By Nadine M. Post

# Structural Engineers Labor To Unravel Mysteries of Building Codes

**Designers fear future collapse from misinterpretation or miscalculation**

Until recently when he started running marathons, structural engineer Clifford W. Schwinger's only true obsession was cracking the mysteries of the codes. Deciphering complexities and clarifying ambiguities in building design standards is not exactly Schwinger's idea of a good use of time.

But he does not expect his compulsion to subside until there is code reform.

"You're in big trouble if you design a new building structure and don't meet the letter of the code," says Schwinger, quality assurance manager at Cagley Harman & Associates, King of Prussia, Pa. "Even if there is no 'real' problem, there could be potential serious ramifications from a liability standpoint."

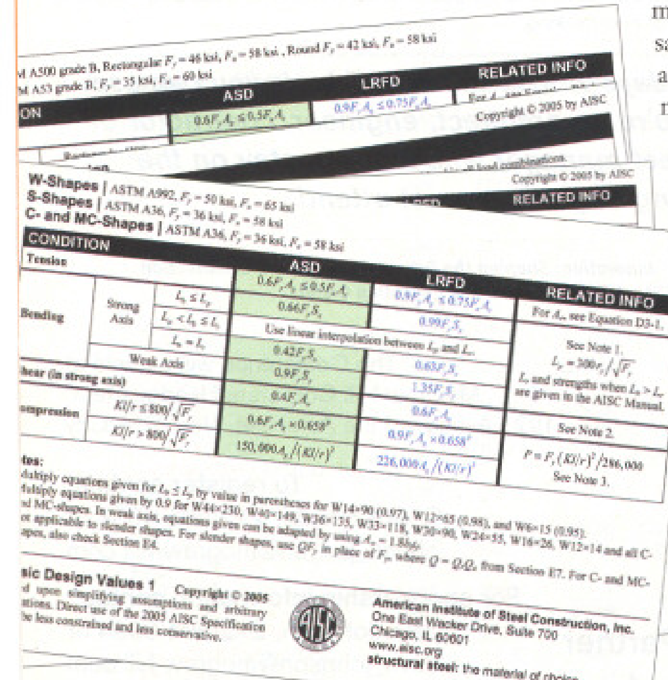
Increasing code complexity has given Schwinger and other designers "in the trenches" a bad case of code anxiety. "The problem is reaching a critical mass," he says.

Engineers get "stomach knots" from overly complex equations; unclear language and poor explanations. They also complain about code cycles that are too short, making it virtually impossible to keep up with changes. And many object to code committees packed with engineers, including managers and academics, who don't actually use the codes on a day-to-day basis.

Time spent deciphering codes is time away from creating quality designs, say sources. Incomprehensible codes help no one "except the lawyers," says Schwinger.

When Schwinger solves a code conundrum, he e-mails a "TEK note" to 31 people in his office. Since 2001, he has written 700 notes. TEK 568 was on large uplift forces on column base plates. TEK 581 was on clear cover to reinforcing steel in shear walls. TEK 587 was on efficient structural steel connections.

