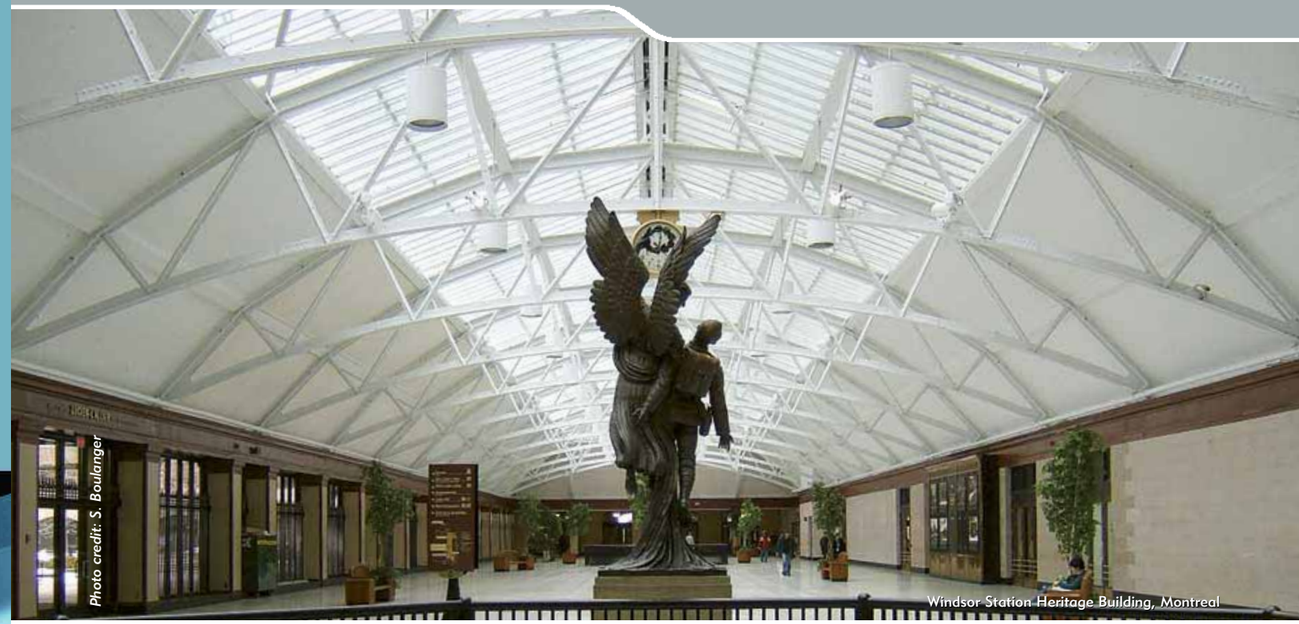


Photo credit: S. Boulanger

Windsor Station Heritage Building, Montreal

THE CANADIAN MATRIX:
A CATEGORY APPROACH FOR SPECIFYING AESS

Sylvie Boulanger, Terri Meyer Boake

Since the turn of the millennium, architects have let their hair down when expressing the framing members within their overall scheme to the point where the steel structure becomes the architecture, or architecturally exposed structural steel (AESS).

Although architects look like they are having fun, it has created a paradigm shift in the sequential communication that usually takes place in a more conventional building where the steel structure is hidden. The architect now wants direct access to the fabricator's shop to verify and comment on the edges and surfaces of the imagined product, and the engineer is dealing with aesthetic aspects that impact the structural integrity of the frame. That leaves the fabricator and the erector somewhere in the middle between aesthetic and technical requirements.

The paradigm shift would not be a big deal if everyone understood what the other wanted! But it turns out that a "nice looking connection" or a "smooth surface" has very different meanings whether you are talking to an architect, an engineer or a fabricator. Such a situation creates a misalignment of expectations in terms of what can be accomplished within a specific budget envelope. Welds that are contoured and blended are not the same price as ASTM A325 hexagonal bolts for example.

For those reasons, CISC formed a national Ad Hoc Committee on AESS (see inset) and focused on differentiating Categories because not all AESS need be created equal. For example, viewing distances, coating thicknesses and connection types should matter (see images). To facilitate communication, Categories and their associated Characteristics are presented in a Matrix. In total, three AESS documents reference the Matrix: A Sample Specification, an addition to the CISC Code of Standard Practice and a Guide.

