

Aesthetic Dimensions of Exposed Steel: Global and Indian Perspectives

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Abstract

Aesthetics of exposed steel structures are regulated by international standards, such as those set by American Institute of Steel Construction (AISC) and Canadian Institute of Steel Construction (CISC), which outline precise requirements for bolting, welding, finishes, and connections. This research analyzes how exposed steel structures are made aesthetically pleasing in India by focusing on details which may or may not be consciously done. This is done by comparing international standards of Architecturally Exposed Structural Steel (AESS) with Indian practices. Through literature review; standard analysis; and case studies of public buildings, i.e. museum, commercial building and railway station in Bhopal, the study examines the finishes, connections, and visual impact of exposed steel. The research aims to set parameters for architects and engineers, helping them make informed decisions on the appropriate level of detailing for steel connections based on visual and tactile interactions and proximity to viewers.

The findings will offer a framework for future steel structures in India, providing clarity on aesthetic detailing standards. This research concludes that incorporating these parameters can lead to more refined and contextually appropriate use of exposed steel in Indian architecture.

Keywords: Connections, Visual impact, Finishes, Aesthetics, AESS

1. Introduction

a. Evolution of Steel

Over the last three centuries, the evolution of architectural design has shown a link between the choice of materials and the possibility of various approaches to construction. Prior eras saw a strong reliance on stone, domes and vaults as structural solutions to maximize span through compression. By utilizing tensile strength, new options in architectural structures have been introduced, by technological advancements in materials such as steel, concrete, etc . This change has made it possible for contemporary architects to investigate numerous design possibilities that were not possible before (Boake, Exposed! The Impact of Structural Materiality on the Design of Architecture, 2013).

During the Industrial Revolution, steel emerged as a revolutionary material for construction, prized for its strength and ability to support large spans. Steel was primarily used for its structural properties, hidden behind facades and other finishes to bear loads and provide stability in factories, bridges, and skyscrapers (Boake, Exposed! The Impact of Structural Materiality on the Design of Architecture, 2013).

Steel's use nowadays is no longer limited to structural needs; it started to acquire aesthetic value and evolved from a hidden support system to an exposed design element. Modern architecture has come to

be defined by Architecturally Exposed Structural Steel (AESS), where steel is kept visible integrating structural integrity of the building and to improve its aesthetic appeal (Boake, Exposed! The Impact of Structural Materiality on the Design of Architecture, 2013).

b. AESS In Modern Architecture

Steel has been transformed from a hidden structural element to a visible and essential component of a building's aesthetic language during the past few decades by Architecturally Exposed Structural Steel (AESS), which has completely changed current architectural design. Steel was traditionally used just for structural strength, with coatings and facades covering it up. But as design methods and material technologies have advanced, steel has taken center stage and is now praised for its strength as well as its form, texture. These days, exposed structural elements (AESS) are used in projects ranging from high-end commercial buildings to urban infrastructure, where they create dynamic, visually engaging areas that enrich the architectural elements (Boake, Exposed! The Impact of Structural Materiality on the Design of Architecture, 2013).

AESS differs from regular structural steel in that it fulfills practical as well as aesthetic purposes. Because of its dual function, it must adhere to higher standards in terms of design, detailing, construction, and erection in order to guarantee both structural integrity and aesthetic effect. A thorough understanding of how steel acts as a medium of architectural expression as well as a load-bearing material is essential to the design and implementation of AESS. During the design phase, it is important to take into account details like surface treatments, bolted connections, welds, and even how steel corrodes/weathers over time (Boake, Exposed! The Impact of Structural Materiality on the Design of Architecture, 2013).

c. Global Standards for AESS Design

International organizations like the American Institute of Steel Construction (AISC) and the Canadian Institute of Steel Construction (CISC) have created extensive norms and codes to standardize the structural and aesthetic qualities of AESS. These standards specify the many AESS categories and attributes, offering fabricators, architects, and engineers exact guidelines to adhere to. Specific guidelines for bolting, welding, and finishing exposed steel elements are provided by CISC's Guide for Specifying Architecturally Exposed Structural Steel and AISC's Code of Standard Practice for Steel Buildings and Bridges. These specifications are essential for guaranteeing that steel maintains its aesthetic and tactile characteristics while fulfilling its bearing role (Boake, Exposed! The Impact of Structural Materiality on the Design of Architecture, 2013).

These provide a range of finishes and tolerances based on the building's function, viewing distance, and level of weathering exposure, among other criteria. AESS 4 is meant for showcase features that demand precise detailing and premium finishes, whereas AESS 1 is meant for basic elements that are observed from a distance and where finishing is modest and economical. By combining cost, function, and aesthetics, this approach enables architects and engineers to choose the right level of detailing based on the requirements of the project (Boake, Exposed! The Impact of Structural Materiality on the Design of Architecture, 2013).

d. AESS in Indian Context

In India, AESS use is still growing even though it is well-established in Western nations. Nonetheless, the Indian construction sector lacks a substantial gap in the standardization and regulation of AESS procedures. The aesthetic problems surrounding exposed steel are still not fully addressed by Indian building codes, therefore architects and engineers must either rely on foreign norms or modify them to

fit specific local situations or these have been ignored over time (Boake, Exposed! The Impact of Structural Materiality on the Design of Architecture, 2013).

Numerous issues are brought up by this lack of standardization. Indian fabricators and architects have a difficult time striking a balance between regional labor laws, material availability, and climate norms and international aesthetic standards. Furthermore, a different strategy for using exposed steel is required due to India's distinct cultural and environmental setting. Steel buildings in India must include particular protection measures, like corrosion-resistant surfaces and carefully planned connections to prevent water infiltration, due to factors like intense monsoons, drastic temperature swings (Boake, Exposed! The Impact of Structural Materiality on the Design of Architecture, 2013).

e. Case of Bhopal

One of India's growing towns, Bhopal, will be studied for the use of exposed steel in different typologies of projects.. This study focuses on three notable Bhopal structures that use exposed steel in different ways: the Tribal Museum, DB Mall, and Rani Kamlapati Station. Examining how international AESS standards are implemented or altered in the Indian context or not followed is made possible by these case studies.

For instance, exposed steel is a key component of the sleek, contemporary design of the Rani Kamlapati Station, a major transit hub. In this case, the steel components serve a practical purpose. Similar to this, exposed steel is used to create an openness and grandeur in DB Mall, one of the city's largest commercial complexes, and in the Tribal Museum, which showcases exposed steel in a way that emphasizes the fusion of modern design and cultural heritage, traditional aesthetics are combined with contemporary materials.

1.1 Relevance/ Need

Fabricators often face challenges in creating steel that meets both design requirements and aesthetic expectations. 'Therefore, its constructability affects the ability of the fabricator/erector to deliver the project on time' (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012). It's easy to get an estimated construction time period and requirements for construction when standards are considered. There are predetermined norms for the same in several nations, including America and Canada. Therefore, it's essential to ensure whether India has standards for Architecturally Exposed Structural Steel (AESS) that are adhered to. Ultimately, it would contribute to faster and precise construction quality.

1.2 Aim

Analyzing whether the international and national standards for Architecturally Exposed Structural Steel (AESS) are applied in Bhopal.

1.3 Objective

- To study the international standards mentioned in AISC, CISC and Indian standards (IS) for AESS.
- To identify connections between exposed steel members in these buildings in an Indian context.
- To recognize the finishes done over these members which contributes to the structure's appearance.
- To compare the existing literature study with practical applications.

1.4 Scope

The study discusses and establishes guidelines or standards for engineers and architects who were previously left to determine what standards were suitable. It would enable them to make informed decisions on the precise level of detail required for the connections of steel members in future projects. This is based on its visual and tactile interaction with people and its proximity.

1.5 Limitation

The study is conducted in only one city i.e. Bhopal in India. It includes popular landmark public buildings (cultural, commercial and transportation structure) of Bhopal. The research doesn't include categorization on the basis of price range of adopting steel members and labor cost. Only steel connections are considered for connecting members, no other materials are considered for this study. It only includes structures built in Bhopal, India. This assessment is done irrespective of structural strength data of steel. Therefore, the count of members or components doesn't count.

2. Methodology

Literature study for identifying techniques and finishes of steel structures used in international context. Referring codes for AESS. To study a diverse range of buildings in Bhopal where exposed steel is prominently featured. This could include public buildings, commercial spaces, etc. Identifying and photographically documenting 3 case studies of Bhopal which are exposed steel structures. Interviewing for better understanding of the structures and its time period of construction to tally with the time of applicability of standards. Therefore, recognizing upto what extent the standards are applied which may or may not be consciously done.