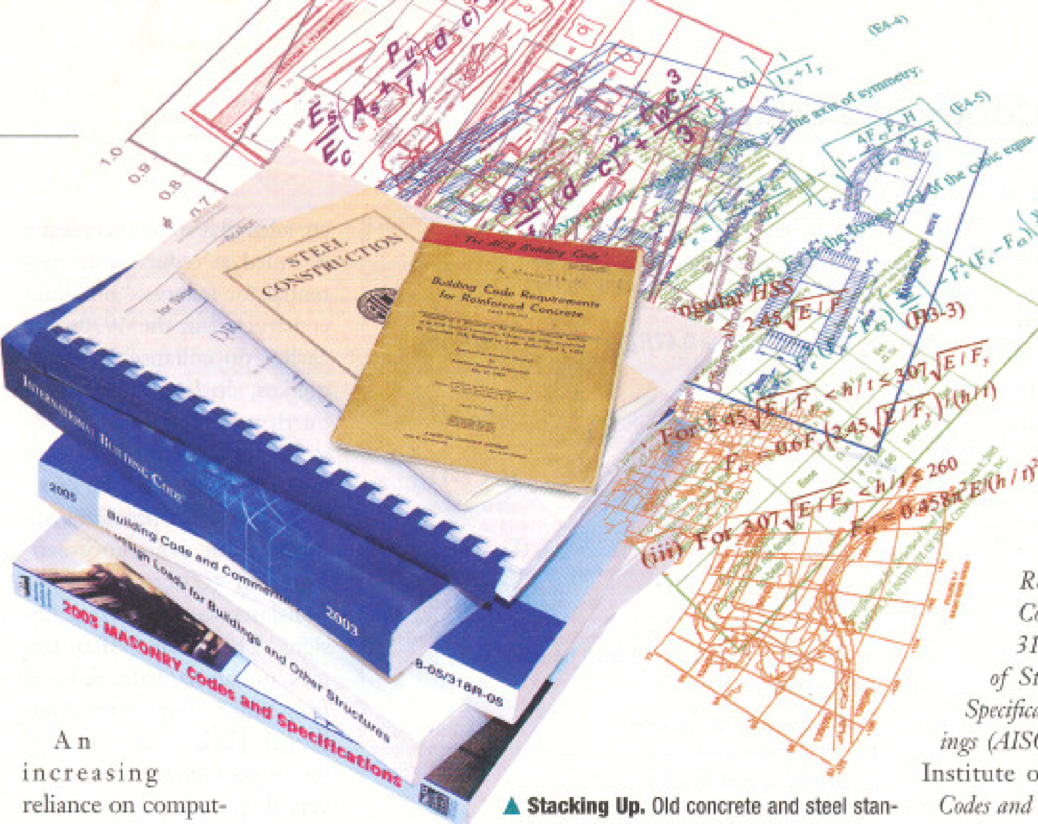
Not all firms have or can afford a Schwinger. Perhaps that's why James B. DeStefano, senior partner of the Fairfield, Conn., firm bearing his name, thinks it's only "a matter of time" before a major structural collapse results from a building code misinterpretation.




▲ **Relief.** Cards will replace 220-page text for simple steel frame design, say steel spec writers.

### Labyrinth of Provisions

Others agree. Maneuvering through the labyrinth of provisions can lead the engineer to lose sight of critical "big picture" issues, including overall stability and punching shear, says Aine Brazil, a managing principal of Thornton-Tomasetti Group, New York City. "Codes and commentaries do very little to give direction on priorities," she says.




▲ **Stacking Up.** Old concrete and steel standards (two on top) contrast with current codes in size and in complexity of content.

An increasing reliance on computers, especially among young engineers, to solve the complex code equations also is a concern. "Complex formulas practically require the use of spreadsheets and eliminate the ability of the engineer to get a 'feel' for the design," says Brazil.

That can lead to errors. To guard against this, some firms still insist engineers do manual calculations to verify globally the computer results.

Schwinger and others suffering from code trauma do not consider themselves Luddites against change. Research on the real behavior of structures needs to continue, many agree. "But engineers in the trenches need this research synthesized down to relatively straightforward, simplified design criteria and formulas," says Robin A. Kemper, assistant director of the structures division of French and Parrello Associates, Holmdel, N.J. That isn't happening, she says.

Frustration is not limited to engineers in the trenches. Jonathan C. Siu, principal engineer of the Dept. of Planning and Development, Seattle, says his staff and some principals of local firms tell him that increasing code complexity, especially in wind and seismic design, "is not increasing the chances of getting to a 'correct' or consistent answer." It's the opposite, says Siu.

Code complexity has been increasing since the 1970s, and so have complaints. But sources say the code quagmire is exacerbated recently by "hyper-track" job schedules, slashed fees and a "tsunami" of work.

The transition to the model *International Building Code*, published by the International Code Council and adopted so far by jurisdictions in more than 40 states, isn't helping in the short run. Already there are different versions of IBC, intended as a unified model code, in New York, New Jersey, Ohio and other states. Malcolm G. McLaren, president and CEO, McLaren Engineering Group, West Nyack, N.Y., says "a truly universal building code would be helpful," but would require the cooperation of state and local regulators.

**The problems associated with code complexity are reaching "a critical mass."**

— CLIFFORD SCHWINGER, STRUCTURAL ENGINEER

IBC references structural and materials standards. The standard that stresses engineers the most is *ASCE 7-02, Minimum Design Loads for Buildings and Other Structures*, published by the Structural Engineering Institute of the American Society of Civil Engineers. The three main materials standards present fewer difficulties, say engineers. They are the American Concrete Institute's *Building Code Requirements for Structural Concrete and Commentary (ACI 318-05)*, *The American Institute of Steel Construction Inc.'s 2005 Specification for Structural Steel Buildings (AISC 360-05)*, and the Masonry Institute of America's *2003 Masonry Codes and Specifications*.

Even so, Schwinger says ACI 318, sections 10.10-10.13, which deal with slenderness and stability of compression members, has good information that is not explained well. And he has problems with confusing column buckling equations in the third edition of AISC's load and resistance factor manual.

