



ARCHITECTURALLY EXPOSED STRUCTURAL STEEL FACADES LUKE SMITH, AIA

even greater detail.

Last year the AISC updated their Code of Standard Practice to include a new categorization system for AESS, based upon the Canadian system. This shift marks a departure from the previous categories as outlined in a supplement published by Modern Steel Construction in May of 2003, and compiled by the Rocky Mountain Steel Construction Institute. This latest document aims to provide a foundation for architects and consultants to base their assumptions and decision on, as well as serving as a communication device between designers and fabricators. As useful as this is, the document is reductive of the issues that can arise with steel fabrication and, if used without a full understanding of steel fabrication, could lead to disappointment with the end result.

This essay takes a brief look at the history of AESS and provides insight into some of the more common misconceptions which have arisen from discussions with certified US fabricators, in particular, those issues which are not addressed in the Code of Standard Practice.

BACKGROUND



There is nothing new about using steel in construction. Since the invention of the Bessemer process in the last half of the 19th century, structural steel has been used in innovative and ever more impressive ways to defy our perception of what is possible. Whether it is bridging the widest river or building the world's tallest building, the solution is almost certainly steel. Though, as impressive as the strength of this material is, it is also a messy business. Mill and fabrication tolerances are low, and connections between members can be crude – not necessarily a problem if the final product is a piece of infrastructure, or will be encased in drywall. Architecturally Exposed Structural Steel, or AESS, is structural steel members and components which are exposed to view for the occupants of buildings, whether it is a long-span roof truss for a shopping mall, or a tall-span lobby wall of an office tower, AESS applications demand a higher quality of detailing and fabrication than those which cannot be seen. Enclos has seen an increasing number of specialty facade projects which include the use of AESS elements within our scope, which warrants spending the time to study this expansive topic in

The beginnings of steel as an architecturally exposed element lie with the Structural Rationalism movement of 19th century France, where architects and engineers sought honesty through material expression, and primary structure was celebrated and adorned with elaborate motifs. Much of these structures were fabricated from cast iron, making use of repetitive manufacturing processes, and

AESS Category Matrix							
	CATEGORY	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
Id	Characteristics	Showcase Elements	Showcase Elements	Feature Elements in close view	Feature Elements not in close view	Basic Elements	Standard Structural Steel
1.1	Surface preparation to SSPC-SP 6		•	•	•	•	
1.2	Sharp edges ground smooth		•	•	•	•	
1.3	Continuous weld appearance		•	•	•	•	
1.4	Standard structural bolts		•	•	•	•	
1.5	Weld spatters removed		•	•	•	•	
2.1	Visual samples		optional	optional	optional		
2.2	One-half standard fabrication tolerances		•	•	•		
2.3	Fabrication marks not apparent		•	•	•		
2.4	Welds uniform and smooth		•	•	•		
3.1	Mills marks removed		•	•			
3.2	Butt and plug welds ground smooth and filled		•	•			
3.3	HSS weld seam oriented for reduced visibility		•	•			
3.4	Cross sectional abutting surface aligned		•	•			
3.5	Joint gap tolerances minimized		•	•			
3.6	All welded connections		optional	optional			
4.1	HSS Seam not apparent		•				
4.2	Welds contoured and blended		•				
4.3	Surfaces filled and sanded						
4.4	Weld show-through minimized		•				

AESS Categorization



permitting intricate designs, something that fell out of favor in the 20th century with the advent of the Modern Movement. In particular the International Style stripped away the ornament which had previously masked steel members, and instead made use of them in their 'raw' structural shape. These parts became central to the works of architects such as Mies van der Rohe and Skidmore Owings Merrill (SOM).

The High Tech movement later in the century took a new approach to exposed steel, playing off of the work of engineering pioneers such as Buckminster Fuller, and the fanciful musings of architects such as Archigram. This experimentation happened to coincide with the invention of the HSS, or Hollow Structural Section, in Sheffield marking a departure from the preceding visual language of exposed steel, and introducing a new aesthetic for structure as a series of primitive shapes. This would eventually lead to the question of how to connect and intersect these shapes, which became the primary detailing focus of many buildings during the High Tech movement.

The Lloyd's Building in London by Rogers, and Centre Pompidou in Paris by Rogers and Piano are probably two of the most notable examples of an exposed steel aesthetic, although other architects such as Foster and Grimshaw were also making significant contributions to the movement in Europe. Here in the United States the Javits Center by I.M. Pei used tube members to create a space frame system, and SOM were using steel as a material on their facades, although arguably more the vain of modernism than the fetishized detail-oriented High Tech. A TABLE 1 AESS Category Matrix.

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FIGURE 1 The four predetermined AESS categories are based upon viewing distance. Another noteworthy project on the west coast is the Crystal Cathedral in Garden Grove, California by Philip Johnson, which also uses a space frame comprised of tubular members, a project discussed further in the forthcoming pages.