Note: Kindly refer to Flowchart.1 attached at the end of paper.

2.1 Rational of Selecting Case Studies

The selected buildings for this research are all public buildings and large span structures. Exposed steel components are evident in all of these and are apparent to the unaided eye. They are all used as navigational landmarks.

2.1.1 Tribal Museum

Located near Regional College and Regional Science Centre, beside State Museum on Shyamla Hills road. This building is an Assembly building having steel components in proximity to physical touch.

2.1.2 Rani Kamlapati Railway Station

Located in Habibganj near Arera colony and Zone-II, on Habibganj road. This building serves the purpose of public transit, has long roof span structure. This construction was not primarily intended to be aesthetically pleasing.

2.1.3 DB Mall

Located in MP Nagar near Bhopal Haat and Shaurya Smarak. It's a visually attractive Commercial building having large roof span than Rani Kamlapati Railway Station.

3. Literature Review

At the outset of this research, several regulations and standards that describe the structural systems and architectural aesthetics of the building were studied. Various articles on materials, finishes, connections, and steel structure members were reviewed; the most relevant codes and articles discussing the "aesthetics" of exposed steel structures and the factors influencing them were selected.

Transcending its conventional function as a strictly structural element, **Architecturally Exposed Structural Steel (AESS)** has become a major element in modern architecture. Buildings can be made more aesthetically pleasing by using AESS, which provides designers with a flexible medium for expressing their creativity in addition to carrying loads. An architectural structure's visual and structural

character are enhanced when exposed steel is used, showing the material's inherent strengths, durability, and flexibility along with aesthetics.

3.1 Parameters affecting aesthetics of exposed steel structures

There are various parameters to decide upon the type of AESS to be used and how exposed steel is perceived in the build environment (Leberer, 2017).

3.1.1 Viewing Distance

The farther the members located detailing tends to disappear. When the object is beyond 6m (20ft), the difference between components is not clearly visible than when it's within range. The category system for AESS recognizes that viewing distance is critical to the level of fabrication and erection required for structural steel (Leberer, 2017).

3.1.2 Connection Details

Different connections could be used at joints according to requirements and cost. It not only supports the building structurally but it also improves the aesthetic appeal of a structure (Leberer, 2017).

3.1.3 Coatings

Glossy coats show more imperfections and variations in surface. A glossy coat combined with bright accent lighting within a close view range requires greater care and surface preparation for AESS. A thicker intumescent coating or matte finish tends to cover surface marks and blemishes (Leberer, 2017).

Majorly the above mentioned parameters affect the aesthetics of exposed steel.

Other Parameters:

3.1.4 Location

The presence of AESS on exterior or interior of the structure played a pivotal role in deciding on the coatings and finishes to be used. If it is placed externally then it should be corrosion resistant and the connection should be carefully decided so that water does not seep into the structural member (Leberer, 2017).

3.1.5 Lighting

Lighting typically has the greatest impact on interior AESS, whereas sight lines are the most important for AESS located on the exterior. Details are not as visible in high ceilings with low lighting, but when elements are brightly lit, they may tend to expose more texture and blemishes on the surface. The location and type of lighting with relation to AESS components should be determined prior to specifying the appropriate category (Leberer, 2017).

3.1.6 Members Visibility

Exposed steel if not visible, it is not required to be considered as AESS, if it's partially visible that could be considered as AESS, which could optimize construction cost, workmanship, Construction time (Leberer, 2017).

3.1.7 Style

Two types of styles- Tectonic and Plastic A tectonic look is more expressive of the details that showcase the steel assembly and tends to emphasize bolted construction. A plastic aesthetic is uniform and smooth, using more welded or cast connections for a near-seamless appearance (Leberer, 2017).

3.1.8 Adjacency

The AISC Code distinguishes between standard tolerances and tighter tolerances with different AESS categories. Depending on the composition of the structure, tighter tolerances may or may not be necessary. Several factors have a direct impact on the selection of an AESS category (Leberer, 2017).

3.2 Categorization

3.2.1 On the basis of Viewing distance

The following categories shall be used when referring to AESS (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012):

- ‘AESS 1: Basic elements
- AESS 2: Feature elements viewed at a distance greater than 20 ft (6 m)
- AESS 3: Feature elements viewed at a distance less than 20 ft (6 m)
- AESS 4: Showcase elements with special surface and edge treatment beyond fabrication (2)
- AESS C: Custom elements with characteristics described in the contract documents
- **Mixed category**’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012)

3.2.1.1 AESS 1: Basic elements

- ‘This type of application would be suit-able for “basic” elements, which require enhanced workmanship. This type of ex-posed structure could be found in roof trusses for arenas, warehouses, big box stores and canopies. AESS 1 applications will see the use of fairly straightforward section types such as W (wide flange), HSS (high speed steel), and exposed profiled decking as shown in Fig 1’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- ‘These types of applications may or may not require special fire protection design. The detailing on AESS 1 elements should not be greatly impacted by the relative thickness or finish of the intumescent coating, as much of this type of steel will be located well above eye level and out of range of touch’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- ‘Fig 2 shows AESS 1 for the ceiling or skylight support elements of a design, where the distance to view is in the 6 m or greater range, and use a higher class of AESS for those elements, like columns, that are located at a closer proximity. This must be clearly marked on a schedule of drawings’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).



Fig.1 ‘Semiahmoo Library, Surrey, B.C.: The project uses a very simple exposed structure consisting of W sections and OWSJ with a painted finish’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).



Fig.2 ‘Ricoh Centre, Toronto, ON: The trusses that span the arena proper in the Ricoh Centre, given their roughly detailed design style as well as the less refined nature of the space’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

3.2.1.2 AESS 2: Feature elements

- a. ‘It is suitable for “feature” elements that will be viewed at a distance greater than 6 meters. The process requires basically good fabrication practices with enhanced treatment of welds, connection and fabrication details, tolerances for gaps, and copes’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- b. ‘AESS 2 will generally be found in buildings where the expressed structure forms an important, integral part of the architectural design intent. This sort of steel is found in high-level roof or ceiling applications’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- c. ‘It will be more common to see W or HSS members specified for this category, rather than more industrial members such as OWSJ (open web steel joist). This type of application may use a combination of bolted or welded connections as shown in Fig. 3’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).



Fig.3 ‘Pierre Elliott Trudeau Airport, Montreal: The trusses supporting this skylight are quite characteristic of AESS 2 type steel. The viewing distance is over 6 meters but the design needs something more than a standard joist or truss. The detailing is simple, and the viewer is not close enough to see the texture of the connection, only the form of the truss’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

3.2.1.3 AESS 3: Feature elements

- a. ‘Includes structures that will be viewed at a distance $\leq 6m$. The Category would be suitable for “feature” elements where the designer is comfortable allowing the viewer to see the art of metal working. The welds should be generally smooth but visible and some grind marks would be acceptable. Tolerances must be tighter than normal standards’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- b. ‘This structure is normally viewed closer than six meters, it might also frequently be subject to touch by the public, therefore warranting a smoother and more uniform finish and appearance. This type of structure could be found in airports, shopping centers, hospitals or lobbies. The natural look of welds that would be out of view in AESS 2 steel will now be visible to the occupant in the space’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- c. ‘Fig 4 and 5 shows simple bolted connections may need to be designed to look more artful if they art to become part of the architectural language. Proper surface preparation has to be done to increase its smoothness and ensure that some of the natural finish on the steel and mill marks do not show through the paint. Welds cannot be done in the shop, where conditions are more controlled and jigs can be used to ensure precise alignment of the components. AESS 3 welds will be expected to have a very uniform appearance. Complete grinding of all welds would not be included in this category of steel’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- d. ‘It is assumed that good quality, uniform welds would be left exposed. Simple approaches such as ensuring all bolt heads are located on uniform sides of the connections can greatly enhance the details with little extra cost. If bolted connections are required for erection ease but are visually unacceptable, concealed connections can be employed to give the appearance of a seamless or welded connection. If this is to be an exterior application, concealed connections must be made corrosion-resistant to prevent hidden rust’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).