Code-writing committees should not be adding more coefficients and parameters to formulas unless they would have a real and significant impact, many say. For a 5-10% variation in results, the refinement does not seem worth the increased chance of messing up the calculation and using very erroneous values," says Brazil.

John G. Tawresey, a vice president in the Seattle office of KPFF, thinks all proposed code additions should be trial-designed. Tawresey, long active in the code arena, has a "litmus test" for whether a proposed regulation should be adopted: Can it be enforced by the building official? Is it a result of unsubstantiated research? Has it been too compromised by the politics of the process? Has it been trial-designed? "If the answers are 'yes, no, no and yes,' the regulation passes my test for simplifying the code," he says.

Another veteran of code wars, Lawrence G. Griffis, president of the Austin-based structures division of Walter P. Moore & Associates Inc., adds two more questions: Does the proposed change have an impact on life safety? What is the economic impact of the change?

Griffis wants a standard format developed to justify a specific change. "Code changes must only occur within the national technical bodies responsible for them," he says. "Local code bodies [should not] be allowed to make technical changes to a national standard without going through a predefined process."

Many call for more research dollars to vet proposed changes. Standardization of the commentary format is also needed, as are user guides, say sources. And, in general, engineers should spend more time on training and education.

$R$, the resonant response factor, is given by

$$R = \sqrt{\frac{1}{\beta} R_n R_h R_B (0.53 + 0.47 R_L)} \qquad \text{(Eq. 6-10)}$$

$$R_n = \frac{7.47\, N_1}{(1 + 10.3 N_1)^{5/3}} \qquad \text{(Eq. 6-11)}$$

$$N_1 = \frac{n_1 L_{\bar{z}}}{\overline{V}_{\bar{z}}} \qquad \text{(Eq. 6-12)}$$

$$R_\ell = \frac{1}{\eta} - \frac{1}{2\eta^2}(1 - e^{-2\eta}) \text{ for } \eta > 0 \qquad \text{(Eq. 6-13a)}$$

$$R_\ell = 1 \text{ for } \eta = 0 \qquad \text{(Eq. 6-13b)}$$

where the subscript $\ell$ in Eq. 6-13 shall be taken as h, B, and L respectively.

$n_1$ = building natural frequency;
$R_\ell = R_h$ setting $\eta = 4.6 n_1\, h/\overline{V}_{\bar{z}}$;
$R_\ell = R_B$ setting $\eta = 4.6 n_1/\overline{V}_{\bar{z}}$;
$R_\ell = R_L$ setting $\eta = 15.4 n_1 L/\overline{V}_{\bar{z}}$;
$\beta$ = damping ratio, percent of critical h, B, L are defined in Section 6.3; and
$\overline{V}_{\bar{z}}$ = mean hourly wind speed (ft/sec) at height $\bar{z}$ determined from Eq. 6-14.

$$\overline{V}_{\bar{z}} = \bar{b}\left(\frac{\bar{z}}{33}\right)^{\bar{\alpha}} V \left(\frac{88}{60}\right) \qquad \text{(Eq. 6-14)}$$

where $\bar{b}$ and $\bar{\alpha}$ are constants listed in Table 6-2 and $V$ is the basic wind speed in mph.

▲ **Boggling.** Schwinger calls "6.5.8.2" the most complex code section.

### Trial Designs

To test code provisions, Tawresey spearheaded formation of SEI's trial design program, another all-volunteer effort. Since, 1998, six have been done.

In the fourth, engineers were given a shear wall elevation with a foundation and asked to find the footing length based on allowable soil pressure and the factors of safety against sliding and overturning, both for wind and seismic forces. The 13 respondents used six different codes to come up with solutions. Nine had a 14-ft-long footing; four had 12 ft.

The effects of overturning were not included in the four solutions, which indicates 30% did not perform the engineering fundamental basics, says the report on the trial design. The use of load combinations was also not consistent.

"We've learned that the code is interpreted differently throughout the U.S., that the language of the code is not clear and concise and that the code is taking the engineering out of engineering," says Craig Baltimore, associate professor of engineering at California Polytechnic State University, San Luis Obispo, and the current trial design leader.

The argument is not over whether codes are increasingly complex. It is over whether that is good, bad or both.

James R. Harris of the Denver firm that bears his name and chair of the ASCE/SEI 7-05 committee, says increased complexity results from a need to make more economical use of resources, a demand for more complex structures, and an increasing understanding of the magnitude of seismic demands coupled with a need to manage the costs of seismic-resistant construction. But for simple buildings, "in many instances there are simplified alternative provisions," he says.