Today the most common application for AESS we see at Enclos is in the lobby or feature space of large scale projects, where steel is used for its ability to bridge large spans. The ever persistent trend of detailing glass up against steel with little or no interfacing components means that the supporting structural members often fall into the facade contractor's scope, becoming the bones of the facade system itself. What follows is a list of areas where the intricacy of steel fabrication or detailing can be overlooked during the design phase, and issues that should be considered when working with this material. A major difference between the 2016 AISC Code of Standard Practice and the preceding versions is the introduction of a categorization system for an array of AESS finishes. Prior to the release of this document last year the most comprehensive categorization system in the United States was an outline specification published as an AESS Supplement in Modern Steel Construction in May of 2003. This document contained three distinct categories of AESS, with the highest quality being Category 1, and the lowest Category 3. Confusingly this latest version in the Code of Standard Practice flips the order, making AESS 1 the lowest quality finish of steel, and AESS 4 the highest. This seems like it may be counter intuitive to switch the order and cause potential confusion in the industry,

EASY AS 1, 2, 3

but this is more in-line with the categorization systems in place internationally (in particular in Canada and New Zealand), and will hopefully lead to a more unified system of categorization between countries. It is important to be aware that many architects, consultants, contractors, and even fabricators may not yet be aware of this new system, and may still be referencing old categories.

The Code of Standard Practice includes an AESS Category Matrix, as shown in Table 1. It would be prudent to issue a copy of this matrix along with your specification, or drawings, or other documents to ensure that all parties involved with the design, pricing, and construction of your projects are working towards the same goal. Figure 1 describes the documents suggested relationship between occupant





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FIGURE 2 Welded seams on HSS members are unavoidable, but these lines can be oriented away from view.

FIGURE 3 View from the interior of the Crystal Cathedral. The weld quality at the individual nodes becomes inconsequential at this scale.

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FIGURE 4 Intermittent welding is cheaper than continuous welds and can reduce distortion from heat. and steel components when deciding which category to specify. This viewing distance based classification further reinforces the need for an understanding of the relationship between workmanship and visibility. Put simply: there is little point spending money to grind smooth welds that are not visible to the human eye.

Per Table 1 and Figure 1, the categories run 1 through 4; 4 being the highest quality and cost, and 1 being the lowest. There is also "Custom Element" which permits the user to define their own specification for a category, and pick and choose which features are important to the project. Again cost runs from 1 at the lowest end, to 4 or Custom at the upper end.

W, WT, M, L, C, HP, HSS..

The palette of steel shapes available to designers and engineers is the standard structural sections: wide flange, channels, L angles, HSS, and so on. Each section has an appropriate structural application as defined by its properties which, for a structurally rational application, would govern where to use what. For AESS projects, the selection of steel sections often becomes a conflation of engineering requirements and aesthetic inclination, the latter part of which could be divided into three very broad groups:

- the structurally raw aesthetic, employing mostly open sections (such as wide flanges, C channels, and angles) for their infrastructural or industrial 'honesty';
- the reductive, clean aesthetic, making use of HSS closed sections for simple intersections between square or round members, reducing the visual complexity; and
- the custom made aesthetic, using a series of plates and bars of various thicknesses

A common misconception for square and rectangular HSS members is that these shapes have right angle corners, which is unfortunately not the case, and they do in fact have a radius (Fig. 3). Of course it is possible to build up a sharp cornered box section from plate material, but the continuous welding and grinding that is required to do so can cause other problems (see *Welding* later on). When designing exposed steel, the concept of sharp corners can be problematic. There are safety concerns for fabricators, installers, as well as space end users, as these edges can pose a danger, but also designers should consider how these edges will look. Assembling, shipping, installing, as well as day



to build up bespoke members that are not standard mill products, typically to create sleek minimal detailing.

Of course many projects use members from all of these groups, but it is useful to think of these distinctions in order to identify the potential advantages and pitfalls of each. to day use of spaces all lead to wear and tear, and sharp edges are particularly vulnerable to dents and scratches.

Another misinterpretation when it comes to HSS members relates to their seams. These tubes start life as a plate, which is rolled into a round section, and welded along its length. These are then either left as round HSS members, or compressed on four sides to create a square section from the round (hence the radius corners mentioned above). It is not possible to remove the seams in these members. They can be oriented such that the seam is less visible from certain angles, but complete erasure is not possible (Fig. 2). By choosing an appropriate finish the seam locations may not be evident.

When selecting steel sections the design team should also look into the availability of desired shapes. Many of the shapes listed in the AISC Steel Construction Manual are not readily available, and may be a special mill order. Steel fabricators or mills can provide information



on availability, thus reducing the risk of encountering unexpected mill costs or delays due to uncommon shape selection.

Finally, when selecting which member to use, have a good understanding of tolerance. Many mills do not operate the same level of tolerance as specified by the AESS documents. An unreasonable level of precision will increase project cost, based upon the need for excessive straightening and fit-up. Facades are typically held to a high tolerance level, so additional accommodation between steel parts and glazing or exterior finish may be required.