CATEGORIES AND CHARACTERISTICS OF THE MATRIX

The Committee felt that baselines needed to be established that could characterize each of the Categories, and that each Category would reference recognizable building types as a point of visual orientation. The initial point of technical reference was selected as Standard Structural Steel (SSS) as defined in CSA S16 as it was already an established and well-understood baseline in

Photo: T. Bouke

Distance plays a factor. O'Hare International Airport. The steel at the ceiling level is not capable of receiving the same scrutiny as that at the pedestrian level.

construction Specifications. A set of Characteristics was then developed that was associated with each Category. Higher-level Categories include all of the Characteristics of the preceding Categories, plus a more stringent set of additional requirements.

AESS 1 – Basic Elements, would be the first step above Standard Structural Steel. This type of application would be suitable for "basic" elements, which require enhanced workmanship. This type of exposed structure could be found in roof trusses for arenas, warehouses and canopies (see Fig. 2 right) and should only require a low cost premium in the range of 20% to 60% due to its relatively large viewing distance as well as the lower profile nature of the architectural spaces in which it is used.

1.1 The surface preparation of the steel must meet SSPC-SP 6. Prior to blast cleaning, any deposits of grease or oil are to be removed by solvent cleaning, SSPC-SP 1.

1.2 All of the sharp edges are to be ground smooth. Rough surfaces are to be de-burred and ground smooth. Sharp edges resulting from flame cutting, grinding and especially shearing are to be softened.

1.3 There should be a continuous weld appearance for all welds. The emphasis here is on the word "appearance". The welds themselves need not be continuous. Intermittent welds are made continuous, either with additional welding, caulking or body filler. For corrosive environments, all joints should be seal welded. The seams of hollow structural sections would be acceptable as produced.

1.4 It is assumed that bolted connections will use standard structural bolts. When bolting, the heads should all be located on one side of the connection, but they need not be fastidiously aligned. There should also be consistency from connection to connection.

1.5 Weld splatters, slivers, surface discontinuities are to be removed as these will mar the surface and it is likely that they will show through the final coating. Weld projection up to 2 mm is acceptable for butt- and plug-welded joints.

AESS 2 – Feature Elements, included structure that was intended to be viewed at a Distance > 6 m. It was suitable for "feature" elements that would be viewed at a distance greater than six metres. The process requires basically good fabrication practices with enhanced treatment of weld, connection and fabrication detail, tolerances for gaps, and copes. This type of AESS might be found in retail and architectural applications where a low to moderate cost premium in the range of 40% to 100% over the cost of Standard Structural Steel would be expected.

2.1 Visual Samples – This Characteristic was noted as an optional requirement for this and all subsequent Categories due to issues of suitability, cost and scope. Visual samples could be a 3-D rendering, a physical sample, a first-off inspection, a scaled mock-up or a full-scale mock-up, as specified in Contract Documents. Visual samples could range from small pieces of fabrication that might include connections or finishes, to full-scale components. Not all projects would benefit from the construction of large-scale mock-ups, hence making this Characteristic optional. In some cases it is suggested that an agreement to incorporate full-scale mock-ups in the final project would make practical and economic sense. Again this decision would depend on the particular job requirements.

2.2 One-half standard fabrication tolerances as compared to the requirements for standard structural steel in CSA S16 will be required for this Category. This is to recognize the increased importance of "fit" when assembling these more complex components. Large tolerances can lead to a sloppier appearance and lack of uniformity in the connections and potentially, problems in the erection of complex geometries. This has direct impact on the erection process and the potential cost implications of making site modifications to members that do not fit.

2.3 Fabrication marks (number markings put on the members during the fabrication and erection process) should not be apparent, as the final finish appearance is more critical on these feature elements.

2.4 The welds should be uniform and smooth, indicating a higher level of quality control in the welding process. Ultimately this would indicate that more of the welds might be carried out in the fabrication shop to reduce site welding where the conditions may not be optimum. This can impact the design of joints as well as the transportation of potentially larger pre-assemblies and the erection on site. This does not infer that high-quality site welding is not possible, only that it might incur a cost premium over shop welding.

