Steel Goes Global

Edited by Beth S. Pollak

Around the world, structural steel is the material of choice for innovative designs and tight construction schedules. From parking structures to chemical plants, bridges to tall buildings, steel is everywhere.

New communications systems, like e-mail, Internet, video conferencing and electronic data interchange, have made it easier to design and construct steel-framed buildings on a global scale. Three-dimensional computer models with sophisticated visuals help bridge language barriers.

Design and construction internationally require careful coordination and cooperation between project team members at home and abroad. *Modern Steel Construction* spoke to five people with insight into what it takes to work on international projects—and what innovations and changes are taking place in the greater world of structural steel.

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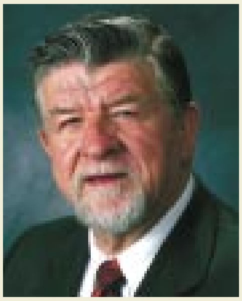

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How does a large international firm handle global work?

Argiris: Arup has about 6000 people worldwide. We break down into groups of about 100-150 people, which are the entities that handle and deliver projects. We also create layers of mechanisms for cooperation, coordination, and tapping into expertise that resides elsewhere in the firm. There are about 12 disciplined skills networks, where you can exchange knowledge and best practices. For example, you have a seismic engineering network and a façades network.

No group is bound geographically by location. I'm a principal in the New York office, but my group does work across the United States and internationally. We usually do design work where the architect and project team are located. If there is an Arup office geographically near to the project site, we make use of their understanding of local conditions.

Whether in the United States or abroad, it's imperative to get a good understanding of what a local contracting community expects on design documents. The only way to do this is to see examples. What details are contractors comfortable with, and what connections are they used to seeing? To get more background, we'll either work with Arup's local offices, or associate with a local engineering office.

Poon: When you select a design team, it's good to have team members on both sides who understand each other's countries and practices. TT has international experience all over the world, which helps us to proactively solve any localized problems—we don't wait until the last minute. You also must respect local culture and practice.

First, you have to know the capabilities of the local trades. You must understand local constraints, like availability of material and skilled labor. When we designed Taipei 101 (see p. 29), we knew that Taiwan did not produce wide-flange sections, and we'd have to find an international contractor for the steel. But we would still use local labor, since most laborers in Taiwan have experience with structural steel.

Second, in some countries, like Taiwan and China—the approval process can take a long time, so you have to pace the design and construction schedule with that local process. You also have to understand local building codes. Third, you must understand the owners' requirements, and comply with them. Talking to the owner and the construction manager, and maintaining an open dialogue with the design team is the key to success. Once you know all of that, you should work in a respectful way with the local team, but without compromising creative ideas.

Can you give any examples?

Poon: In big cities in China, you must work with local design institutes. The institutes sign and seal the drawings. Chinese building codes are a rigid and hard-to-follow combination of a lot of international codes. It takes lots of patience to work step-by-step with local approval authorities and design institutes, especially if you want to be innovative. To avoid compromising creativity, you have to put in more time, and really substantiate the analysis and design. You have to prove that an innovative design will work, will be safe, and will benefit the owner. You have to show previous experience. Sometimes we don't get 100% what we propose, but we achieve as much as possible.

How did things work with Taipei 101?

Poon: For Taipei 101, we did the preliminary design in the United States, and then consulted with the local team. The engineers and architects traveled between the United States and Taiwan, but a lot was done though electronic communications. Many of our staff and their staff members are bilingual. Many engineers in Taiwan understand our industry, and we understand theirs.

Taipei 101 was challenging, but the design-team network was very smooth. When we worked with locals, like professors from local universities, we found out that many of them had graduated from universities in the United States! It's a big plus to work with people who understand the U.S. process.

How are technology and Electronic Data Interchange (EDI) changing project delivery around the world?

Engler: The speed and capabilities of the Internet and EDI make design virtually seamless around the world. Internet conferencing allows you to discuss 3-D models as if you were in the same room with project team members. These tools remove distance from the equation, so it's easier than ever to do international business.

We get involved with projects where the engineering is done in the United States, the detailing in Australia, and the project itself in Brazil. There's no limit on the combinations of locations for project teams. Some

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companies are moving to a completely paperless process. Firms are building a business model around the paperless process, and bringing others with them. Their model requires that subcontractors enter the paperless world, or they won't be able to do business. Maybe in the past, subcontractors pushed the design process, but today, the larger engineering companies are pulling the process by creating design models and passing them back and forth.