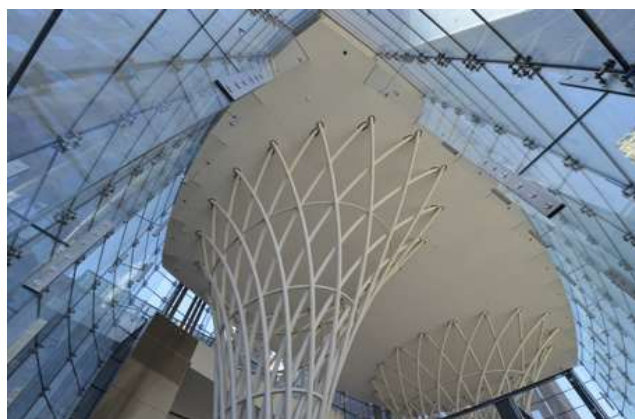
Fig.4 ‘O’Hare International Airport in Chicago was the first airport to use AESS. The complex nature of the sections and connections called for a tighter sizing tolerance and even finish application’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).



Fig.5 ‘The Canadian War Museum in Ottawa uses AESS. Due to the irregularity of the structure, tight tolerances are required. The profiled decking is also left exposed to view’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

3.2.1.4 AESS 4: Showcase elements

- a. “Dominant” elements are 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. Tolerances of these fabricated forms are more stringent, generally to half of standard tolerance for standard structural steel. All of the surfaces would be “glove” smooth’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- b. ‘Many of the members tend to employ steel plates that have been custom-cut to odd geometries. The round corners of HSS tubes would not be considered acceptable. In most cases the weld is ground smooth and any member-to-member transitions are filled and made extremely seamless in appearance as shown in Fig 6’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- c. ‘This type of AESS is often also painted in the fabrication shop, again to achieve the best quality finish. Protection of these members during transportation and erection is critical in order to prevent undue damage to the finish. It is common in some showcase applications to see the use of stainless steel glazing support systems in conjunction with the use of AESS 4 regular carbon steel requiring tighter tolerances and increased care in applying finishes’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).



‘Fig.6 Brookfield Place in New York City uses round HSS members that have been custom curved to create these diagrid basket columns. All of the tube to tube connections have been done in a way to

conceal all connections in order to preserve the visual lines of the steel and make it seem as if the vertical tubes are continuous' (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

3.2.1.5 AESS C: Custom elements

- a. 'It was created to allow for a custom selection of any of the Characteristics or attributes used to define the other Categories. It will allow flexibility in the design of the steel but will therefore require a high level of communication among the architect, engineer and fabricator' (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- b. 'It allows architects and engineers to create their own checklist for a project so as to better reflect the nature of the project's aesthetics or function. The Custom checklist also allows for the addition of extra fabrication criteria that must be agreed upon among team members and used to achieve particular or unusual finishes. This category will be suitable where specialty castings are used, as these require different handling and finishing than do standard steel sections due to their inherently different surface finish as a direct result of the casting processes shown in Fig. 7' (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).



'Fig.7 Heathrow Terminal 5 in London, England by Sir Richard Rogers Architect uses a range of AESS Category types throughout the terminal. These specialty connections use a combination of custom work for the central hinge, castings to connect the ends of the large HSS supports and truss members to the hinge, and showcase level of fabrication and finish for the legs/column supports' (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

3.2.1.6 Mixed Categories

'As shown in Fig.8 these are to be expected on almost all projects. Generally no more than two categories would be expected. It will be very common to specify, based on the viewing distance, lower-level categories for roof/ceiling framing elements and higher-level categories for columns and sections that are nearer to view and touch. It is also possible to mix categories on individual elements as a Custom category. This may be done for sections with a side exposed to view/ touch and a side that is buried or otherwise hidden from view' (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).



‘Fig.8 Angus Technopole, Montreal is a unique reuse application of a former locomotive shop as offices and commercial space. New steel is required in this project, a custom specification is required in order to make it fit into the aesthetics of the old building’ (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

	Category	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
ID	Characteristics	Custom Elements	Showcase Elements	Viewed at a distance $\leq 6\text{ m}$	Viewed at a distance $> 6\text{ m}$	Basic Elements	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 spatter 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 surfaces 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							

Table.1 Matrix for specifying AESS (CISC, 2015)

	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 and 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.
2.4	—
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 of 3 mm between abutting members is required.
3.6	Hidden bolts may be considered.
4.1	HSS seams shall be treated so that 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	Steel surface imperfections should be filled and sanded.
4.4	The back face of a welded element caused by the welding process can be minimized by hand grinding the back side of the weld. The degree of weld show-through is a function of weld size and material.
C.	Additional characteristics may be added for custom elements.

Table.2 Explanation of each matrix specified in Table 1 (CISC, 2015)

Table. 1 is used in our research study to categorize structures of Bhopal to specify AESS category.

3.2.2 Connection Design

Connections in Architecturally Exposed Structural Steel (AESS) projects fulfill structural as well as aesthetic functions. They must not only support loads but also improve the building's aesthetic appeal. Once the AESS category has been chosen, taking into account variables such as building usage, viewing distance, and budget, attention turns to planning the connections and selecting steel members (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).

In general, bolting is done on-site and welding in the shop is preferred, though site welding is possible if necessary safety measures are taken. The team should be ready for shop painting, which is frequent but necessitates cautious handling during shipment and erection to prevent damage (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).

3.2.2.1Types

3.2.2.1.1 Splice connection

In AESS, splice connections are used to reduce or hide the operation of joining steel pieces entirely. Due to transportation restrictions, these connections are frequently required, necessitating the fabrication of components in smaller portions and on-site assembly. Splices are used to give the impression that the pieces were put together as a single unit (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).

Splice connection refinement is influenced by the AESS category. AESS 3 and 4 necessitate more seamless, remediated connections, whereas AESS 1 and 2's longer viewing distances permit easier splice techniques. In higher AESS categories, hollow structural sections (HSS) are frequently utilized, and three popular splice techniques are usually used (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012):

a. **Completely remediated welded splices** (AESS 3 and 4), where welds are ground smooth to create a

seamless appearance. Refer Fig 9(b) (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).

- b. **Hidden bolted connections** with cover plates (AESS 2 and 3), where filler is used to conceal voids between the plate and steel member. Refer Fig 9 (a) (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).
- c. **Discreet bolted connections** with exposed bolts (AESS 2 and 3), offering a slim profile while maintaining structural integrity (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).

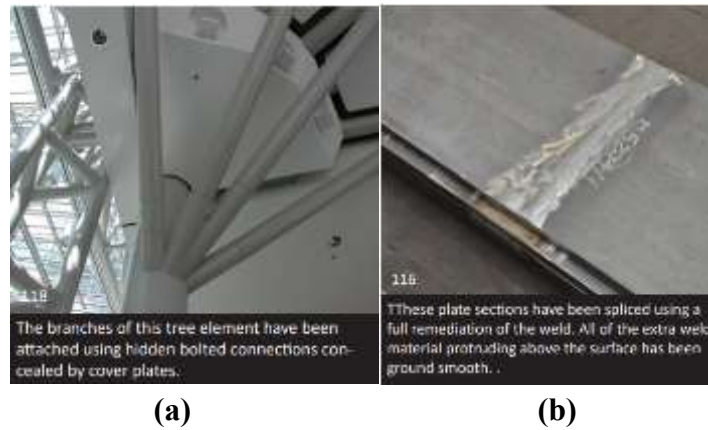


Fig. 9

3.2.2.1.2 Bolted connections

Bolted connections are frequently utilized in AESS projects because they are simpler to handle on-site and during transport, or because they give the project a robust, industrial appearance. Bolted connectors have a rough appearance that goes well with W, C, or L-shaped steel sections. AESS connections need additional attention to detail, with bolts and members meticulously positioned for improved visual appeal as shown in Fig 10 (a), (b) (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).

When using bolted connections, it's crucial to select the appropriate kind of bolt, such as tension control or hex head bolts, and make sure that all of the bolt heads are positioned on the same side for a uniform appearance (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).

However, tightening requirements often make accurate bolt head alignment impossible.

In order to facilitate on-site assembly, steel members for Hollow Structural Sections (HSS) are often welded together in the shop and fastened with end plates. More elegant choices, like as cap plates, can be used to make the connections look neater if the end plates appear too bulky, but this comes at an additional cost (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).

