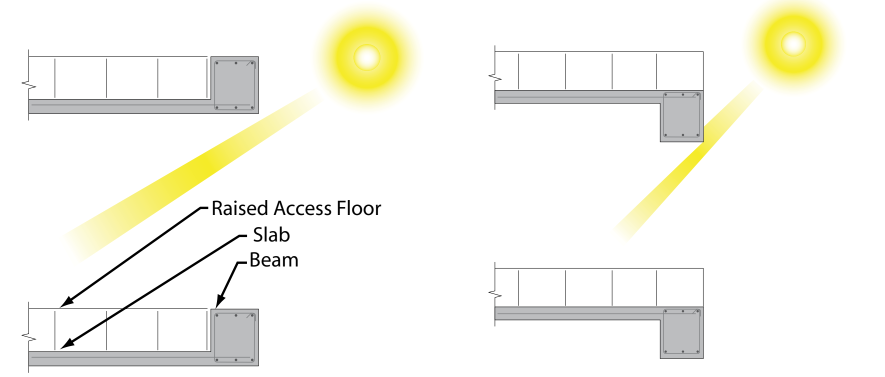
"Extraordinary" Sustainable Thinking for "Ordinary" Projects

By Ruben Aya-Welland, P.E., S.E., LEED AP

It is not difficult to find inspiring landmark building designs from around the world that capitalize on the fundamental principles of sustainable design. Such examples include green buildings that utilize intensive green roof constructions, that integrate high-tech exterior curtain wall systems, and that find innovative uses of recycled and reused materials and components for building construction. Many of these "state-of-the-art" green building designs also implement extensive energy modeling, and require engineering systems commissioning to help validate original design intentions. These "high profile" sustainably designed building projects have demonstrated the potential success that comes with an integrated and multi-disciplinary approach to sustainable design. Very often these same projects have also enjoyed enthusiasm and encouragement from both the owner and the contractor, most notably when it came to supporting life cycle cost analysis considerations and construction budget allowances for doing things "differently" than the accepted norm. But, what about the everyday buildings that make-up the majority of our collective construction effort? What about the projects that are typically driven to be designed quickly and on a tight budget? What if a detailed long-term life cycle analysis is neither considered nor even desired? What if LEED® (Leadership in Energy and Environmental Design) certification is not even a topic of discussion? Does this mean that sustainable thinking is therefore not at all relevant to the design process? Absolutely not. Sustainable design practices should be part of any and every building design process. Furthermore, with the more modest budgets of our everyday projects, sustainable design strategies can be considered and implemented to maximize the passive energy potential of a given building design.

Land Use and Siting

Proper site selection is rarely a decision left to the structural engineer. When analyzing site-specific project data, the structural engineer is typically concerned with review of the geotechnical engineering report and subsequent recommendations for foundation systems. Typical foundation engineering challenges might include mitigation of weak soils, interfacing with existing infrastructure, and designing for high water tables. But beyond providing the engineering for more typical design solutions, the structural engineer can also be instrumental in helping his clients better understand the tradeoffs involved in choosing a particular site density strategy.



Upturned Alternate

Typical Reinforced Concrete Framing

For example, foundations for shorter buildings are generally less expensive due to the relatively low structural loads involved. But shorter buildings also require more widespread site development to meet predetermined square footage requirements. Furthermore, the more that a site is built upon, the less of that site remains available for permeable ground cover that aids in storm water infiltration. On the other hand, although foundations for taller buildings are generally more expensive from a construction point of view, they also allow for a smaller built site footprint.

But even with a smaller building footprint, native weak soils may still require significant and widespread soil improvement measures. This can include generating a significant amount of spoils and depositing large amounts of concrete for foundation elements. Efforts to minimize spoils on site might favor the selection of "displacement" installation methods for auger pressure grouted piles, or the use of "helical" pile techniques. For placing large amounts of concrete, it should be relatively easy to specify high percentages of recycled supplemental cementitious materials (SCM's) to replace Portland cement in the concrete mix designs for foundation elements. The structural engineer might even consider specifying a 56-day concrete strength for foundations to account for slower setting times with high fly ash concrete mixes: keep in mind that there are many instances when the full concrete strength of a foundation element may not actually be needed until the entire superstructure has been built.

By becoming much more involved with site issues, the structural engineer can help the design team find that overall balance of land use and density by helping evaluate strategic options for building size, extent, and location.

Daylighting

Options for land use and site selection working in tandem with building programmatic requirements can suggest design options for building mass, shape, and form. Daylighting is a sustainable design strategy that tries to minimize the daytime need for artificial interior lighting. Its relative success depends, to a large degree, on the ratio of physical building height to building width. Common floor and roof framing systems of structural steel, reinforced concrete, cold formed metal, or wood can all be designed to accommodate virtually any shape or aspect ratio of a building floor plate. But when working with the architect, the structural engineer can also be proactive and anticipate the strengths and weaknesses of certain structural framing systems as they relate to daylighting strategies.

For one story structures, if a building's plan dimensions become necessarily large compared to the overall height, rooftop skylights can be introduced fairly easily that can help bring natural light to the depths of the building's interior footprint. Rooftop openings for such structures are already fairly common for accommodating rooftop mechanical units and access hatches; swapping in skylight elements can therefore be a fairly simple and effective strategy for increasing daylighting in such "warehouse" type structures. For multi-story structures, daylighting strategies can be a combination of direct and indirect or even reflected daylighting.

Perimeter spandrel structural framing is an important design element that can help maximize the potential use of daylighting.

