describing Escala's structure, the intended use of the rebar, the limitations of use recommended by concrete experts familiar with it and the advantages of its use.

Pfeiffer decided to grant the permit. "Experts think it is OK, the engineer of record has a good reputation" and the model code-change proposal has passed two ACI committees, he says.

The builders of the \$140-million Escala share Kopczynski's enthusiasm for the steel product. "The whole process should take less time and cost less," says John Plaggmier, Escala's superintendent for the local general contractor, JE Dunn-NW.

The beam-column connection is expected to be 25% faster because of the lower number of perimeter ties, called hoops, and hairpins to tie them to the standard 60-ksi vertical rebar. Hoop spacing is increasing from a typical 3 in. on center to 4.5 in. to 6 in. on center, says Plaggmier. And for column ties, 100-ksi material not only increases rebar spacing, it reduces rebar diameter, says the engineer.

Placement of concrete in the columns and the boundary elements of the shear walls is expected to take less time because of reduced congestion. Dunn's workers can use normal vibrators, which typically result in a higher-quality and better-looking product, he adds.

## Concern Expressed That High-Strength Rebar Is Proprietary

Sources say 100-ksi reinforcing steel for use as seismic confinement in tall concrete buildings is a bright spot on the horizon. But they are concerned about the ability of the sole supplier of the proprietary material to meet growing demand. They also worry about a lack of competitive pricing.

"Owners and contractors have frequently been reluctant to commit to this because of its proprietary nature and because it cannot be supplied by multiple vendors," says Donald W. Davies, a principal with Seattle-based structural engineer Magnusson Klemencic Associates. "As the 100-ksi rebar distribution network expands and availability improves, provided the cost remains competitive, this is a

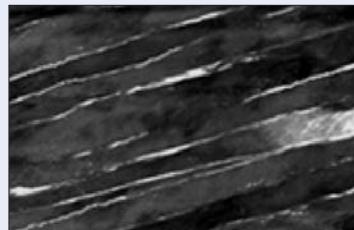
great solution for saving material and reducing congestion."

Another engineer who declines to be identified but is familiar with the material agrees it has potential, with several caveats. "You have distribution issues, on-time delivery issues, and you can't just intersperse 100 ksi and 60 ksi without worrying about the contractor screwing up the placement," he says.

The single-supplier situation is not likely to change. MMFX Technologies Corp., a nine-year-old Irvine, Calif., materials science company, holds a patent on the steel. But MMFX hopes to meet production concerns. Before the end of the year, it plans to start production at a mill in Welland, Ontario. The annual capacity

would be 400,000 tons. Later, the firm expects to boost that to 1 million tons.

MMFX recently received an ASTM specification for the 100-ksi material, originally made for corro-



▲ **Microcomposite.** Ductile material is layered with a strong material.

sion resistance. The steel has a microstructure "fundamentally different from conventional steel at the nano, or atomic, scale," says Greg Kusinski, MMFX director of research and development.

Typical carbon steels form a matrix of chemically dissimilar materials—carbide and ferrite, he explains. The carbides are strong yet brittle and immovable at the grain boundaries.

MMFX steel is a microcomposite of very thin layers of a very ductile material and a very strong material. "The steel looks like plywood," says Kusinski.

MMFX was formed to commercialize research done at the Lawrence-Berkeley Laboratories and at the University of California, Berkeley. Kusinski says the steel could be developed for use as high-strength structural steel, steel pipe and sheet steel. But MMFX is "only focusing on rebar," he says. ■

So far, deliveries to the rebar fabricator seem to be adequate. “We are getting deliveries in a pace sufficient to meet the schedule,” says Lyall Hadden, general manager for Harris Rebar Seattle Inc., Tacoma, Wash. “But we’d like to have more on hand.” He says MMFX says it can deliver more if Harris wants it. “We’ll see,” says Hadden.

The fabricator likes the 100-ksi steel, even though it takes steel out of a project. Hadden agrees with Plaggmier that the rebar improves constructibility, improves the fit of horizontal and vertical structural elements, requires fewer hours of labor and puts less demand on hoisting equipment because of reduced weight. “There are some real benefits, even though the material is more expensive,” he says. The unit cost is about 30% higher.

Use of the material does introduce the need for greater quality control, says the fabricator. That’s because the different grades—60 ksi for vertical, or longitudinal rebar, and 100 ksi for transverse rebar—can get mixed up. “We segregate the 100 ksi from all other grades because it looks the same from a distance,” says Hadden.

Harris also has a separate production line to avoid mixing up the differently graded steel. For the Escala project, Harris is pre-tying rebar cages in the shop.

Hadden says the high-strength rebar is “pretty easy” to bend but is more difficult to cut. Therefore, it is harder on the shear blades, so it takes longer. “It’s not a horrible problem,” he says.

The use of 100-ksi rebar also reduces the amount of vertical rebar and further simplifies rebar placement. Tall buildings have high loads, which requires use of high-strength concrete, says Kopczynski. The quantity of seismic ties increases linearly with concrete strength, which on Escala is 14,000 psi. This requires more cross ties, called J-bars. Each J-bar has to hook around a vertical bar. “That often results in additional vertical bars, for no other reason than to satisfy the requirement,” says Kopczynski. For Escala, the 100-ksi ties reduced column vertical-bar tonnage by 6 to 7%.

Kopczynski and Hadden agree that the reduction in the number of pieces speeds rebar placement. “Confining ties are the most difficult bar for the rebar



▲ **Gearing Up.** Escala set to open in mid-2009.

placer,” says the engineer. “The grins on the faces of the placers are getting increasingly wider as they develop more experience with 100-ksi bar,” he says.

“Lots of time is typically spent adjusting the vertical bars to capture hooks on confinement bars,” Hadden adds.

Escala is scheduled to open in June 2009. With column and shear-wall work just getting under way, Dunn’s project manager, Mike Moore, says the process of analyzing the dollar savings of the 100-ksi rebar is still under way. But he’s optimistic. “We were extremely satisfied with the results of some test columns,” he says. ■

*By Nadine M. Post*