WELDING

Welding is an art, craft, and science all rolled into one very complex procedure. The use of welding equipment with an understanding of how the metal reacts is a highly skilled, labor-

intensive operation, which results in reactions and deformations that cannot always be accurately predicted. This is the first consideration for welding. Excessive heat buildup from large or long continuous welds can create warpage in members, which can be problematic to remove. When creating custom members from a series of plates, the desire can often be for smooth box like constructs with sharp corners. If these are made from a series of plates with continuous complete penetration welds, ground smooth, the result is going to be a lot of member warpage, and potentially an out of tolerance member. If two plates do need to be welded perpendicular to each other, consider where they will be located. If they fall outside of the scope of Category 4, you may be able to use intermittent welds (Fig. 4), resulting in less deformation. Excessive use of complete penetrations welds (CJP) or even partial penetration welds (PJP) increases the risk of warpage.

The Crystal Cathedral by Johnson / Burgee Architects in 1977 is a fully glazed modernist space, with an aluminum curtainwall supported on a steel space frame. For a structure that is entirely visible to the occupants, the intersection detail for these space frame members is certainly pretty crude. Each member is notched around a gusset plate, and welded along its intersecting edges (Fig. 6), creating a primitive node, which certainly does not fall into the Category 4 standards, and looks pretty difficult to clean. But although these elements fall within touching distance, and today might be specified differently (note this building far precedes the advice printed in Modern Steel Construction in 2003), the overall effect at the macro-scale, for an occupant within the space, is unaffected. The expansiveness of the space frame itself detracts from the relatively minor inconsistencies at the joints between tubes (Figs. 3 + 6), and further reinforces the notion that a specified weld quality can be a function of scale, and not only distance from viewer.

FIGURE 5 Vertical details: hard edges vs. standard section.

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FIGURE 6 Impact of viewing distance in exposed structures: though the welds at a microlevel (top) are visibly present, when viewed at a macrolevel (bottom) distance—as seen here from the floor of the Crystal Cathedral—they become practically unrecognizable.







MATERIAL 109



270 BRANNAN ATRIUM CANOPY

owner 270 Brannan Street, LLC.

architect Pfau Long Architecture

engineer **Tipping Mar**

gc Charles Pankow Builders, Ltd.

facade Enclos

rod/cable **TriPyramid Structures**

completion 2016

TREATMENTS

Finishes for AESS demands an entire article in itself, but there are a few key considerations that warrant mentioning here. Firstly galvanizing, a process which coats the fabricated steel in molten zinc for protection, has a few limitations. The process is carried out once the members have been welded into their assembled form, but before they are painted and installed. This means an additional step in the production process, which may require trucking to another location. The heat from the molten zinc bath also has the potential to create deformations in steel assemblies, which are then hard to rectify, further compounding some of the tolerance issues mentioned above. For projects with HSS members, it's impossible to guarantee the application of the zinc on the interior faces of the members. Therefore it is necessary to close the ends of all closed sections with welded plates. It's also worth noting that during the process the molten zinc will be attracted to welds, even if ground smooth, more than other areas. This causes a higher concentration of galvanization in those areas, and can make the welds more visible. Galvanizing AESS requires a lot more work post-assembly to ensure a decent finish, including additional sandblasting, and should be avoided on architecturally exposed elements where possible.

When painting AESS consider the location that the finish is applied. There are essentially two options: in the shop, or in the field. If the finish is shop applied then the connections between parts will either need to be bolted or taped off for welding in the field, and then finished at a later date during field touch-up. The drying time of the product may also become an important factor for this approach, making sure that there is adequate storage space at an appropriate humidity and temperature for the finish to cure before being moved to site. Climactic conditions



FIGURE 9 Photo of 270 Brannan Atrium Canopy: stainless steel HSS, pipes and tension rods supporting laminated glass. ∧ FIGURE 10

When specifying weld or connection samples, choosing a complex intersection at full scale can ensure expectations are consistent across the project team.

are also a concern if finishing in the field, but there is greater flexibility in whether connections can be field welded. Access becomes a major factor for finishing in the field, as other trades and components move in around the steel, and block access. An understanding of where the project is finished should be something architects and contractors discuss early in the design stages.

FINAL NOTES

There is no shortage of information when it comes to specifying AESS and how to deal with classifications, but there needs to be an understanding of the processes involved with steel manufacturing. There is often a large gap between what is specified and what is fabricated, whether it means a higher level of finish than is warranted for the application, or a misunderstanding of what is to be reasonably expected from the material and the associated fabrication processes.

The most failsafe way of ensuring that all parties are fully aware of the product to be delivered is to invest in mock-ups. These should be representative samples, which take into account the maximum complexity of the project, and are of a size large enough to include multiple conditions. Even better would be to produce multiple examples of different AESS categories, so architects and clients are able to see the difference between finished products, and understand what they are paying for. Without this contextual comparison it is often difficult to envision what the propagation of this level of detail would be across an entire facade system.