AESS 3 – Feature Elements, included structures that would be viewed at a distance ≤ 6 m. The Category would be suitable for "feature" elements – where the designer is comfortable allowing the viewer to see the art of metalworking. The welds should be generally smooth but visible and some grind marks would be acceptable. Tolerances must be tighter than normal standards. As this structure is normally viewed closer than six metres it might also frequently be subject to touching by the public, therefore warranting a smoother and more uniform finish and appearance. This type of structure could be found in airports, shopping centres, hospitals or lobbies and could be expected to incur a moderate cost premium that could range from 60% to 150% over Standard Structural Steel.

3.1 The Mill marks are to be removed so as not to be visible in the finished product.

3.2 Butt and plug welds are to be ground smooth and filled to create a smooth surface finish. Caulking or body filler is acceptable.

3.3 The normal weld seam that is the product of creating HSS shapes is to be oriented for reduced visibility. In general the seams are to be oriented away from view in a consistent manner from member to member, or as indicated in the Contract Documents.

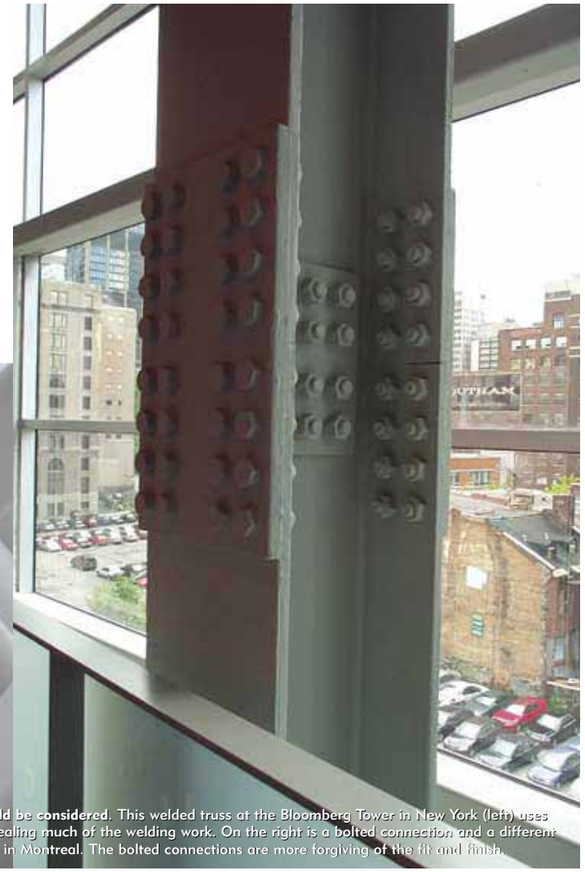
3.4 Cross-sectional abutting surfaces are to be aligned. The matching of abutting cross-sections shall be required. Offsets in alignment are considered to be unsightly in these sorts of Feature Elements at a close range of view.

3.5 Joint gap tolerances are to be minimized. This Characteristic is similar to 2.2 above. A clear distance between abutting members of 3 mm is required.

3.6 AESS 3 Feature Elements may require all welded connections. This is noted as optional; acknowledging that a particular aesthetic might purposefully choose bolted connections. Alternatively if an entirely welded appearance is desired, hidden bolts may be considered.

AESS 4 – Showcase Elements, or "dominant" elements would be used where the designer intends that the form be the only feature showing in an element. All welds are ground and filled edges are ground square and true. All surfaces are sanded and filled.

Photos: T. Bouke



Connection types and finish should be considered. This welded truss at the Bloomberg Tower in New York (left) uses a thick intumescent coating concealing much of the welding work. On the right is a bolted connection and a different coating at the Palais des Congrès in Montreal. The bolted connections are more forgiving of the fit and finish.

Tolerances of these fabricated forms are more stringent, generally to half of standard tolerance for structural steel. All of the surfaces would be "glove" smooth. The cost premium of these elements would be high and could range from 100% to 250% over the cost of Standard Structural Steel – completely as a function of the nature of the details, complexity of construction and selected finishes.

4.1 The normal weld seam in an HSS member should not be apparent. This may require grinding of the weld seam.

4.2 Welds are to be contoured and blended. In addition to a contoured and blended appearance, welded transitions between members are also required to be contoured and blended.

4.3 Steel surfaces are to be filled and sanded. Filling and sanding are intended to remove or cover any steel surface imperfections, again due to the close range of view of the members. This particular point can incur a high cost premium and is a particular case in point that all AESS need not be created equal. Procedures such as this are not required where the members cannot be seen.