Right now, we're seeing a convergence of many things. The Internet operates efficiently. 3D-analysis and modeling programs also are efficient, which wasn't the case 10 years ago. 3D models now are used on commercial projects and even simple buildings. Computer hardware and software is cheaper. Detailing software has evolved and can take downloads from 3D design models. With EDI, information flows through a giant relational database to the subcontractors. All the trades are using more and more electronic data—even the decking, precast, and wall-panel contractors are moving to a one-model world, with relational information for subcontractors to draw from.

Manuel: Bechtel uses a paperless work process, going straight into fabrication without paper drawings. With the old process, you have RFI cycles and delays, and lengthy shop-drawing review cycles. In the new process, engineers produce a fabrication-quality model and transfer it electronically to a fabricator, which cuts out weeks. You can create 1000-metric-ton structures in a couple of weeks. In the past there was a six-to-eight-week delay just for the shop-drawing review.

Many other countries are not as sophisticated with their technology, but we don't like going backwards in our work process. Training is key. If you want to elevate the bar, you must engage people. To hold on to the old work process creates a labor sink. The amount of time it takes to review with the old process compared to the new is significant, so there's every incentive for us to pass on this knowledge and capability wherever we have projects.

We're working with a company in Australia right now. In the United States we like to do things our way—but over there, they want things done their way. By switching to 3-D models and EDI, not only do we really reduce the schedule, but we also add a new form of flexibility so everyone can have it the way they want it.

We had a kick-off meeting with the fabricator, and we let them tell us what connections work best for them, what presentation styles for the shop drawings work best for them, and we plugged that in—so everyone gets what they want at a minimum effort, with no huge paper trail.

The core is CIS-2 and EDI. Having CIS-2, a single logical model, is ideal. In a global market, you compete with different labor centers, and you've got to use every advantage. The benefit of 3-D modeling is that the quality is so much better. You don't have the opportunity for errors.

Poon: At TT, our office also is using a paperless process. We do structural steel detailing with Xsteel, and integrate design and detailing directly with the fabrication shop. More and more projects integrate design, fabrication and construction. We push for it in every project we can, but we need the owners' and industry's support.

Local contractors in different countries do not always have sophisticated technology. Unfortunately, many owners go for the lowest bid, and contractors with the best technology might not win the job. However, if a client understands the value of quality work and construction, you can push to contract companies with good technical capabilities. The paperless process eliminates a lot of waste. There are fewer mistakes, less waste of steel, and less time and money wasted. And even from an environmental approach, the less waste the better.

Dobbie: Dowco has its own Internet service provider (ISP). Using that and video conferencing, we communicate quickly with other offices. It saves money and time on flying.

For global projects, most design and detailing work is done in North America. We pass files back and forth electronically between different offices. Right now we're working on a project in Indonesia. We e-mailed the final drawings to the site. To get there by FedEx, it would have taken days, but with the electronic exchange, it was instant.

Many companies use offshore detailers in countries like Romania, India, China and Indonesia. It works because of EDI and the ease of electronic communication. There also has been a paradigm shift in our industry: In the past, detailers worked with a steel fabricator as part of a shop's detailing offices, but now detailers increasingly are working with engineers and EDI, building 3D models and exchanging them back and forth. Once the model with details and connections is done, it goes out to bid, and typically gets competitive prices, because a lot of the risk is removed. We've done a number of jobs where we've used this integrated design process. It ties design and detailing together before the job is awarded to a fabricator.

Do you find language barriers, working internationally?

Dobbie: Language isn't a problem, because we deal mainly with electronic communication, which is pictorial. A beam looks the same in every country. So do columns and braces. A structure looks like a structure. The only time that you have a language problem is when you add labels and make notes on drawings. We avoid labels and use as little text as possible. When you stick to symbols and dimensions, the drawings are international. And even though the United States uses imperial units, while most other countries use metric, a computer can switch easily to metric units.

Manuel: Being model-based, we have a common language. You don't have to be good with language skills—you just have to look at the model and work with it. It tells a very good story.

Dobbie: The funniest language misunderstanding was when someone told me they wanted "a bolt and two lunatics." Eventually we figured out that they meant a bolt and two nuts!!