**New regs should be enforceable, substantiated, justifiable and trial-designed.**

— JOHN TAWRESEY, STRUCTURAL ENGINEER

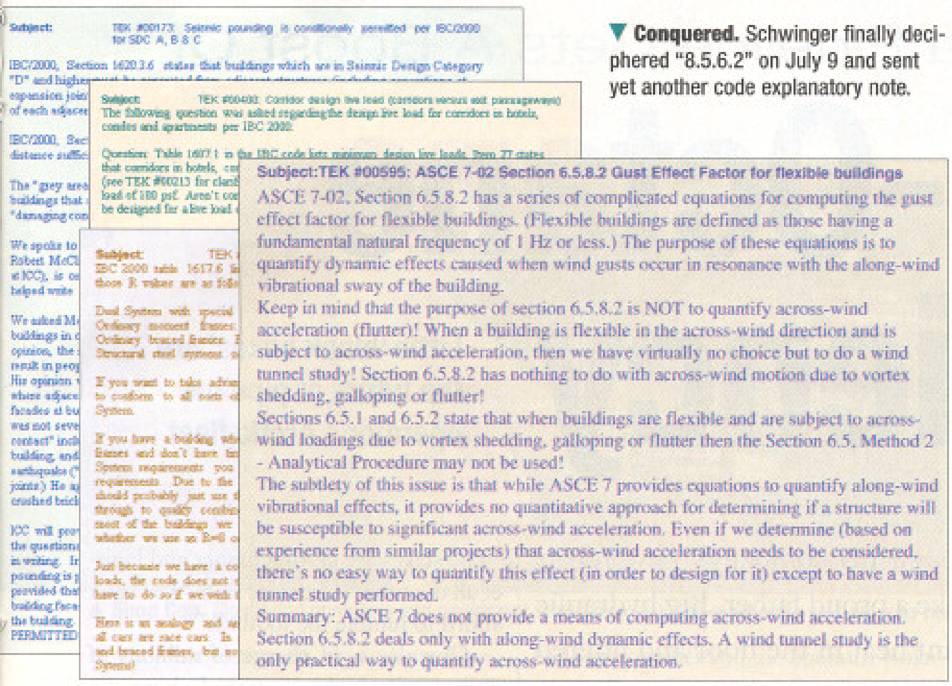
Ron O. Hamburger, principal of Simpson Gumpertz Heger, San Francisco, adds that some complexity is aimed at reducing the potential for failures. "Buildings constructed in the 1970s and earlier do collapse in earthquakes, do lose cladding in hurricanes and severe windstorms, and do experience roof failures in blizzards," he says.

Competitive pressures are pushing for ever-more-economical structures. That translates to more-exact designs. That means safety factors are substantially reduced from historic levels, says Hamburger. He advocates a tiered set of provisions that permit very simple, though not necessarily economical solutions for simple buildings and progressively more complex requirements for more complex buildings.

For steel frames, simplification is happening. With the 2005 steel spec, AISC is providing two, 5 x 8-in. cards that distill only the typically needed and used information. With these, one can perform simplified analysis and design all typical beams, columns, braces, tension members and connections, says Charles J. Carter, AISC's chief structural engineer. The cards cover W-shapes, channels, hollow structural sections, pipe, bolts, welds and connected parts.

For ASCE 7–05, due out by September, effort has been devoted to clarifying the main body of seismic requirements and to developing simplified alternatives for simple buildings, says Harris.

Code and standards groups have been striving to reformat the codes so the body of the model code governs scoping, policy, hazard definition and administrative


Subject: TEK #00173: Seismic pounding is conditionally permitted per IBC/2000 for SDC A, B & C

IBC/2000, Section 1620.3.6 states that buildings which are in Seismic Design Category "D" and higher

Subject: TEK #00400: Corridor design live load (corridors versus exit passageways)
The following question was asked regarding the design live load for corridors in hotels, condos and apartments per IBC 2000.

**Subject:TEK #00595: ASCE 7-02 Section 6.5.8.2 Gust Effect Factor for flexible buildings**

ASCE 7-02, Section 6.5.8.2 has a series of complicated equations for computing the gust effect factor for flexible buildings. (Flexible buildings are defined as those having a fundamental natural frequency of 1 Hz or less.) The purpose of these equations is to quantify dynamic effects caused when wind gusts occur in resonance with the along-wind vibrational sway of the building.