4.4 Weld show-through must be minimized. The back face of the welded element caused by the welding process can be minimized by hand grinding the backside of the weld. The degree of weld-through is a function of weld size and material.

AESS C – Custom Elements, was created to allow for a completely custom selection of any of the Characteristics or attributes that were used to define the other Categories. It would allow complete flexibility in the design of the steel, but would therefore require a high level of communication amongst the Architect, Engineer and Fabricator. The premium for this type of AESS could range from 20% to 250% over regular steel. A wide range may seem odd for "custom" elements, but the lower bound of this Category also includes specialty reused steel for sustainable purposes, and steel that might be purposefully less refined in its Characteristics.

DESIGN PROCESS IMPLICATIONS

The Categories need to be specified at the design stage. A building could, for example, include two Categories within the exposed portion of the project: AESS3 for the lower part of the atrium, and AESS2 for the upper, more distant portion. The Matrix approach helps qualify what is expected within each Category. Hence, the structural engineers need to include the AESS Specification in the Structural Steel Division of their contract. The Categories are specified following close communication between Architects and Engineers, which then need to appear directly on Architectural and Structural Documents. The Fabricator then makes a cost estimate based on these Categories and relays the AESS2 and AESS3 labels on their shop drawings and later on the erection plans.

BACKGROUND

By 2003, AISC produced its AESS Guide. During the same period, concerns about AESS were also emerg-ing in several regions of Canada. Regional CISC initiatives eventually culminated into the na-tional CISC Ad Hoc Committee on AESS in 2005. The idea was to create a dynamic industry dialogue, including architects and engineers, in the hopes of providing a series of documents that would assist in re-visioning the design, specification, and construction process for AESS.

In the following two years, CISC did adapt components of what AISC had developed but it also introduced an underlining Category approach and reduced its scope. The committee committed to the elaboration of a Sample Specification (for engineers), an addition to the CISC Code of Standard Practice (for fabricators) and a Guide (for architects). Common to all these documents would be a unique Matrix of Categories and Characteristics used by all.

In parallel, several roundtables were held in Montreal, Toronto and Vancouver, which would typically involve architects, engineers and fabricators. Those sessions helped shape the orientation and direction of the Committee's work on the documents. For example, the Matrix was extremely well received and confirmed we were on the right track. They also told us that the Specification should be part of the Engineer's contractual documents rather than the Architect's. And they couldn't wait to use the material.

IN A NUTSHELL

The Category approach emphasizes that when dealing with AESS, one-size-does-not-fit-all which led to a set of fabrication requirements above and beyond those necessary for strength and safety. This prompted a new approach to specifying AESS that includes different Categories of AESS, each Category's Characteristics, and the use of a Matrix to compare the Categories. The Categories recognize the different levels of workmanship and finish of the steel surface to suit the specific architectural expression of the building. It is hoped these documents will make it easier for architects and engineers to specify those requirements to fabricators at bid time and to communicate their needs during the entire design process so their vision of the final form, fit and finish of the structure becomes reality. These documents are:

- **A Sample AESS Specification**: Architecturally Exposed Structural Steel (AESS), a suggested AESS subsection of Section 05120 that includes the distinc-tive Matrix chart. This is the standard Specification Subsection that is proposed for inclusion in the overall project Specification document.
- **An Appendix in the CISC Code of Standard Practice** - Architecturally Exposed Structural Steel (AESS). The Appendix includes definitions and materials, related to scope, that clarify the terms of reference of the Specification outlined above as well as the Matrix.
- **A Guide for Specifying AESS**. This docu-ment will not form part of the con-tractual Specification, but will be used to clarify the intentions of the Specification, Matrix, and Appendix. This document will contain images, examples and more detailed information about protective systems (against fire and corrosion) and coatings.

It is felt that these documents will help make AESS more competitively priced by eliminating a great range of fabrication and installation work that may be quite unnecessary. As an increasing number of AESS projects are constructed, we begin to realize that AESS is not all created equal, nor should it be specified to be so.

Note: CISC's AESS documents, plus the longer version of this article presented at NASCC 2008, are or will be available for download from the Canadian Institute of Steel Construction's web site: www.cisc-icca.ca/aess.