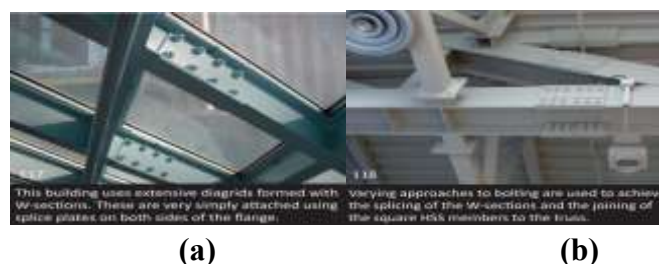


Fig. 10

3.2.2.1.3 Welded connections

In AESS projects, welded connections are frequently utilized to create a smooth, unified appearance, particularly for internal connections of hollow structural sections (HSS) and W, C, or L shapes. Using the right tools, welding is frequently done at the fabricator's shop to guarantee improved quality and alignment as shown in Fig. 11 (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).

Welded connections are best handled in the shop, especially for complex geometries (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012). But in order to make movement easier, transportation restrictions like bridge clearance frequently call for the splicing of massive welded pieces. If cover plates are used to conceal the discrete bolted connections, these splices can be constructed to retain the impression of a continuous welded structure (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).

Care must be taken not to overwork welded connections, as unnecessary grinding can reduce their structural strength. Grinding and smoothing should only be used in AESS 3 and higher, where aesthetics demand it, but should be avoided unless absolutely necessary. In many cases, welding does not need to be continuous unless required for structural reasons or moisture protection (Boake, ARCHITECTURALLY EXPOSED STRUCTURAL STEEL:, 2012).



Fig.11

3.2.2.2 Factors influencing Connection choices

- Viewing Distance:** Bolted connections might be a better choice for elements that are observed from a distance (more than 6 meters), like those in AESS 1 and 2, as the connection details are less evident. On the other hand, welded connections provide a more elegant and tidy appearance for pieces that are visible up close (within 6 meters), as those in AESS 3 and 4 (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- Member Selection:** The connection type is also influenced by the selection of tubes, forms (W-sections), and other members. For example, angle sections could be more suited for exposed bolted connections, but tubular members sometimes need hidden or blended connections for a more streamlined appearance (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).
- Budget and Constructability:** Bolted connections may be installed more quickly and at a lower cost, which makes them perfect for projects with limited funds or schedules. Welded connections are

more costly, but they provide a more refined visual appearance, which makes them appropriate for showcase projects (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

- d. **On-Site vs. Shop Work:** Welding is typically done in the shop to ensure quality and precision, while bolting is often reserved for on-site assembly. However, on-site welding can be done with careful planning, though it requires greater effort and cost due to the challenges of access and environmental conditions during erection (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

3.2.3 Coatings and finishes

3.2.3.1 Paint systems

The aesthetic and maintenance objectives of the project are taken into consideration when selecting paint solutions for AESS buildings. Despite their striking appearance, high-gloss coatings highlight even the smallest surface imperfections, while flat surfaces are more forgiving. As shown in Fig.12, Since light-colored paints easily expose dirt and corrosion, they are not recommended in polluted locations (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

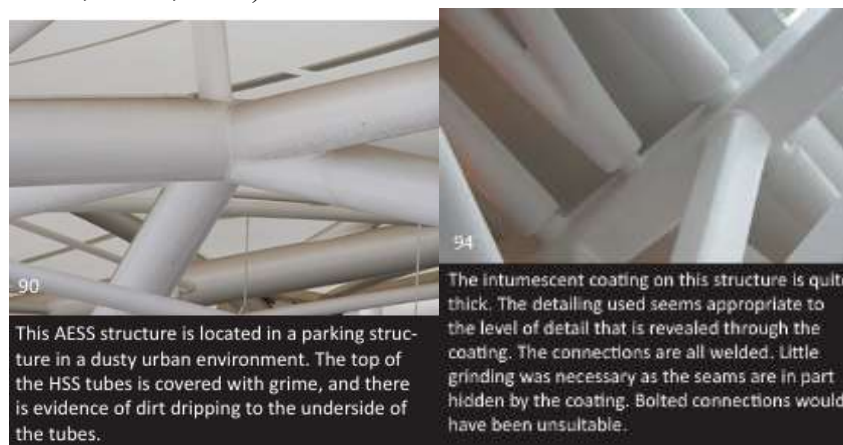


Fig.12 (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012)

3.2.3.2 Fire-Resistant Intumescent Coatings

Steel is coated with intumescent materials to prevent fires. When exposed to high temperatures, these coatings expand form an insulating char layer, which delays heat transfer to the steel and prolongs its structural integrity. An outline of their application procedure is provided below:

Preparation of the Surface: The steel surface needs to be cleaned and prepared. Oil, dust, rust, and mill scale should all be removed because they may have an impact on adhesion (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

Applying a suitable primer that is compatible with the intumescent coating is necessary to stop corrosion and guarantee that the intumescent layer sticks properly. It is applied by brush, roller, or spray in several thin layers to achieve the desired thickness. Because thin coats dry evenly, there is less chance of cracking. Before applying the following coat, each one must completely dry (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

If the building is in an exposed or heavily trafficked region, a protective top coat may be applied for improved longevity and aesthetic finish. To keep the efficacy and attractiveness over time, routine inspections can be necessary. AESS constructions are guaranteed both fire safety and aesthetic excellence because to this meticulous, multi-layer application technique (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

3.2.3.3 Galvanizing

For AESS buildings, galvanizing offers durable corrosion protection, which is especially advantageous for outdoor installations. Over time, the zinc coating transforms into a corrosion-resistant patina, creating a long-lasting barrier. However, because of variations in application and exposure to the environment, galvanized coatings can have different looks as shown in Fig.13 (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012).

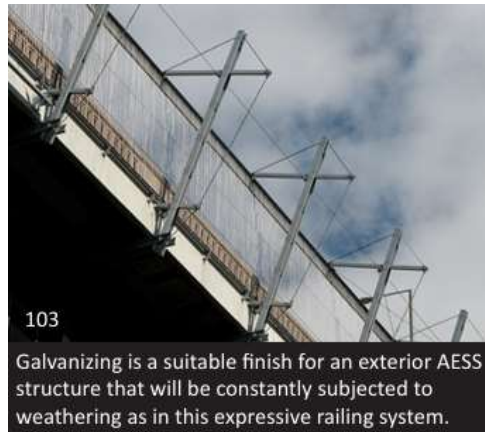


Fig.13 (Boake, B.E.S., B.Arch., M.Arch., & AP, 2012)

3.2.4 Comparison of standard structural steel members with AESS steel members (Leberer, 2017)

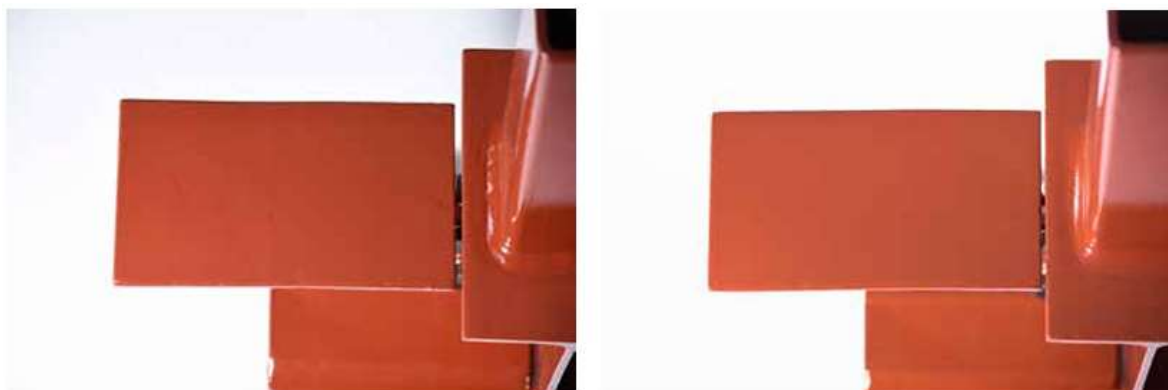
3.2.4.1 Overall appearance



▲ From left to right: Standard structural steel (SSS), AESS 1, AESS 2, AESS 3 and AESS 4.

