Architecturally Exposed Structural Steel (AESS)

Custom curtainwall has been the staple of Enclos Corp that has given us the ability to assert ourselves as one of the leading facade specialty contractors in North America. Along with cladding the exterior of some of the most renowned and expansive buildings, we have also incorporated storefronts, cable nets, cable walls, and space frames into our business model. Now we are seeing owners and architects investing more time in the design of not only the main portion of the building, but also the entrances, pavilions, and skylights of their projects. As they begin to express this trend, we too have to accommodate to meet all the requirements set forth and position ourselves to continue to lead the way in all areas of facade design and installation.

As we begin to see this trend take hold, the most common material used in these designs is Steel. The efficient use of structural steel in buildings goes back to the 17th century. Structural steel is the backbone of many buildings both small and large. In the past, it was general practice to hide the structural steel behind plaster or drywall to mitigate any imperfections, large connections, or just the raw look of the material. However, we are beginning to see more and more architects use structural steel in their design as an artistic expression prominently displaying it for physical viewing. We have come to know this art form as Architecturally Exposed Structural Steel (AESS). With the steel now on display for everyone to appreciate, Architects want to minimize the imperfections in steel and be able to get as close to a perfect product as possible. With minimizing these imperfections, comes more precise tolerances and higher quality finishes, resulting in increased labor and rising costs compared with the typical structural steel specifications. There are different levels of AESS acceptability and standards where if you do not notify your manufacturer precisely what to fabricate, your project could have higher costs in manufacturing than necessary, or possibly not high enough standards resulting in having to re-fabricate or re-finish the product. In this paper I will layout what you need to be aware of when installing AESS, and list the different tolerances, finishes, welds, and any other information that may help you when receiving pricing for any AESS products.

When receiving construction documents that call out AESS where do we begin? The first place we should familiarize ourselves with is ASTM A6/A6M, “Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Steel Piling”, along with this Specification we should review AISC 303-05, “Code of Standard Practice for Steel Buildings and Bridges” specifically section 10 on AESS. After we gain a basic understanding of the specifications and codes for structural steel we need to get a feeling for what the architect is trying to communicate through his/her design. The AISC (American Institute of Steel Construction) has created a helpful matrix to specify techniques that need to be taken to achieve the different levels of appearance for AESS. It begins with the AESS basics cover in section 10 of AISC 303-05, and next moves to the matrix which they created starting with Category 3, which is “high profile conditions that are out of reach to touch and can be viewed from a distance of 20 feet or more”. Next, Category 2 is “high profile conditions that are out of reach to touch and can viewed in close proximity within 20 feet”. Category 1, is the highest level specified as “high profile conditions that are within reach to touch and can be viewed in close proximity”. There is also the option where the user can specify a combination of the 3 noted categories based on their project requirements.

The most important component in achieving the desired look of AESS is the initial stage of fabrication. Before fabrication begins however, you will need to find a competent fabricator that has previously performed AESS projects. Just the fact that they are a steel fabricator will not qualify them as an AESS fabricator. Truss Works International, for example, has the following certifications; City of Los Angeles Approved Fabricator, ISO 9001 Quality Systems Certified, Member of AISC, and has LEED AP green building professionals on staff. Be sure to choose carefully when you are selecting your fabricator as this will make or break your project from the start. Next, you will need to have a full understanding of each fabrication process listed in the cost matrix. This is the basic platform that will help you identify and set AESS apart from standard structural steel. In the sections to follow I will talk in more depth about the fabrication, finishing, and on-site requirements.