ACKNOWLEDGEMENTS

CISC is grateful that AISC has allowed the Committee to access the May 2003 Modern Steel Construction Supplement on AESS. It provided the possibility to use some text and images from the Supplement and integrate them into CISC's efforts to produce their own documents.

The authors would like to acknowledge all the Regional Committees who took time to review the documents within their local area and provide comments. The Alberta Region did a particularly thorough job in their feedback documents.

Finally, we thank the members of the Committee and the participants of the roundtables who assisted so greatly in the development of the new CISC Sample Specification (as part of the Structural Steel Division), Appendix I for the CISC Code of Standard Practice, the AESS Category Matrix and the upcoming CISC Guide for specifying AESS.

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THE NEW CISC CATEGORY MATRIX FOR SPECIFYING ARCHITECTURALLY EXPOSED STRUCTURAL STEEL (AESS)

Terri Meyer Boake (from left 1-3) | Sylvie Boulanger (4)

The CISC Category Matrix encompasses 4 Categories (AESS1 through AESS4). Each category represents a set of characteristics, which clarifies what type of work will be performed on the steel, the tolerances to be met, and if a visual sample is needed. For AESS1, the associated characteristics are 1.1 through 1.4, for AESS2, they are 1.1 through 2.4, and so on. The categories are selected by the architect. They are specified at bid time, as an AESS subdivision of the Structural Steel division (05120) in the engineer's documents. The categories appear on architecture, engineering, detailing and erection documents. In general, it is expected that AESS2 (for elements viewed at a distance) and AESS3 (for elements viewed at close range) will be the categories most commonly specified. For more detailed information, see **www.cisc-icca.ca/aess**.

TABLE 1 - AESS CATEGORY MATRIX

Id	*Characteristics*	**AESS C** Custom Elements	**AESS 4** Showcase Elements	**AESS 3** Feature Elements *Viewed at a Distance ≤ 6 m*	**AESS 2** Feature Elements *Viewed at a Distance > 6 m*	**AESS 1** Basic Elements	**SSS** Standard Structural Steel *CSA S16*
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	Mill 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		√				
C.1							
C.2							
C.3							
C.4							
C.5							
	Sample Use:	Elements with special requirements	Showcase or dominant elements	Airports, shopping centres, hospitals, lobbies	Retail and architectural buildings viewed at a distance	Roof trusses for arenas, retail warehouses, canopies	
	Estimated Cost Premium:	Low to High (20-250%)	High (100-250%)	Moderate (60-150%)	Low to Moderate (40-100%)	Low (20-60%)	None 0%

NOTES

1.1 Prior to blast cleaning, any deposits of grease or oil are to be removed by solvent cleaning, SSPC-SP 1.

1.2 Rough surfaces are to be deburred and ground smooth. Sharp edges resulting from flame cutting, grinding and especially shearing are to be softened.

1.3 Intermittent welds are made continuous, either with additional welding, caulking or body filler. For corrosive environments, all joints should be seal welded. Seams of hollow structural sections shall be acceptable as produced.

1.4 All bolt heads in connections shall be on the same side, as specified, and consistent from one connection to another.

1.5 Weld spatter, slivers, surface discontinuities are to be removed. Weld projection up to 2 mm is acceptable for butt and plug welded joints.

2.1 Visual samples are either a 3-D rendering, a physical sample, a first off inspection, a scaled mock-up or a full-scale mock-up, as specified in Contract Documents.

2.2 These tolerances are required to be one-half of those of standard structural steel as specified in CSA S16.

2.3 Members marked with specific numbers during the fabrication and erection processes are not to be visible.

3.1 All mill marks are not to be visible in the finished product.

3.2 Caulking or body filler is acceptable.

3.3 Seams shall be oriented away from view or as indicated in the Contract Documents.

3.4 The matching of abutting cross-sections shall be required.

3.5 This characteristic is similar to 2.2 above. A clear distance between abutting members of 3 mm is required.

3.6 Hidden bolts may be considered.

4.1 HSS seams shall be treated so they are not apparent.

4.2 In addition to a contoured and blended appearance, welded transitions between members are also required to be contoured and blended.

4.3 The steel surface imperfections should be filled and sanded.

4.4 The backface of the welded element caused by the welding process can be minimized by hand grinding the backside of the weld. The degree of weld-through is a function of weld size and material.

C. Additional characteristics may be added for custom elements.

AESSmatrix/sb/070412 NotesRev071005