Fig.14 (Leberer, 2017)

3.2.4.2 Gap tolerance

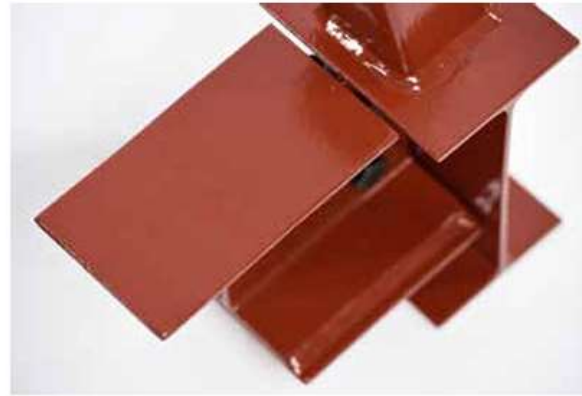


▲ AESS 3: Joint gap tolerances minimized, butt and plug welds ground smooth and filled.

▲ AESS 4: Surfaces filed and sanded.



▲ AESS 2: Standard joint gap tolerances.



▲ AESS 3: Joint gap tolerances minimized and butt and plug welds ground smooth and filled.

Fig.15 (Leberer, 2017)

3.2.4.3 Bolt orientation



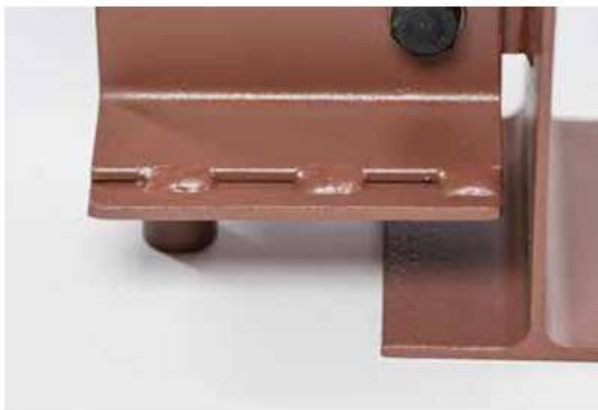
▲ SSS: Bolt head orientation not defined.



▲ AESS 1: Bolt head orientation defined, backing bar removed.

Fig.16 (Leberer, 2017)

3.2.4.4 Joint Appearance



▲ SSS: Intermittent/stitch weld between bottom flange and cover plate.



▲ AESS 1: Continuous weld appearance.



Fig.17 (Leberer, 2017)

3.3 Discussion

ISC has not mentioned about AESS or anything about architectural aesthetics of exposed structural steel. The checklist that is used during the case study was taken from CISC, and then introduced to the cases of Bhopal. India has always seen exposed steel through the structural point of view and not on the visual and aesthetics of it and therefore Architecturally Exposed Structural Steel (AESS) needs to be studied and incorporated in Indian codes. Internationally, these structures are made according to the category of AESS chosen during design discussions.

4. Data Collection

The study encompasses detailed data derived from analyzing multiple case studies, each discussed comprehensively in the following sections. This data not only underscores the versatility of AESS in India's buildings but also reveals how these structures meet visual and structural demands. Each case study presents insights into uniquely overall identity of exposed steel structure has been showcased.

Checklist

This study utilizes two key checklists. The first is a categorization of Architecturally Exposed Steel Structures (AESS) based on standards outlined in the CISC and AISC codes, as shown in Table 1. The second checklist was developed through an extensive literature review, providing additional criteria and insights for evaluating AESS applications in architecture.

PARAMETERS		REMARK
Coating and finishes		
1	Thin coat or glossy finish	
	Thick coats and matte or mottled finishes	
2		
3	Coating	
	a Primers	
	b Intumescent Coatings ementitious/Fibrous	
	c Fire Protection	
	d Galvanizing	
	e Metalizing	
4	Smooth finish	
5	Texture	
6	Flaw, scratches or other defects	
Connections		
7	Hot-rolled shapes (such as W, C and L-shapes)	
8	Hollow structural sections or tubes	
	a Tapered tube	
	b Elliptical tube	
	c Cylindrical tube	
9	Shop Fabricated	
10	Site Erected	
11	Splice Connection	
12	Welded Connection	
13	Bolted Connection	
14	Cast Connection	
15	Clean and finished	
16	Visually appealing	
17	Welding and bolting visible	
18	According to standards	
Curves and cuts		
	(Curve)	
	(Cutting method)	
19	Shearing/ die cutting	
20	CNC cutting	
21	Plasma cutting	
22	Torch/ flame cutting	
23	Hole punching and drilling	
Erection Considerations		
24	Members aligned correctly at joints	
25	Maintainance	
26	Visual aesthetics of members kept intact	
27	Combining Steel with Timber	
28	Combining Steel with Glass	

Table.3 Parameters

Source: authors

4.1 Case Studies

Architecturally Exposed Steel Structures (AESS) in India exemplify diverse aesthetic expressions, enhancing the visual appeal and functionality of public spaces. This study analyzes several case studies of AESS, each representing unique interpretations of aesthetics within large-span, public buildings. In

these structures, exposed steel elements are prominently visible and form integral parts of the architecture, making these buildings easy to recognize.

4.1.1 Tribal Museum

4.1.1.1 About

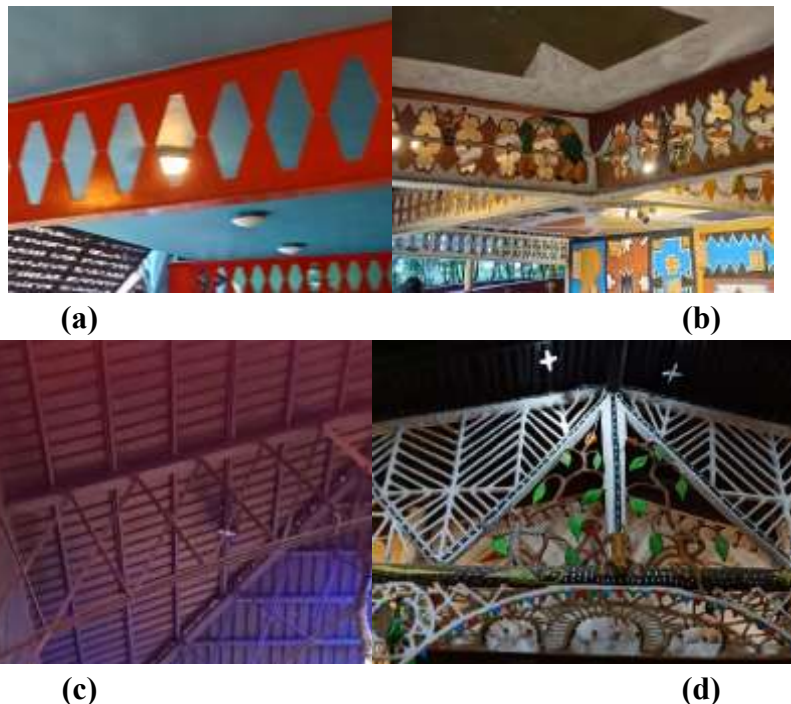
The Tribal Museum in Bhopal, Madhya Pradesh, also known as the Indira Gandhi Rashtriya Manav Sangrahalaya (National Museum of Mankind), is a unique cultural institution dedicated to celebrating and preserving India's tribal heritage. This museum highlights the traditions, art, and culture of various tribal communities from across India, particularly those from central India, such as the Gonds, Bhils, Baigas, and Korkus.

Architectural Style:

- The museum's architecture reflects traditional tribal designs and aesthetics, creating a natural connection with the surrounding landscape.
- With open spaces, natural light, and a close relationship to nature, the architecture embodies tribal ways of life.