FABRICATION

Now that you have found an appropriate AESS fabricator, you will need to determine what type of processed steel you need to purchase, cold formed or hot rolled. This can be determined by the shapes required for your project, and how you can make the required components out of the typical steel shapes. Keep in mind that cold formed steel is considerably most costly than hot formed steel, but often is more desired by architects due to their sharp corners. Once you have determined what category of AESS needs to be provided for your particular project, you can provide them with the specifications required for your project. For simplification of this paper I will begin with discussing the basic requirements for AESS from section 10 of AISC 303-05, and work my way through the matrix categories as the fabrication requirements increase. To begin, the basic fabrication requirements that make AESS different from standard structural steel are;

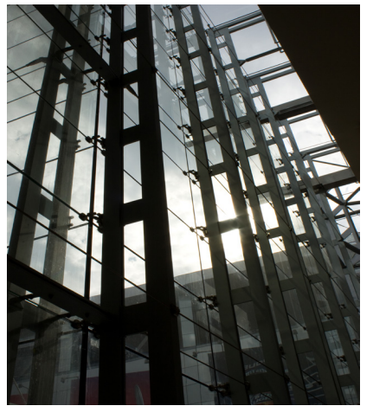

Figure 1. LA Live Podium AESS trusses.

• Special Care in Processing AESS – Upgraded care in process of fabricating, trucking, handling, storing, and erecting the material is required to obtain minimally acceptable AESS.

• Tolerances: One Half Standard – The tolerances for structural steel frames are set by AISC Code of Standard Practice. If AESS is specified, these tolerances are required to be one-half of those of a standard structural steel.

• Coping and Blocking Tolerances Minimized – Requires that all copes, miters, and cuts in AESS material are to be made with a uniform gap of 1/8”

• Joint Gap Tolerance Minimized – A clear distance between abutting members of 1/8” is required.

• Piece Marks Hidden – AESS pieces are marked in inconspicuous places whenever possible, but there are many cases where these marks are seen. If removal of these marks is required for aesthetic reasons, this classification should be specified

• Surface Defects Minimized – In the process of handling the materials, the flanges of the beams and columns will inevitably be deformed and scarred. If this classification is specified, these deformities and scars will be removed.

The above processes provide the basic fabrication processes required for AESS. You should be able to describe to the customer that these are the processes they will receive unless they specify otherwise. The next level, Category 3, “high profile conditions that are out of reach to touch and can be viewed from a distance of 20 feet or more”. The additional requirements for this category are;

• Rolled Members: Minimize Distortion – When rolling members into various shapes, the member will be distorted. Distortion must be minimized.

• Bolt Head Orientation Dictated – Special attention is required in the shop and the field for the bolt heads to be orientated in a particular direction

Category 2, “high profile conditions that are out of reach to touch and can be viewed in close proximity within 20 feet”, additional requirements are as follows;

• Welds Ground Smooth – In standard structural steel, welds are left in as is welded condition with slag and weld spatter removed. This is the same for AESS, however, if it is specified, welds must be ground smooth

• Welds Contoured and Blended – If transitions of smoothly grounded welds are required to be contoured and blended, this process will be done by hand and will leave blemishes around the weld area. Samples should be submitted for review.

• Weld Show Through Minimized – Weld show through is seen on the opposite side of where the piece was welded. If required, weld show through is ground by hand, and may leave a blemish.

• Field Welding Aids Removed – Sometimes field welding aids are not removed due to structural integrity issues. If specified, special attention is required in the shop and field.

• Close Weld Access Holes at Full Pen Welds – Weld access holes are holes in the web of beams and columns to allow the welder to weld in areas of the member’s web. If they are required to be closed for aesthetic reasons, special attention is required in the shop and field.

Category 1, “high profile conditions that are within reach to touch and can be view in close proximity”, is the highest set standard for AESS. It requires considerably more work, and also a significant cost increase over standard structural steel. The requirements, in addition to all previously listed requirements, are as follows;

• Continuous Welds – Intermittent welds required for strength, may be required to be continuous for aesthetic reasons. Special attention is required to avoid distortion of the member.

• Mill Marks Removed – Steel mill marks with their heat numbers and producer information identifying the material chemistry and strength, must be removed.