Keep in mind that the purpose of section 6.5.8.2 is NOT to quantify across-wind acceleration (flutter)! When a building is flexible in the across-wind direction and is subject to across-wind acceleration, then we have virtually no choice but to do a wind tunnel study! Section 6.5.8.2 has nothing to do with across-wind motion due to vortex shedding, galloping or flutter!

Sections 6.5.1 and 6.5.2 state that when buildings are flexible and are subject to across-wind loadings due to vortex shedding, galloping or flutter then the Section 6.5, Method 2 - Analytical Procedure may not be used!

The subtlety of this issue is that while ASCE 7 provides equations to quantify along-wind vibrational effects, it provides no quantitative approach for determining if a structure will be susceptible to significant across-wind acceleration. Even if we determine (based on experience from similar projects) that across-wind acceleration needs to be considered, there's no easy way to quantify this effect (in order to design for it) except to have a wind tunnel study performed.

Summary: ASCE 7 does not provide a means of computing across-wind acceleration. Section 6.5.8.2 deals only with along-wind dynamic effects. A wind tunnel study is the only practical way to quantify across-wind acceleration.

▼ **Conquered.** Schwinger finally deciphered "8.5.6.2" on July 9 and sent yet another code explanatory note.

requirements only, says John D. Hooper, director of earthquake engineering for Magnusson Klemencic Associates, Seattle, and chair of ICC's structural code committee. The technical engineering requirements are then referenced.

Hooper admits that the long-term goal of using reference standards has created some short-term confusion. The good news is that "unless future, substantial changes are deemed necessary and successfully undertaken," there will likely be only "maintenance" changes in the standards, says Hooper.

Many engineers support stretching code cycles to five or six years, with critical and unsafe provisions addressed mid-cycle. Local jurisdictions would benefit by reducing the frequency of the effort needed to evaluate new provisions. Engineers would benefit by reducing the frequency of the effort to relearn the code. The public benefit for all proposed changes would be vetted more thoroughly, say sources.

But Claude G. Cooper, chairman of the American Major Building Officials Association and the Richmond, Va., building commissioner, thinks the three-year IBC cycle is "ideal." It provides opportunity to use the code, while enabling "quick" adjustments to provisions not working, he says.

Though IBC's cycle has been driving new editions of the standards, ASCE/SEI does not plan to publish again until 2010. "I am convinced we have been changing structural design standards too rapidly" for people to keep up, says Harris.

The edition will be out early enough for the materials standards targeting the 2012 model code to cite it in 2011 editions, he says. ASCE 7 will then issue a supplement updating its references to the then-current materials standards. If the stretched cycle is successful, others are expected to follow ASCE, says Harris.

> **The current three-year cycle for reissuing the model code is "ideal."**
>
> — CLAUDE COOPER, RICHMOND BUILDING OFFICIAL

The next steel spec is planned for 2010, based upon the planned IBC cycle. "If ICC extends, we will," says Carter.

ACI is eyeing a six-year overall cycle, with minor changes after three years, as not perfect but reasonable for code activities, says Jim Wight, chair of the ACI 318 committee and a professor at the University of Michigan, Ann Arbor.

The trend toward lengthening standards cycles bodes well for the future, but has little impact on daily work. Problems are most pronounced in loading criteria in Chapter 16 of IBC and in ASCE/SEI 7, sources say. "Formulas, tables and charts are confusing and sometimes use inconsistent terminology," says DeStefano. That could be dangerous, he adds.

In 1980, establishing loading criteria was not a big adventure for engineers, says DeStefano. Codes had simple, unambiguous tables that defined snow, wind and live loads. There was a simple formula for determining equivalent static lateral forces for seismic design. "Most of an engineer's time was spent designing and analyzing, not trying to figure out what loading criteria to use," he says.

In 2005, determining a simple roof snow load requires a detailed analysis that considers factors such as how exposed the site is, how much heat is lost through the roof and how slippery are the shingles. "Evaluating wind loads is a bit more involved and evaluating earthquake loading is a real adventure," says DeStefano.

For Schwinger, the most mind-boggling sections in ASCE 7 are 6.5.8.1, 6.5.8.2, 6.5.12.3, which address the gust effect factor. The worst of these, 6.5.8.2, was so daunting that he kept avoiding cracking it. That was until July 9. At 9:15 p.m., he "sent" TEK 595.

Schwinger recently decided to shed his pocket protector, at least occasionally, and become a "poster engineer" for code reform. For starters, he joined AISC's manuals and textbooks committee.

The "fresh blood" is welcomed by veterans for the cause. "If we want to improve the process, we must get out of the office, join the debate and participate in the struggle," says Griffis, who admits he has no patience for "whining from the sidelines." ■

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