4.1.1.2 Context

Tribal Museum is an assembly building in Bhopal. It has steel components in the roof which is also in proximity to physical touch. These steel members are covered with materials like ropes, paints and different finishes for aesthetic purposes which blends with the concept and art in the museum as shown in Fig.18



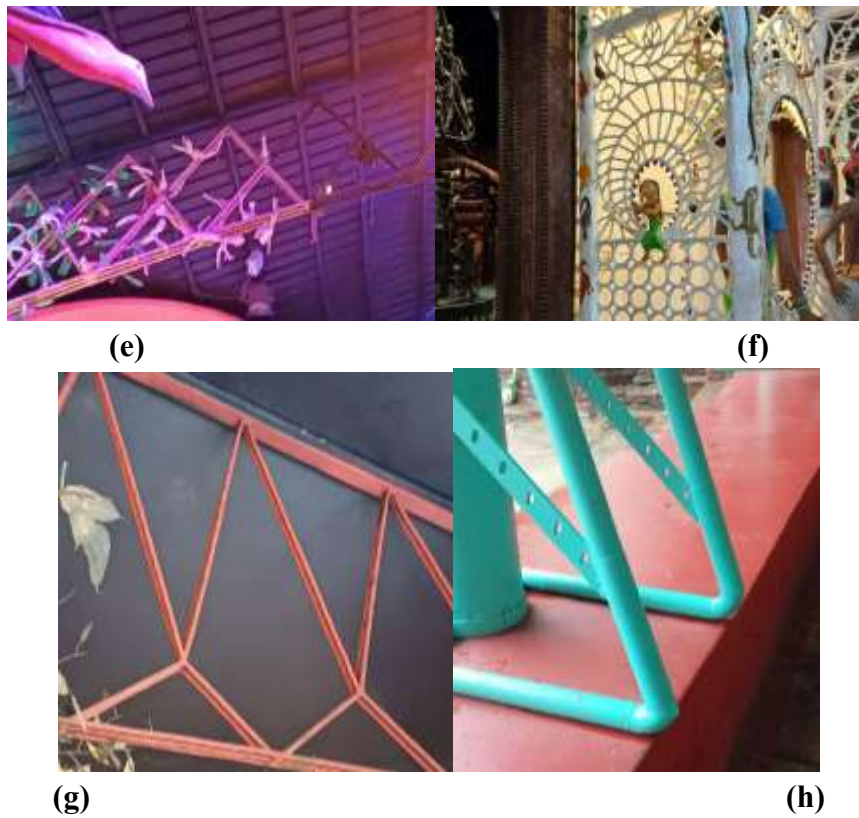


Fig.18

4.1.2 Rani Kamlapati Railway Station

4.1.2.1 About

Rani Kamlapati Railway Station, formerly known as Habibganj Railway Station, is a major railway station in Bhopal, Madhya Pradesh, India. It was renamed in 2021 to honor Queen Kamlapati, a revered 18th-century Gond queen known for her courage and strong leadership. Rani Kamlapati Station is India's first ISO-certified, world-class station operated under a public-private partnership. Indian Railways, in collaboration with a private firm, modernized it with airport-like amenities, including spacious waiting lounges, luxury restrooms, escalators, and more.

Architectural Style:

- The station has been designed with eco-friendly features like rainwater harvesting, sewage treatment plants, and LED lighting.
- There are provisions for rooftop solar panels, making it a green energy hub. Other amenities include Wi-Fi, food courts, shopping complexes, and a high-quality security system.

4.1.2.2 Context

In Rani Kamlapati Station steel members are used prominently. The large roof is supported by these members which gives it a vault-like shape. Beautification was not the primary requirement while designing the station and structural elements are to support the roof rather than the aesthetics. Skylights are present for light during the day as shown in Fig.19

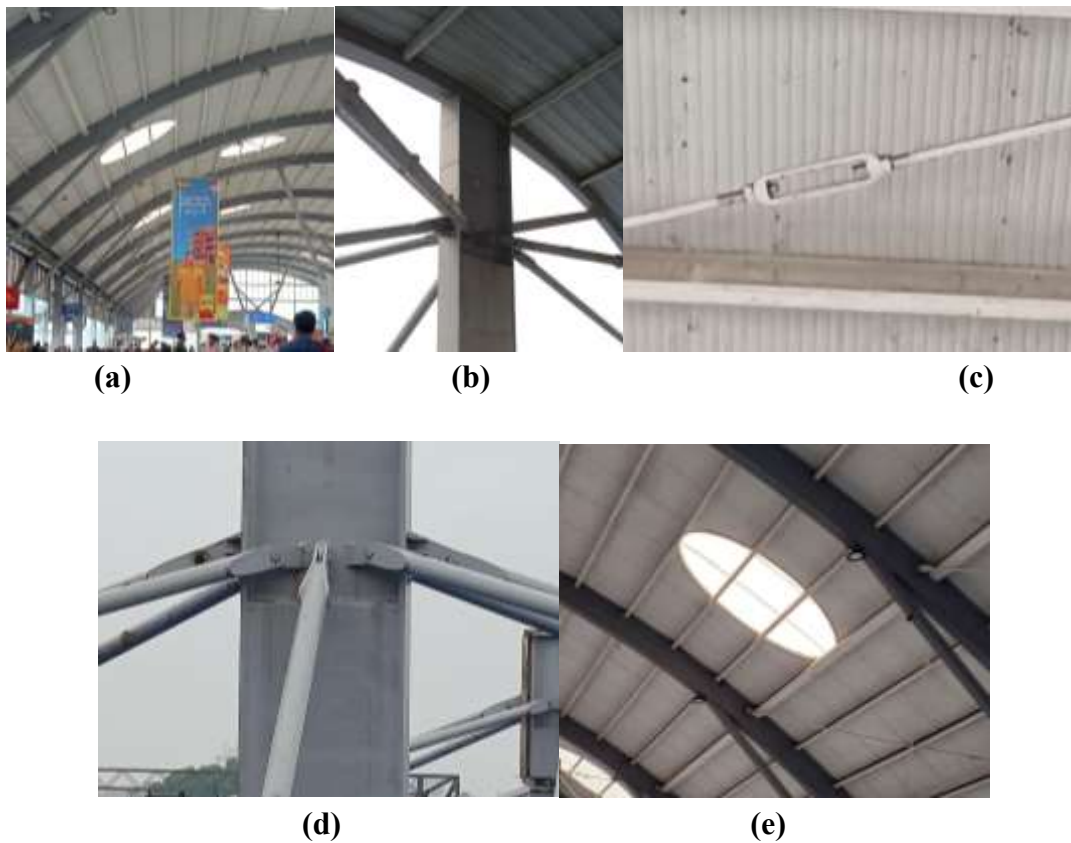


Fig.19

4.1.3 DB Mall

4.1.2.1 About

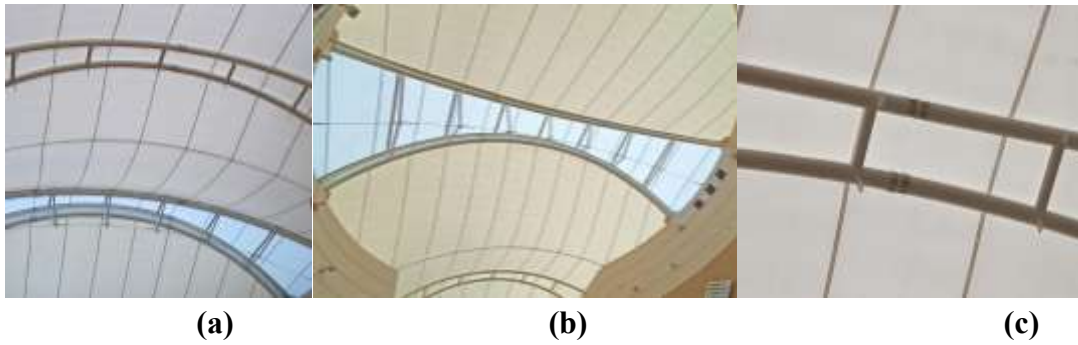
DB Mall, located in Bhopal, India, is one of the largest shopping and entertainment complexes in the region. Operated by the Dainik Bhaskar Group, the mall spans over a vast area with multiple floors featuring a wide variety of retail stores, restaurants, and entertainment options. It is known for hosting major international and domestic brands, from fashion and lifestyle to electronics and home decor.

Architectural Style:

- a. The interior is designed with multiple floors connected by escalators and elevators for easy access. Atriums are open and airy, often adorned with seasonal decorations or large digital screens, enhancing the visual appeal.
- b. DB Mall incorporates sustainable practices, including energy-efficient lighting, optimized airflow, and waste management systems, reflecting a modern approach to eco-friendly architecture.

4.1.2.2 Context

DB Mall is a commercial building. The dome, typically at the top of the atrium, combines steel and glass to create a visually impressive architectural feature. The steel framing supports the large glass panels, offering a panoramic view of the sky. The dome's glass and steel combination allows natural light to cascade down into the mall during the day, and LED lighting around the dome enhances its look at night. The steel frame's sleek lines provide a modern, dynamic touch to the architecture as shown in Fig.20

**Fig.20**

4.2 Analysis

This checklist has been generated after studying all the parameters specified in codes and papers which is important to classify the structure according to AESS. It has been used during the case study.