• Grinding of Sheared Edges – Materials with sheared edges during the fabrication

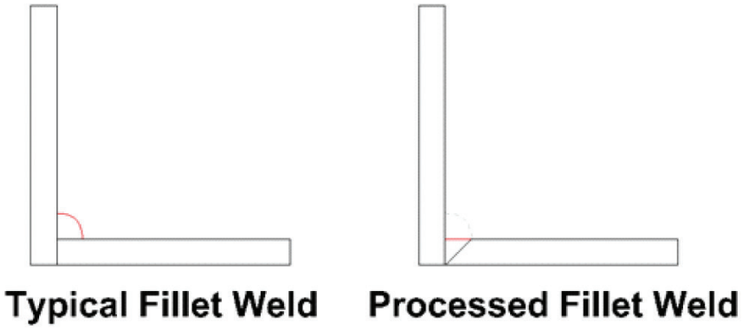

Figure 2. Different types of fillet welds.

process may demand that rough surfaces be deburred and ground smooth

• Seal Welds to Close Open Gaps – Frames may require welds to seal gaps from environmental implications or aesthetic reasons. Note that this may cause distortion.

All the above fabrication classifications are the most commonly referred to requirements. There may be other requests desired by the customer, at which point you will have to discuss with your fabricator if they can provide the additional requests and at what price. This should give you a good stepping stone on where to start and how to price the fabrication for your project.

WELDING

There are many different types of welds and welding processes that may add additional costs to your project. Many of the typical welding processes are listed in the fabrication section above. You should be aware that these processes will add cost due to additional work being performed. For example, a typical fillet weld will be left as is. However, if the fillet weld is called out to be ground smooth, you have to miter the steel plate then grind the weld flat adding additional processing time.

We will not go to in-depth regarding the different welds and so forth as the fabricator should let you know the price per foot of each type of weld and also why it may be costing more than another type of weld. For example, a MIG (Metal Inherent Gas) Weld versus a TIG (Tungsten Inherent Gas) Weld can have significant cost and time implications. A 12" cosmetic MIG weld will take 10 minutes to complete, where as a cosmetic TIG weld of the same length will take about 45 minutes to complete, resulting in a higher time and cost impacts. So be very aware of what the customer is suggesting, and have a V.E. solution in your back pocket.

Now that you have your steel fabricated, you are ready to choose the appropriate finish.

SURFACE PREP

To begin you must have your steel properly cleaned and prepped before applying any coating. The platform to start off with for AESS is "Power Tool Cleaning" (SSPC-SP3). This will remove all loose mill scale, loose rust, loose paint, and other foreign material. Performing this level of cleaning will be in combination with (SSPC-SP1) requiring solvent cleaning prior to using the power tools. The next level of cleaning would be (SSPC-SP6) "Commercial Blast Cleaning". The definition of this is "… when viewed without magnification, shall be free of all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign material." The difference between the two is a 10%-20% cost. (You can refer to http://www.sspc.org/standards/spscopes.html for additional surface preparations).

GALVANIZING

Galvanizing is a surface protection that adds a thin layer of metal (usually zinc) over the steel to protect the steel from rusting. You would generally only need to galvanize the steel if it is to be used in an exterior application. A common practice for galvanization is hot dip galvanizing, where the steel is dipped into a tank and an electrochemical process occurs resulting in a layer of zinc to be deposited to the steel surface. Note that this will affect the surface of the steel making it less uniform or "rough". There are ways to smooth the surface such as sand blasting, but the surface will not be 100% smooth, and this will also be an added cost to the project.

Reminder - Steel cannot easily be welded after it has been hot dipped galvanized. If you do weld hot dipped galvanized steel, it is extremely expensive and hazardous, and you will have to apply a cold galvanized spray over the top of the weld to seal it from the weather.

PRIMERS

There are several different types of primers that can be used for steel; Alkyd, Acrylic, Epoxy, and Zinc Rich. The first two are lower end and also cheaper, however, on our projects we would typically see either an Epoxy based primer or a Zinc Rich primer as these are generally used for higher end coatings. Epoxy Primers are used for corrosion resistance and hide small imperfections in the steel as they have a high build film. A wide variety of finishes can be used in conjunction with Epoxy primers. Zinc Rich Primers are used for superior corrosion resistance, and have cathodic protection which protects the steel galvanically. They can be specified as organic or inorganic which meet the requirements for class B slip coefficient for bolted connection. Keep in mind there is a longer curing time for the inorganic primer and you will need a minimum relive humidity of 40% for the primer to dry. It would best suit you to contact your paint applicator to discuss what type of primer to use in conjunction with the finish coating specified. Also find out if there are any non-conformances that may result between the primer and top coat.

