Current Practices in Steel Construction

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I do not represent myself as an expert on systems building or an expert in modular construction or an encyclopedia of new developments and ideas. However, I do believe that a brief review of current practice in steel construction will be helpful to those interested in systems building. Therefore, my purpose is to describe briefly current practice in steel construction, placing it in terms and perspective of systems building, and to examine ways of reducing on-site construction time of bridge building.

Systems building, of course, involves the standardizing of the dimensions and the strengths of the individual components so that they can be combined in different ways to meet a variety of needs. The dominant requirement for reducing on-site construction time is to minimize the number of pieces to be handled and the connections to be made at the site. Over the years the steel suppliers and fabricators have, in my judgment, done an outstanding job within the limits of technical knowledge and owner acceptance. Those limits include economics of providing a variety of types of steel and shapes of sections in standard modular sizes separated by practical increments. This is not necessarily to their credit because the economics of the marketplace has virtually dictated this.

The basic components of all steel construction are the rolled shapes and plates that have been readily available for years. Wide flange sections are available in depths from 6 to 18 in. in 2-in. increments and from 18 to 36 in. in 3-in. increments. I-beams come in 1-in. increments from depths between 3 and 8 in. and in increments of 2, 3, or 4 in. in depths from 8 to 24 in. All other types of rolled shapes are similarly available. Other steel components have also been standardized extensively. The more familiar ones include line pipe, corrugated pipe, corrugated sheets, stay-in-place metal forms, plate culverts, open-web joists, steel grating, wire rope, and reinforcing bar. In recent years, as we aimed toward orthotropic steel plate decks, standard closed-stiffing ribs have been offered. Also, in recent years, prefabricated parallel wire strands have been added to the list. All of these individual components are supplied in a range of strengths. Structural steels are available with minimum yield strengths in tension of 36, 50, 60, 70, and 100 kips/in.^{2}, all conforming to standard requirements described by the American Society for Testing and Materials.

Systems building also involves subassemblies. We find that current practice has already taken maximum advantage of this technique. Nearly all steel work is "prefabricated" into the largest subassemblies that can be reasonably shipped and handled. Because time and work at the site are expenses, to minimize the number of pieces to be handled and the number of connections to be made at the site usually means the least expense.

The subassemblies, however, are neither standardized nor stocked for the simple reason that they are not the same from job to job. The chances of being able to use a particular fabricated beam from one bridge in the next bridge are too remote to justify stocking. However, within a given structure or project, it is common practice to detail the pieces so that maximum duplication is achieved. This reduces cost by allowing the use of manufacturing techniques to produce large quantities of identical pieces; it allows the use of jigs to speed assembly and increase accuracy. To obtain this duplication, we sometimes give away weight by extending thicker plates or heavier sections into areas where their additional strength is not needed.

The advent of numerically controlled equipment has made practical the manufacture of identical pieces that are such exact duplicates that they can be interchanged. It has made practical the fabrication of pieces to such accuracy that the desired geometry can be maintained regardless of the length or shape of the finished structure. It has eliminated the need for reaming, riveting, making bolt holes, and assembling parts in order to obtain good fit and proper geometry. On numerous structures the individual members have been drilled with full-sized holes, shipped, and erected easily without any assembly of mating pieces until they came together in their final position in the structure. This use of numerically controlled equipment has other advantages. If one piece is lost or damaged, another of the same erection mark can be substituted to keep the erection going. A duplicate can be made in full confidence that it will fit.

The use of numerically controlled equipment makes possible the fabrication of pieces in exact modular dimensions and, thus, makes systems building practical for steel bridge members. It is common practice to subassemble sections of the structure at the bridge site into the largest piece that can be handled. In the construction of suspension bridges, float-in techniques have been used for complete spans weighing more than 1,000 tons, and it is common practice to assemble a large section weighing as many as 400 tons and to pick and place this piece. The ultimate of this subassembly technique is the roll-in technique that is often used in constructing railroad bridges whereby the complete new bridge is assembled adjacent to its permanent position and in a matter of one or two days the old bridge is rolled out of the way and the new bridge is rolled into place. The limitations, of course, on both shipping and field subassembly are size and weight, i.e., what can be handled.

In short, then, the economics of construction has forced the steel industry into miminizing on-site time as much as possible within the bounds of technology. It seems doubtful that much additional time saving can be realized in the steel construction. I do not think, therefore, that it is fruitful to spend time trying to squeeze a little bit more time out of that phase of construction.

However, there is an area in steel construction to which I think we should direct our attention. One of the major deterrents to systematized steel construction in my judgment seems to be the individual sovereignty of the various owners and designers. Although designs generally follow the requirements of AASHO and design tables have been provided by both industry and consultants, the details of design vary considerably. For example, one state will not put lateral connection plates on the web of a girder, and most states will. This kind of thing totally precludes prefabrication in the sense of making up standard components and having them in stock. It precludes the use of standardized manufacturing techniques.

Something else that inhibits the stocking of material is the cost of having pieces in inventory. Probably the chief deterrent to systems building in bridge steel superstructures is that every bridge is unique, mainly through geometrics. Immediately there comes to mind a plate girder bridge with parallel plate girders in which the girders flare down and out so that no two pieces in the bridge are the same. There was no piece in that bridge that could be used in any other bridge. Its seems to me that if we are going to have systems building in steel superstructures, the owner is going to have to standardize on design requirements, and he is going to have to be willing to give up some of the flexibility and uniqueness of each of his structures. Indeed in steel the trends have been quite the opposite. The trend has been to facilitate unique design. In addition, the use of welding and the advent of welding 3 plate beams have made available an infinite variety of members. The designer takes full advantage of this infinite variety, and it would be foolish for anyone in the steel business to stock prefabricated sections for bridge superstructure.

Another inhibitor of systems building is that every owner insists on his own particular specifications and his own particular inspection. There have been instances in which even a relatively standard butt weld was rejected because the owner's inspector did not happen to be there at the time it was made. If we are going to have systems building, we are going to have to have relatively standard specifications, to have relatively standard inspection techniques, and to devise the mechanism whereby pieces that are fabricated well in advance and perhaps even stocked can be accepted by an owner on the basis of somebody else's inspection or somebody else's quality control. Maybe this would mean having inspectors licensed by the state or, as is frequently done in the case of weld qualification, having the state accept the judgment and certification of an independent inspecting agency.