Turning Green into Gold
Structural Sustainability

by Alan Whitson, RPA

A building's structural system is frequently overlooked in the pursuit of sustainability. The reason may be that the LEED rating system doesn't directly address it. One structural engineer told me that the only discussion she ever had with an architect about sustainability was when he needed the recycled content of the steel and the percentage of fly ash in the concrete. Structural engineers are underutilized in our efforts to design high performance and sustainable buildings. They have a proven skill set that can save time, money and resources.

To demonstrate, let's examine the **Aladdin Hotel** in Las Vegas. Like most hotels on the Vegas Strip, this 38-story, 2,600-room hotel was originally designed as a concrete frame structure. When the bids were higher than expected, some creative alternatives were needed. SMI-Owen Steel Co., Columbia, SC, submitted a proposal for a staggered steel truss structural system that cost 10% less than the original concrete frame design. In addition to saving over $4.5 million in hard construction cost, a similar sized reduction in construction interest expense was possible since the hotel was completed four months sooner. Yet, the really big money was in the ability to start hotel and casino operations 120 days sooner. At $2-million-a-day in revenue that's almost a quarter of a billion dollars!

Developed by MIT in the late 1960s, the staggered-truss system is appropriate for apartments, condominiums, dormitories, hospitals, and hotels that are six stories or more in height. This innovative system has most of the advantages of flat-slab concrete construction at significantly lower cost. **Neil Wexler,** PE, author of *The AISC Design Guide for Staggered-Truss Buildings*, says it's the use of geometry that is the basis for the savings over concrete and traditional steel designs.

Other benefits include minimum deflection and greater stiffness in the structure while reducing seismic loads and foundation costs. The heart of the system is the story-high trusses that span the width of the building. The trusses are concealed inside demising walls with vierendeel openings in the trusses for corridors and door openings. This allows column-free areas up to 60 by 70 feet, while the column spacing for conventional post-and-beam steel construction is 25 feet to 30 feet; for a concrete structural system, it is 18 feet.

In typical post-and-beam construction structural elements align from floor to floor. However, in a staggered truss system, the trusses form a staggered pattern; hence, the name. To illustrate, the trusses on the second floor would extend across the building at column lines 1, 3, and 5; on the third floor the trusses would be at column lines 2, 4, and 6. The top chord of the second-floor trusses aligns with the bottom chord of the third-floor trusses. Precast concrete planks are used to create the floor deck, producing a semi-finished floor and ceiling in one operation, eliminating the wet trades and allowing all-weather construction.

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Currently, 95% of all structural steel in the United States is made from recycled steel. But sustainability goes beyond a product's recycled content to include the most efficient use of the product or material. A typical post-and-beam steel frame uses 8 to 10 pounds of steel per square foot, compared to the staggered-truss that uses 5.5 to 6.5 pounds of steel per square foot. This can reduce the amount of steel used by one-third to one-half.

There's a synergy to this design. Fewer columns are needed and less steel is used. Even the pre-cast floor planks weigh up to 30% less than poured-in-place concrete methods. This allows a simpler foundation which further reduces the amount of steel and concrete used in the project.

It is also a practical solution for reducing floor heights. The obvious benefit is the opportunity to increase the number of floors within the building envelope. Another is the ability to reduce the ratio of building skin to building floor area. While a subtle benefit, a building's exterior skin can costs more than its structural frame. Also reducing a building's exterior surface area can reduce the heating and cooling load for the mechanical system. This reduces the size and first cost of the mechanical system, and its operating costs.

Other areas for savings include reductions in all vertical riser heights, and the time and cost of applying fireproofing to the steel.

There are construction management benefits too. Using prefabricated steel and pre-cast concrete allows the work to be done by a single subcontractor rather than multiple subcontractors. Bidding is usually energetic due to a large pool of qualified subcontractors. Since there are fewer structural elements, this translates into fewer shop drawings, fewer trucks making job site deliveries, and faster erection that allows other trades to begin sooner.

Another example of structural innovation is the **Wellesley Gateway Center.** This four-story, 270,000 square foot office building is the corporate headquarters of Harvard Pilgrim Health Care. Challenged by zoning restrictions that limited the building height to 50 feet, the design team needed to fit four floors into a three floor building envelop. To do so the structural design had to accommodate a ceiling height of 8'-6" with a floor-to-floor height of 11'-6" while providing the flexibility to distribute ductwork throughout the building.

The Cambridge, MA office of Weidlinger Associates met that challenge. This cost effective structural systems consists of a composite steel construction with a typical office bay dimensions of 30' x 45'. The typical floor consists of 3" composite steel deck (18 gauge) and a 3 ¼" lightweight concrete topping slab, which provides a 2 hour fire rating without spray on fireproofing. The floor deck spans between 14" deep beams that in turn are supported by the 45' span girders.

The key element is a "half-tree" column with an 8' long x 24" deep "branch" that cantilevers off one side of the column. Shallow wide flange beam segments (14" deep) span between the branch tips to complete the 45' span. This enables the 10" high area beneath the shallow beam to be used for MEP systems while keeping the ceiling height within a few inches of the typical bottom steel elevation. Areas that are not directly under a beam have a clear height of 24" from top of the ceiling grid to the bottom of the floor deck.

Contributing to the effectiveness of this structural system is the efficiency in both fabrication and erection costs. Each "half-tree" column is shop fabricated and erected in one piece. Also fabrication costs were significantly reduced due to the identical size and dimensions of the "half-tree" frames.

Architects, engineers, contractors, developers and building operators should work together throughout a building's lifecycle. The integrated design process and software tools like building information modeling can greatly improve project quality, avoid wasted time, and be more profitable as everyone is now free to focus their attention on producing high performance and sustainable buildings.

This column is published in conjunction with the Corporate Realty, Design & Management Institute and the Center for Sustainable Real Estate. Click on www.squarefootage.net for a seminar schedule, books, and white papers on high performance and sustainable buildings. More than 30 educational seminars are planned in 2006. Alan Whitson will also speak at National Facility Management & Technology Conference, CleanMed Europe and IFMA World Workplace. You can contact Alan Whitson at awhitson@squarefootage.net