FIREPROOFING

Generally we will not have to concern ourselves with this step, but in the instance that our steel is part of the primary structure we will have to apply fireproofing to the steel between the priming and finishing steps. There are several different ways to fireproof steel, but generally the best way to fireproof AESS to maintain and not detract from its appearance, is to use an intumescent paint. This application differs from job to job, but commonly is a multi-layered process requiring drying between each layer. Although it wasn't in our scope of work for one of my jobs, there were structural steel columns requiring 20+ layers of intumescent paint prior to applying the top coats. So if you have this condition make a note that you will need to include plenty of time in your schedule for the painting process. Also keep in mind that if there is damage to the intumescent coating, an extensive patch repair process must be completed to fix the coating. http://www.albi.com/ Product - Fireproofing for Exposed Structural Steel

http://www.haifire.com/magazine/AESS.pdf Article - "Fire Protection Materials for Architecturally Exposed Structural Steel (AESS)

FINISHING

With finishing any material we would like to keep it in a controlled environment such as the shop, however you cannot always have this option. In some conditions, such as when you have to field weld for the attachment of your steel, you will need to leave the paint set back so it does not interfere with the welding process. Make a note of these conditions when choosing a finish type. The architect should call out the type of finish and color he would like to use, but again check with your applicator to make sure the finish is compatible with the primer and will work for the applications required to cure and apply the finish. Similar to the primers, the finishes also have the option of Alkyds, Acrylics, Epoxies, and Polyurethanes. Again the first two are cheaper and instead we will generally see Epoxy and Polyurethane finishes called out in our specifications. Epoxies will cover up imperfections much like the primer, and are good for high traffic areas where abrasion resistance is required. Epoxies are not to be used for exterior applications as they will chalk when exposed to UV rays; this is where you would see Polyurethanes specified, for exterior applications. They too will cover up minor imperfections in steel. These should be sprayed applied for best appearance.

Figure 3 (left). Cosmetic MIG weld.

Figure 4 (right). Cosmetic TIG weld.

Figure 5 (below). AESS Sample QC Document.

QUALITY PLAN CHECKLIST - STEEL FABRICATION
NEWSEUM GL-1D - BIG WINDOW Job# 2004-158

Characteristic or Item	Design, Target & Tolerance Reference	Test and Reporting Method	Sample Size and Frequency	Completed: Provided By	Received	Design Review: Accept	Reject	Reviewed
Sample Parts								
Painted welded steel sample	Steel Structures Paint Council (SSPC)	ASI / Client Approval	5 each	F A B				
Material Certifications & Testing Requirements								
Steel Plates	ASTM A36 (Fy=36ksi, Fu=58ksi)	Mill Certs for all items are to be submitted to ASI for review prior to delivery to fabricator or field site.	Prior to each Shipment	F A B				
Steel Bar	ASTM A572 Grade 50 (Fy=50ksi, Fu=65ksi)			F A B				
Welding	E70XX Rod (Fu=70ksi min)			F A B				
Structural Bolts	ASTM A325 N (Fy=92ksi, Fu=120ksi)			F A B				
Threaded Rods	ASTM A449 (Fy=58ksi, Fu=90ksi)			F A B				
Tube Steel	ASTM A500 Grade B (Fy=46ks, Fu=58ksi)			F A B				
Shop Welding								
Visual Inspection	Per AWS D1.1	Verification Reports (In Shop Fabricator QC's Possession for Review by ASI)	100% of All Welds	FA B				
Ultrasonic Inspection	ASTM E164		25% of Penetration Welds	FA B				
MAG Particle Testing	ASTM E709		25% of Fillet Welds	FA B				
Welders Qualification	Per AWS D1.1		Prior to Fabrication	FA B				
Welding Procedures	Per AWS D1.1		100% of All Welds	FA B				
Dimensional Checking (Carbon Steel Vertical Members)								
All Vertical Tubes	All shall be within +/- 1/8" at its overall pin-to-pin length.	Verification Reports (In Shop Fabricator QC's Possession for Review by ASI)	Shop Fabricator to Perform Dimension Check on 100% of the Items. ASI to Review Submittals & Perform Intermittent Check in the Shop (10% of Total Package).	FA B				
All Horizontal Tubes				FA B				
Critical Dimensions (pin-to-pin)	Per ASI Design & Fabricator's Shop Dwgs, Latest Revision			FA B				
Balance of Dimensions				FA B				
Identification, Painting & Shipment								
Piece Mark Identification Number (All Parts)	Per ASI Design & Fabricator's Shop Dwgs. Latest Revision	Visual Verification to be documented and submitted to ASIC prior to shipment.	Shop Fabricator to Perform Visual Check on 100% of the Items. ASI to do Intermittent Check	FA B				
Primer & Finish Coats	Per Project Specification			FA B				
All Shop Fabricated Items Delivered to Site	Package and Protect Members to Avoid Damage During Shipment. Shipping Method Details are to be Submitted to ASI.	Visual Packing Verification Prior to Shipment (digital photos)	100% Verification Prior to Shipment	FA B				
Quantity Check	Total of items for project are to be in accordance with the Bill of Materials reflected on Fabrication Dwgs, latest revision.	Shipper's bill of lading from the fabricator to be sent to ASI for review with project Bill of Material.	100% Verification Prior to Shipment	FA B				