PARAMETERS	TRIBAL MUSEUM	REMARK
Coating and finishes		
1 Thin coat or glossy finish		
2 Thick coats and matte or mottled finishes		
3 Coating		
a Primers		
b Intumescent Coatings		
c Galvanizing		
d Metalizing		
4 Smooth finish		
5 Texture		Covered with different material
6 Flaw, scratches or other defects		
Connections		
7 Hot-rolled shapes (such as W, C and L-shapes)		I sections used
8 Hollow structural sections or tubes		
a Tapered tube		
b Elliptical tube		
c Cylindrical tube		Cylindrical steel rods instead of tubes . Steel TMT bars are used
d Others		
9 Shop Fabricated (Prefabricated)		
10 Site in situ		
11 Splice Connection		
12 Welded Connection		
13 Bolted Connection		
14 Cast Connection		
15 Clean and finished		
16 Visually appealing		
17 Welding and bolting visible		Welding joints were visible
Curves and cuts		
(Curve)		
(Cutting method)		
19 Shearing/ die cutting		
20 CNC cutting		Patterns made within beams
21 Plasma cutting		
22 Torch/ flame cutting		It could have been used
23 Hole punching and drilling		
Erection Considerations		
24 Members aligned correctly at joints		
25 Maintainance		
26 Visual aesthetics of members kept intact		
27 Combining Steel with Timber		
28 Combining Steel with Glass		
29 Combining Steel with Bamboo		

Table.4 Tribal Museum, Source: authors

PARAMETERS	RANI KAMLAPATI	REMARKS
Coating and finishes		
1 Thin coat or glossy finish		
2 Thick coats and matte or mottled finishes		to Reduce visibility of imperfections if any
3 Coating		
a Primers		
b Intumescent Coatings		Fire resistant
c Galvanizing		
d Metalizing		
4 Smooth finish		
5 Texture		
6 Flaw, scratches or other defects		
Connections		
7 Hot-rolled shapes (such as W, C and L-shapes)		
8 Hollow structural sections or tubes		
a Tapered tube		
b Elliptical tube		
c Cylindrical tube		
d Others		Box sections were used ,various sizes for different functions were used
9 Shop Fabricated (Prefabricated)		
10 Site in situ		
11 Splice Connection		
12 Welded Connection		
13 Bolted Connection		
14 Cast Connection		
15 Clean and finished		
16 Visually appealing		
17 Welding and bolting visible		bolting was visible
Curves and cuts		
(Curve)		
(Cutting method)		
19 Shearing/ die cutting		
20 CNC cutting		
21 Plasma cutting		
22 Torch/ flame cutting		
23 Hole punching and drilling		
Erection Considerations		
24 Members aligned correctly at joints		
25 Maintainance		
26 Visual aesthetics of members kept intact		
27 Combining Steel with Timber		
28 Combining Steel with Glass		
29 Combining Steel with Bamboo		

Table.5 Rani Kamlapati, Source: authors

PARAMETERS	DB	REMARK
Coating and finishes		
1 Thin coat or glossy finish		
2 Thick coats and matte or mottled finishes		
3 Coating		
a Primers		
b Intumescent Coatings		Fire resistant
c Galvanizing		
d Metalizing		
4 Smooth finish		
5 Texture		
6 Flaw, scratches or other defects		
Connections		
7 Hot-rolled shapes (such as W, C and L-shapes)		
8 Hollow structural sections or tubes		
a Tapered tube		
b Elliptical tube		
c Cylindrical tube		
d Others		
9 Shop Fabricated (Prefabricated)		
10 Site in situ		
11 Splice Connection		
12 Welded Connection		it is used to join the main curve members to achieve longer length
13 Bolted Connection		Used at corner joints
14 Cast Connection		
15 Clean and finished		
16 Visually appealing		
17 Welding and bolting visible		Bolting was visible
Curves and cuts		
(Curve)		
(Cutting method)		
19 Shearing/ die cutting		
20 CNC cutting		
21 Plasma cutting		
22 Torch/ flame cutting		
23 Hole punching and drilling		for bolted connections
Erection Considerations		
24 Members aligned correctly at joints		
25 Maintainance		
26 Visual aesthetics of members kept intact		
27 Combining Steel with Timber		
28 Combining Steel with Glass		
29 Combining Steel with Bamboo		

Table.6 DB Mall, Source: authors

	Category	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
ID	Characteristics	Custom Elements	Showcase Elements	Viewed at a distance ≤ 6 m	Viewed at a distance > 6 m	Basic Elements	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 spatter removed	✓		✓		✓	
2.1	Visual samples						
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 surfaces aligned	✓		✓			
3.5	Joint gap tolerances minimized						
3.6	All welded connections	✓		✓			
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							

Table.7 Tribal Museum, Source: authors

	Category	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
ID	Characteristics	Custom Elements	Showcase Elements	Viewed at a distance ≤ 6 m	Viewed at a distance > 6 m	Basic Elements	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 spatter removed			✓	✓	✓	
2.1	Visual samples						
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 surfaces aligned			✓			
3.5	Joint gap tolerances minimized						
3.6	All welded connections			✗			
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							

Tbale.8 Rani Kamlapati Railway Station, Source: authors

	Category	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
ID	Characteristics	Custom Elements	Showcase Elements	Viewed at a distance $\leq 6\text{ m}$	Viewed at a distance $> 6\text{ m}$	Basic Elements	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 spatter removed				✓		
2.1	Visual samples						
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 filed						
3.3	HSS weld seam oriented for reduced visibility						
3.4	Cross-sectional abutting surfaces aligned						
3.5	Joint gap tolerances minimized						
3.6	All welded connections						
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							

Table.9 DB Mall, Source: authors

4.3 Discussion

In the **Tribal Museum**, the structural design uses Architecturally Exposed Structural Steel (AESS) 1 and 3, with some customization to fit the space's unique aesthetic. Only a few of the AESS requirements are fully followed, so even though elements of AESS 2 and 3 are present, the finishes and detailing remain consistent across the structure. The result is rough-finished steel members that manage to look both natural and visually appealing, enhancing the museum's earthy character.

At **Rani Kamlapati Station**, a range of AESS standards—levels 1, 2, and 3—shapes the structure, with particular attention to levels 1 and 2, while level 3 requirements are not fully realized. The design process seemed to apply AESS principles in a more intuitive way, meeting structural needs while creating a cohesive and polished look without necessarily focusing on strict detailing.

DB Mall also includes AESS at level 3, but the design approach seems more organic, meeting AESS standards almost unintentionally. Despite this, the mall's steel elements come together seamlessly, providing a strong and modern aesthetic without the intricate detailing that would typically characterize high-level AESS.

5. Guidelines

The aesthetic detailing of Architecturally Exposed Structural Steel (AESS) in public buildings could be based on common typologies found in India, such as cultural, transportation, institutional, commercial structures. Each typology has unique detailing requirements to meet the aesthetics, taking into account, various factors. Our case studies, covering cultural centers, transportation facilities, and commercial hubs, So we have further proposed guidelines that could be followed in Indian context based on various factors like texture, finish, marking, coating, and connection requirements and categorizing structures

into various categories within 12 m of viewing and proximity distance i.e. touch proximity, close visual proximity, and near visual proximity.

- **Category A** (Touch Proximity > 3m): Designed for elements that are accessible to touch and close inspection, emphasizing texture, material integration, and cultural aesthetics.
- **Category B** (Close Visual Proximity 3m to 9m): For elements that are visually prominent but out of reach, focusing on smooth, clean finishes with moderate detailing to enhance visual quality.
- **Category C** (Near Visual Proximity 9m to 12m): Designed for elements that are primarily viewed from a distance but require precise detailing to maintain visual integrity.