Has there been a global increase in environmental awareness in design and construction?

Argiris: There is more environmental awareness across the globe. Most building owners

Taipei 101 Tops Out

With the lifting of a steel-framed spire assembled within its upper floors, the Taipei 101 project in Taiwan recently reached its full design height of 508 m (1667 ft) and prepared to take its place as the world's tallest building.

A skyscraper must provide space that is physically and psychologically comfortable. For Taiwan, that means designing features for comfort and strength in Taipei's high typhoon winds. A previous article (*Modern Steel Construction*, December 2002) discussed the seismic load-resisting system, but major seismic events thankfully are rare.

The Taipei 101 basic design wind for a 100-year return period is a 10-minute average speed of 43.3 m/s (97 mph) at 10 m (33 ft) height on open ground. It is similar to a 150 mph 3-second gust, like a US hurricane coastline. In addition to direct wind pressure or drag, tall and slender, round or sharp-cornered structures experience crosswind excitation from vortex shedding. The height and original plan dimensions of Taipei 101, combined with the anticipated wind speeds, would have generated large cross-wind forces and accelerations – uncomfortable for occupants and a costly problem.

The solution had three parts. First, the "megaframe" structural system minimizes lateral deflections. With a steel-braced core, multiple outriggers trusses and belt trusses, concrete-filled steel-box perimeter megacolumns, and perimeter frames, the building period is only 7 seconds, rather than the 9+ seconds normally expected for this height.

Second, the building shape minimizes vortex shedding. Wind-tunnel consultant RWDI demonstrated to architect C.Y. Lee that the original sharp-cornered shape generated large vortices. Chamfered and rounded corners reduced the effect, but "sawtooth" or stepped corners provided the greatest benefit. From then on, the architectural design included corners with double steps, 2.5 m (8 ft) on a side, on the upper 70% of the main tower.

Third, supplementary damping was provided to reduce the tower's sway. Small vortex forces accumulate to create tower sway—much in the way a child's leg motions coax a playground swing into motion. Rigidly-connected steel frames provide relatively low inherent damping, about 1% of critical damping (100% prohibits any sway). To further reduce sway accelerations, a large tuned mass damper (TMD) was used. 730 tons (660 Mg) of stacked steel plates form a sphere centered 1 m above Level 88 and hanging on cables from Level 92. Swaying at the same rate as the tower, it pushes on giant shock absorbers that convert motion to heat.

Two small TMDs with 5-ton (4.5 Mg) masses address fatigue life. The 60-m stainless-clad pinnacle mast has a structural steel spine of diagonals and box legs in graduated sizes. Cyclic stresses from vortex shedding and buffeting were converted into equivalent zero-mean-stress cyclic ranges at 2 million cycles using Goodman's simplification and the Modified Miner's Rule for fatigue evaluation. The small TMDs reduce wind excitation in several modes. For 100-year design life, plates bolted across joints reduce cyclic stresses in field-welded splices.

The most public design feature within the 412,500 m^2 (4.44 million square feet) project is a long-span mall skylight support. Two parallel trusses each have a pair of curved steel pipes 80 m (262 ft) long linked to a 750 mm (2.5 ft) diameter bottom chord by vertical T-ribs, creating a hybrid between a Vierendeel trusses and a tied arch. The complex intersection of the T and curved top chords, along with varying T heights up to 10 m (33 ft), was handled in shop drawings by a 3D program.

The distinctive silhouette of Taipei 101 is sure to become an icon for Taipei and Taiwan. Steel is the primary source of the stiffness, strength, security and occupant comfort that the designers and owners intended for this new landmark. ★

Above: The main tuned mass damper is composed of 730 tons of stacked steel plates.

Left: Taipei 101 tops out at 1667'.

*Contributed by **Dennis C. K. Poon**, P.E., Managing Principal, and **Leonard M. Joseph**, P.E., S.E., Principal, both of Thornton-Tomasetti Engineers, New York City; and by **Shaw-song Shieh**, P.E., S.E., President, and **Ching-Chang Chang**, P.E., S.E., Project Manager, both of Evergreen Consulting Engineering, Inc., Taipei, Taiwan, Republic of China.*

look for some sustainability criteria. It's an "in" thing.

Poon: On all buildings we try to be environmentally conscious. We use a lot of fly ash in concrete for composite design. Even with a curtain-wall design—we try to coordinate the steel structure with curtain wall to make it more energy efficient.