Figure 6. Steel finish sample showing cut back layers starting with raw steel (Bottom), 1st layer primer, 2nd layer primer, finish coat (Top). Also an example of how to apply step back paint process for field welding and later paint blending.

PAINTING AND FINISHING ISSUES

When finishing steel components we generally will come across the same problems that we would with aluminum finishes. Listed below are some basic issues that you should plan ahead of time so you don't get in a bind later:

- Allow for proper drying time
  - o Many times we do not anticipate drying time into our schedule resulting in packaging and shipping while paint is still "tacky" or wet. This can result in unnecessary touch-up later in the field

- Finish samples
  - o Remember to tell the paint applicator that the samples they provide must look identical to their finished product
    - Many times they will send the best samples possible on the best pieces of steel. Try to get them to mock-up "actual" steel and paint samples so the architect will not expect something that cannot actually be provided

- Touch up samples
  - o Provide touch up samples that will simulate field condition touch-ups
    - This is critical to your project, as field touch-up will never look as good as the factory applied paint

- Applicator/Paint Representative visit
  - o It is a good idea to have the paint rep come and inspect painted members to:
    - Review the Process
    - Ensure proper mil thickness
    - Quality
    - Approve the vendor that is applying the paint

QUALITY CONTROL

Prior to any work being started your team should have a QC plan already thought out and being devised. One major mistake is starting any fabrication without standards being set in place. A sample QC sheet is included in this paper for reference. Although this QC sheet is a good place to start, every project has different conditions that need to be projected prior to beginning your project. You should have QC plans for both the shop and the field. Another large component of the QC process is packaging and handling. The overall QC process should be similar to our curtainwall QC process as the majority of the work is done up-front in the shop, and we do not want to go back and make any field adjustments or touch-ups.

In shop QC

Review the specs to see if there are any testing procedures that need to be done on the steel. Make sure you allow time for the tests to be completed and also if any steel needs to be re-fabricated or re-purchased. Be sure to get your mill certificates from your suppliers as well. You should check the steel at the shop periodically during fabrication. Prior to finishing you should check all dimensions. Have your engineer create a set of check drawings that include check dimensions and geometric dimensions. This will help you ensure that all the holes, connections, and components are in place so you will not have to make any modifications or adjustments in the field. Once the steel is verified it can be sent for paint. Paint again should be compared to the submitted sample and should be uniform. Also make sure it has had the allotted drying time prior to packaging. Packaging is also a very critical, but often an overlooked step. First and foremost, make sure everything is well protected. Next, the steel components are usually large and may need a rack to be fabricated for their shipping alone. The steel cannot bend in any way as it may deform in the short time it is being transported, resulting in difficulty making your connections upon installation.