BUILDING TYPOLOGY	VIEWING DISTANCE			USE OF STEEL		LOCATION OF APPLICATION		CONNECTIONS / JOINERY		PURPOSE	
	Category A	Category B	Category C	Completely	Integration with other materials	Exterior	Interior	Visible	Hidden	Iconic	Contextual
Commercial											
Cultural											
Transportational											
Institutional											
Industrial											
Residential											
Agricultural											
Recreational and Leisure											
Temporary and Mobile											
Entertainment hubs											

Table.10 Classification, Source: authors

AESS Guidelines for Cultural Buildings							
CHARACTERISTICS	Category A (Touch Proximity >3m)		Rationale	Category B (Close Visual Proximity 3-9m)		Rationale	
						Category C (Near Visual Proximity 9-12m)	
						Rationale	
Texture	Smooth	✓	Tactile appeal/Visual appeal Textured, curved, integrating local or cultural motifs	✓	Smooth with minimal detailing, incorporating paving or patterns or graphics reflecting cultural design	✓	This distance allows for visual engagement but without physical interaction
	Rough	✓		✓			
Finish	Matte	✓	Matte or natural finish to reduce visible imperfections glare and bleed with traditional aesthetics	✓	Variable by context	✓	It is distant, so the imperfections are not easily visible
	Glossy			✓			
Marks	Grinding	✓	Members are visible, so it is necessary to ensure a required finish	✓	Members are visible, so it is necessary to ensure a required finish		It will not be processed
	Mis						
	Scratch						
	Spatter						
	Fabrication						
Coatings	Weld					✓	
	Hot rolled						
	Electroplating	✓	Reduces surface roughness	✓			
	Black Oxide	✓		✓			
	Powder Coating	✓		✓			
	Paint	✓		✓			
	Galvanizing	✓		✓			
	With another material						
Metallizing	✓						
Connection	Fluorescent coating	✓	For fire safety	✓		✓	
	Welds			✓	For visual continuity	✓	For visual continuity
	Buffed			✓		✓	
	Joint gap tolerance minimized	✓		Reduce visible construction marks			
	Crossed Connection	✓					
	Uniform Bolt alignment	✓			Enhances appearance		

Table.11 Guidelines for AESS for Cultural Buildings, Source: authors

AESS Guidelines for Transportation Hubs								
CHARACTERISTICS	Category A (Touch Proximity ≤3m)		Category B (Close Visual Proximity 3-9m)		Category C (Near Visual Proximity 9-12m)			
		Rationale		Rationale		Rationale		
Texture	Smooth	✓	Durable and easy to clean, seamless finish	✓	Maintains clean visual function focused	✓	Encourages low maintenance	
	Rough					✓		
Finish	Matte	✓	Reduces glare for functional spaces, non-slip	✓		✓		
	Glossy				Adds brightness to interiors			
Marks	Grinding	✓	Adds detail to the structure	✓				
	Mill							
	Sawcut							
	Spatter							
	Fabrication	✓		✓	Adds subtle detail to industrial look	✓		
Coatings	Hot rolled	✓	Durability for high-traffic areas, easy maintenance					
	Electropolishing							
	Black Oxide							
	Powder Coating	✓	Resistant to wear and tear, non-slip	✓	For added durability, maintained easily	✓		Not prominent
	Paint			✓		✓		
	Galvanizing	✓	Enhances corrosion resistance	✓				
	With another material							
Connection	Metallizing	✓	For fire safety	✓				
	Fluorescent coating							
	Welded	✓	For structural integrity, seamless finish	✓		✓		
	Bolted	✓		✓		✓		
	Joint gap tolerance minimized	✓	For safety and durability	✓				
	Corroded Connection	✓		✓				
	Uniform Bolt alignment	✓	Industrial look	✓				

Table.12 Guidelines for AESS for Transportation hubs, Source: authors

AESS Guidelines for Commercial Buildings								
CHARACTERISTICS	Category A (Touch Proximity ≤3m)		Category B (Close Visual Proximity 3-9m)		Category C (Near Visual Proximity 9-12m)			
		Rationale		Rationale		Rationale		
Texture	Smooth	✓	Polished look for premium appearance	✓		✓		
	Rough							
Finish	Matte	✓	Adds sophistication	✓		✓		
	Glossy	✓	High-end finish for luxury settings	✓	Adds brightness to interiors			
Marks	Grinding	✓	Adds craftsmanship detailing	✓				
	Mill	✓						
	Sawcut							
	Spatter							
	Fabrication	✓		✓	Adds subtle detail to industrial look	✓		
Coatings	Hot rolled	✓	Adds visual weight for structural elements					
	Electropolishing	✓	For premium polish					
	Black Oxide	✓						
	Powder Coating	✓	For aesthetic durability	✓	For added durability	✓		
	Paint			✓		✓		
	Galvanizing	✓	For longevity in structural parts	✓				
	With another material							
Connection	Metallizing	✓	For fire resistance	✓				
	Fluorescent coating							
	Welded	✓	For seamless appearance	✓		✓		
	Bolted	✓		✓		✓		
	Joint gap tolerance minimized	✓	Adds polish and safety	✓				
	Corroded Connection	✓		✓				
	Uniform Bolt alignment	✓		✓				

Table.13 Guidelines for AESS for Commercial Buildings, Source: authors

6. Conclusion

Many steel structures in India, although not all intentionally designed with aesthetics in mind, already meet certain levels of Architecturally Exposed Structural Steel (AESS) criteria as mentioned in International standards. Steel structures in close proximity often lack the same attention to detail and quality standards as compared to internationally constructed buildings. When designing, it's essential to balance aesthetics with basic structural requirements to enhance the overall visual appeal. The appearance of exposed steel in India can be greatly improved by applying guidelines or parameters as proposed. Designing steel elements to align with the theme and context of a space not only enhances their appeal but also helps them integrate seamlessly within the structure. By following these guidelines,

architects and engineers can make well-informed decisions on the precise level of detailing required for steel connections, setting a strong foundation for future projects that are both structurally sound and visually compelling.

7. Glossary

a. Intumescent Coatings- Intumescent coatings may be designed for protection of metals from fire, such as structural steel. Reviews of the technology are available. They may be based on a number of resin binders including epoxy, and silicone.

b. Cementitious- Having the properties of cement.

C. Galvanizing- A metal plating process in which an iron or steel component is coated with a thin layer of zinc. The zinc acts as a protective layer that shields the underlying surface from corrosion and extends its lifespan.

d. Metalizing- Metallizing is a process which involves depositing a thin metallic film on the surface of non-metallic objects.

e. In situ- *In situ* refers to construction which is carried out at the building site using raw materials

f. Splice Connection- Column splice connection design involves joining two or more column sections to create a longer column or to provide additional strength

g. Welded Connection- Welded connections are connections whose components are joined together primarily by welds.

h. Grinding involves using abrasive tools to remove excess material or imperfections from welds. This process can smooth out the welds, making them flush with the surrounding steel surface. It is often done to improve the appearance of the steel, especially in cases where the connection is highly visible and aesthetics are critical.

i. Smoothing refers to the process of further refining the surface after grinding, ensuring that the steel looks polished and uniform. This might include filling in gaps or small imperfections with body filler, and sanding the surface to achieve a clean, finished look.

j. Bolted Connection- In bolted connection design, selecting the appropriate bolt type is crucial. Commonly used bolts include ordinary bolts, high-strength friction grip (HSFG) bolts, and preloaded bolts..

k. Shearing/ die cutting- Shearing, also known as die cutting is a process that cuts stock without the formation of chips or the use of burning or melting. Strictly speaking, if the cutting blades are straight the process is called shearing; if the cutting blades are curved then they are shearing-type operations.

l. CNC Cutting- A “Computer Numerical Controlled” device can be used to facilitate more complicated or repetitive cutting. The full potential of the device can only be realized if taking its instructions from CAD/CAM software. A CNC method can be used in conjunction with a number of different steel cutting methods. These include torch cutting, routing, plasma cutting, water jet cutting and laser cutting.

m. Plasma cutting- Plasma cutting is a process that cuts through electrically conductive materials by means of an accelerated jet of hot plasma. Typical materials cut with a plasma torch include steel, stainless steel, aluminum, brass and copper, although other conductive metals may be cut as well.

n. Torch/ flame cutting- Torch cutting is also called oxy-fuel cutting. This process uses fuel gasses and oxygen to cut the steel. In oxy-fuel cutting, a cutting torch heats metal to kindling temperature. A stream of oxygen is trained on the metal, and metal burns in that oxygen and then flows out of the cut as an oxide slag.

o. Hole punching and Drilling- Modern equipment has greatly improved hole punching and drilling, allowing for the high level of precision that is required in complex AECS structures. It is essential that the steel used in the project meet the half-standard tolerance characteristic of precision drilling in order to be of ultimate benefit to the project.

p. SSPC-SP 6- Removes all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and any other foreign matter on the surface.

q. HSS- HSS stands for hollow structural sections, a type of metal profile with a hollow tubular cross-section. HSS is used in various industries and structures for its strength, flexibility and appearance.

- A guide to understanding and specifying the various categories of architecturally exposed structural steel (AECS). MAXIMUM Exposure by Robert V Leberer
- Sample specification and an accompanying cost matrix by the joint Steel Committee of the Rocky Mountain Steel Construction Association and the Structural Engineers Association of Colorado

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