Engler: There is increasing concern for sustainability. Owners know that steel is almost 100% recycled in the United States, and they are familiar with the Leadership in Energy and Environmental Design (LEED™) requirements. Even if they don't get LEED credit, they are concerned with sustainability on their projects.

Has blast protection become a global concern?

Poon: After 9/11, blast was really emphasized. We consider different threats and how to design for them. Current technologies can deal with most threats. You also can improve building security with electronic systems and by modifying layout. But don't over-design a project because of fear, and lump all blast-protection suggestions together. You have to strike a balance, and remember that the building can't be a bunker—it has to be functional, economical, commercially viable, and user-friendly. We also have to improve building codes so they deal with threats but also are reasonable for commercial construction. We need to raise safety standards without designing buildings as bunkers.

Argiris: Blast is definitely front and center, and we've seen more concern internationally than in the United States. Extreme threat mitigation is unpredictable—you don't know exactly what you are designing for. We approach it from two standpoints: 1) Risk and threat assessment: Is a building a target for likely attacks, and how can you mitigate those threats? Consider security and architectural solutions to keep threats away from a building. 2) The structural standpoint: Work for robustness and redundancy in a structure to prevent catastrophic results in case of an impact or explosion.

For fire protection, there is a worldwide move to performance-based fire engineering, as opposed to prescriptive approaches. We have fire engineers who work to identify the performance level necessary for a building, and define it in terms of egress and fire load—and then design an appropriate system. It opens up a myriad of alternative solutions and opportunities unique to each project.

Engler: We're see some concern for blast protection in connection design. In high-rise buildings, connections now are being designed not only to carry loads, but also to prevent collapse. Before you'd design a connection to carry forces, and now they are being designed in case of failure as well.

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Have you seen any other new trends in steel design around the world?

Argiris: We see different uses of steel. As fabrication becomes easier, it frees us to create different shapes. In composite construction, designers and contractors are using new solutions to combine steel and concrete.

On the architectural side, Arup uses steel castings on numerous projects. We love them! But they are more difficult to construct in the United States than in Europe, where there are more foundries and there is a greater industry available.

Also, many European architects are working in the United States. American clients want a European design approach, and the European designers are happy to come and provide it.

Dobbie: The Frank Gehry work and similar designs couldn't have been done even 10 years ago. Without computers, it would take forever to design and detail them, if at all. The software has freed architects and engineers to expand into more exciting projects and more interesting structures. They've been able to get away from boxes.

Manuel: More and more buildings I see going up, like parking garages and offices, are steel-framed because of reduced lead times. For oil and petrochemical facilities, we have to build and produce quickly and economically to make a profit, and steel makes that happen. The inclination in the past was to use concrete for plants, but with the market so competitive, we haven't done a concrete pipe rack since 1998.

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Engler: There's a move towards steel parking garages. Their market share is increasing all around the world. There's also more concern for erection safety issues, especially in Europe. In steel fabrication, there are more automated shops with big drill lines and CNC equipment. The UK still has a higher percentage of shops that use CNC machines, but American shops are moving forward.

Poon: There is more potential for steel buildings in coming years in China. Cities are creating new infrastructure and buildings, and trying to modernize the country. Owners are looking for long-span structures and column-free spaces, and structural steel fits right into that design trend. Also, since seismic problems are a major concern in China, there's a push for structural steel buildings. As engineers and workers gain the knowledge and the experience of working with steel, the number of steel buildings is growing. (**Editor's note: For an example of steel construction in China, read "Steel Showcase," on p. 57**). In countries like Russia, the cold weather situation gives steel a clear advantage over concrete construction. TT is working on a super high-rise mixed office and residential building there that uses structural steel.

What's the best part of working globally?

Poon: The fun part of international projects is that you really have the chance to meet people other than Americans, and learn from them. You learn that some of their ways of doing things are better than our current American system. Local people usually are friendly and excited about learning the American system as well. It's a great experience. After the project is completed, you can see your work outside of America, and it's a very rewarding feeling.

All around the world, you see people fighting against each other—but with a construction project, you're working with people to build something. It seems like there are no global problems that couldn't be solved by working together and negotiating as a team. It's the best part of the international world, seeing people working together, building together, and working to improve society for people's use.