One other issue that you should be aware of, but may not be a factor on every job, is built up tension in the steel due to welding. This is caused by extensive welding and heating of the steel causing the molecules to stress and re-align. The problem is usually seen after the steel is shipped to site, as it vibrates on the road and relaxes back to its original state causing the steel to bend or bow. There are two ways to alleviate this stress. One is to vibrate the steel in the shop to relax the molecules allowing you to make adjustments in the shop. The other is to heat up the steel, then uniformly cool it to relax the steel gradually.

If you have taken all these precautions, your steel should arrive in good shape and be ready for installation.

In Field QC

Prior to any material arriving on site, you must complete your site survey. Make sure all other trades work (concrete, primary steel, drywall, etc) is in tolerance to ensure the most accurate fit of all your components. You cannot count on all trades to have their product 100% accurate, and also their tolerances are not as tight as AESS. One way to accommodate for their tolerances is to make all your anchors the same, and field cut them. When we did this at LA Live it ensured that our trusses were aligned all the way down the wall and we did not have to try to accommodate to the other trades work. The negative side to this was we had to field cut the anchors, and do paint touch-up on the cut areas. There are definite trade-offs involved either way you go, you just have to weigh out your options and choose the best one. If you choose to go off their installed components and you find anything to be out of tolerance, notify the GC immediately so the trade responsible can make accommodations without affecting your schedule. After installation, all you should have to do is inspect your work to make sure no damage has occurred during shipping or installation. Note the damage that has occurred during shipping and installation, and complete the floor-by-floor sign off so if any damage occurs in the future it will be noted as trade damage.

INSTALLATION

Once you have reached this point, all the hard work and planning should have been done so all you have to do is install the AESS components. Having a solid field plan on how you will erect the steel is essential. The type of equipment you are going to use should be well thought out, and also how you are going to hoist the material without it deflecting or bowing should be carefully reviewed. In the rare occurrence that a component will not align, or something is out of tolerance and does not fit properly, you should have back up plans set in place. This will ensure no delays and keep your men working without interruption. There are always disruptions and problems that occur to even the most well thought out plan, so expect some hiccups along the way, but if all your pre-planning is set in place the installation should go fairly smooth.

Architecturally Exposed Structural Steel is finding a place in more and more construction projects and is here to stay. With our current facade knowledge, and our desire to take on more complex and architecturally appealing projects, we find the need to familiarize ourselves with this intricate material. This paper was written for you to gain an understanding of the basic intricacies involved with AESS and give you some resources where you can go find more information for your specific job. I only wrote in-depth regarding AESS and did not discuss stainless steel, extruding steel, castings, or metal spinning which all could have a large section devoted to each topic. Shortly after this paper is written, we will begin producing AESS sample boards that will be distributed to several of the main offices throughout Enclos. These, in addition to the paper, will help you grasp the general concepts involved with AESS fabrication and finishing.

BIBLIOGRAPHY

"AESS_Spec.pdf." AISC | Home. Modern Steel Construction, May 2003. Web. 06 June 2010. <http://www.aisc.org/WorkArea/showcontent.aspx?id=17506>.

American Institute of Steel Construction 303-05 Section 10

Parker, Aurther J., Jesse J. Beitel, and Nestor R. Iwankiw. ""Fire Protection Materials for Architecturally Exposed Structural Steel (AESS)." Hughes Associates, Inc. - Fire Protection Engineers, Fire Protection Consultants, Fire Investigators – Leaders in Fire Testing, Fire Modeling, Fire Protection Design. Http://www.haifire.com/magazine/AESS.pdf, Feb. 2005. Web. 06 June 2010. <http://www.haifire.com>.

Untitled Document. Web. 06 June 2010. <http://www.sspc.org/standards/spscopes.html>.

REFERENCES

American Institute of Steel Construction AISC 303-05

American Society for Testing of Materials ASTM A6/A6M

American Welding Society AWS_D1.1_2006

Albi (Fireproofing supplier)

The Society for Protective Coatings

AESS Sample QC Document (below)