The structural engineer needs to anticipate spandrel depth constraints that the architect will undoubtedly present, and he should help provide design options that not only meet the architect's daylighting goals but also help to control construction costs. If shallower beam depths become unusually expensive in order to control beam deflections, a possible solution could be to suggest that the architect tighten up the perimeter column grid spacing. Of course, this structural strategy may have other less desirable consequences like requiring more column footings, creating potentially adverse effects to interior space planning along the building perimeter, and inserting a greater number of architecturally exposed columns at the windows. If the superstructure is of reinforced concrete, perhaps an upturned spandrel solution would better integrate with a daylighting design criteria.

Interior light wells and atriums are other design features that help bring natural light into an interior building space that would otherwise have been "cutoff" from the exterior environment.

With all of these design options, there will be potential trade offs with respect to reduced square footage, increased construction cost, or modified architectural appearance. The emphasis here is that the structural engineer can help the design team be better prepared to compare design options for daylighting when he can learn to anticipate opportunities for using natural light, and understand how daylighting in turn affects the structural system selection and design.

Glazed vs Non-Glazed Exterior

Windows are no doubt a desirable building design element; they not only allow natural light to flood the interior space, they also provide interesting visual connections between indoor and outdoor activities. But if too many windows are incorporated into the design, the building engineering systems must then work harder to counterbalance both heat loss in the winter and heat gain in the summer. These decisions obviously fall under the realm of the architect, and the structural engineer would typically provide framing solutions for any given design intent. But here again, the structural engineer can find opportunities to be proactive and promote sustainable design.

For example, when discussing architectural design intentions for a fully glazed building exterior, the structural engineer can also introduce ideas about the logical or economical placement of solid shear walls, perforated shear walls, or vertical bracing systems around the building perimeter. These lateral bracing systems are usually not desirable as exposed architectural elements, thereby providing good design rationales for incorporating less glazing into the façade of a building that would otherwise suffer from a high amount of heat loss or heat gain. Quite often, moment frames provide an ideal modular architectural solution for integration of daylighting strategies with perimeter windows or curtain wall systems. But moment frames might normally prove too expensive for the construction budgets of larger scale buildings with moderate to high levels of lateral loading. However, with smaller buildings and their lighter lateral loads, transparent, translucent, and even opaque exterior modular cladding can be complemented by structural moment frames systems without necessarily incurring a substantial premium for construction costs.

The structural engineer serves as a champion for sustainable design when he can engage the architect early enough in the design process to help provide conceptual design feedback to the proposed exterior envelope.

Roofs and Walls

The outer shell enclosure is an extremely important aspect of any building design. It is this barrier that resists the daily environmental assaults from sun, wind, and water in the form of rain, ice, and snow. Roofs and walls form the basis for this environmental separation between interior and exterior conditions. Although it is the architect that dictates the design of the typical exterior wall and roof construction systems, the structural engineer can once again rise to the occasion and propose ideas that strive to enhance the sustainable attributes of a building design.

For example, relatively simple and economical extensive green roof systems are engineered to be light and modular in nature. Structural loads for extensive green roofs can be very similar to normally assumed superimposed dead, live, and snow loading, thereby having a potentially minor overall effect to structural steel tonnages and structural roof decking gauges. If a green roof is simply not appropriate for a given project, the roof plane should still be treated as a surface that will receive plenty of sunlight and water. The structural engineer can propose sloped roof framing systems that uses gravity fed drains for channeling of storm water. For relatively large roof areas, this strategy can greatly reduce the amount of required tapered insulation that would have been used to alternately build up roof slopes for this purpose. Of course, this is not a new strategy, but with more complex geometries and roof framing systems, sloping steel may sometimes seem more cumbersome than simply allowing the architect to specify thick tapered insulation.

Another roof strategy is to consider overhangs as a means of providing sun shade during the summer months. By anticipating overhangs sooner, the structural engineer can propose framing systems that achieve the necessary cantilevered structure in a more economical and constructible manner; this strategy can also create opportunities for exposed architectural expression of overhangs that would otherwise not have been considered, especially if the connection is a field welded steel moment connection where architectural weld quality would have been too cost prohibitive.

Examples of sustainable wall strategies can include concrete masonry unit (CMU) walls that act as load-bearing and shear wall elements while also providing thermal mass properties to a building enclosure. With CMU walls, close attention must be paid to type of block and type of grout used, as this can have an effect on the particular thermal strategy. Will the building benefit from increased insulation? Will the building use its inherent thermal mass in conjunction with the heating and cooling systems? Building load-bearing and shear walls can also be of site cast, tilt-up, or precast concrete. If using concrete walls, do thermal massing strategies benefit if we provide thicker walls than needed for structural strength and stability? Using more materials than needed from a structural perspective can sometimes benefit other sustainable design synergies.

Conclusion

According to its published Code of Ethics, the American Society of Civil Engineers (ASCE) states as its first Fundamental Canon: *"Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties."* One of the prime directives of our profession is to actively promote sustainable thinking into our everyday practice. As sustainably minded structural engineers, we must not be content to sit on the sidelines as major project decisions take shape. Instead, we need to be proactive and remember that any project can benefit from a sustainable design mindset. Even if the project budget, scope, or owner "buy-in" is rather limited in its support for green building practices, the first principles of sustainable design should still be an extremely valuable tool for the design team when seeking green design ideas for our more "ordinary" projects. The better that structural engineers become at speaking about a sustainable design ideology for our everyday projects, the more credible we will be to our clients as sustainable designers.▪

*Ruben Aya-Welland, P.E., S.E., LEED AP is an Associate with Hellmuth, Obata + Kassabaum (HOK) in St. Louis, Missouri. He is a member of the ASCE-SEI Sustainability Committee. Ruben may be reached via email at **ruben.ayawelland@hok.com**.*