

CPE Candidate No. 0115808

July 07, 2015

# **TABLE OF CONTENTS:**

Section 1: Introduction
Section 2: Types and Methods of Measurement
Section 3: Special Factors – Effects on Takeoff and Pricing
Section 4: Overview of Labor, Material, Equipment, Indirect Costs and Mark-Up
Section 5: Special Risk Considerations
Section 6: Ratios and Analysis – Metrics and Review for proper QA/QC
Section 7: Miscellaneous Pertinent Informationp. 8
Section 8: Sample Drawings, Schedules and Sections
Section 9: Sample Estimatep. 12
Section 10: Glossaryp. 15
Section 11: References p. 15

**SECTION 1: INTRODUCTION:** 

The structural component of a project is probably the most straight forward element to estimate. It is usually the

most advanced during the design stages which paints the estimators a good 'picture' of the structural design even at

the early stages. The main structural members are defined early and are easily quantified but, more often than not,

the structural connections are developed at later stages so estimators tend do just capture the cost for the connections

in allowances based on a percentage of the total steel weight or gross square footage (GFA) of the project cost. This

approach is widely accepted when estimating new-build structures, since the structural connection costs are only a

fraction of the overall cost and can easily be covered as an allowance, based on the estimator's judgment. Structural

retrofit projects are different. The structural connections represent a higher cost due to lower productivity rates and

higher difficulty of unforeseen challenges when installing in the field. Most steel components are field fabricated to

fit, which add to the difficulty of the project.

The main intention of this technical paper is to provide the reader a general understanding of different structural

beam and column steel connections and understanding the potential impacts to a structural estimate. This will help

an estimator weigh the cost impact of the structural connections so the allowances applied are rather more

'educated' than just a guess.

MAIN CSI DIVISION:

Division 03000 - Concrete

Division 05000 – Metals

CSI SUBDIVISION:

Subdivision 03100 – Concrete Forming and Accessories

Subdivision 05100 – Structural Metal Framing

#### **BRIEF DESCRIPTION:**

The author will discuss different types of steel connections by providing sample plans and details of these elements. Since there are numerous types of steel connections that have been engineered through the years, only the commonly used are going to be discussed in this paper. The plans and section details will be used to perform the quantity takeoffs for the necessary tasks to develop the direct and indirect costs of the connections. Productivity rates are factored into the Labor costs due to the possible challenges whether in a new-build situation or a retrofit condition. The estimator will need to assess whether a project can be considered 'production work', since this will affect both material and labor productivity rates. Sample takeoffs and cost estimates will be provided to illustrate these. This paper is presented from a cost consultant's point of view as opposed to a contractor's or a material supplier's. The estimate will be prepared as a general contractor bid, which will include the 'General Contractor's (GC)' mark-ups. The estimates anticipate that the GC will hire a subcontractor to perform the tasks. The estimates will show detailed breakdown of the tasks and quantities for the connections costs. Unit rates are then provided for the quantities and extended for the total cost. Once the total cost for each task is determined, these are totaled as the total subcontractor cost, which then is marked up by the general contractor mark-ups. The total cost of these connections is then backed into the weight of the total steel as a percentage or to the GFA as a square foot cost.

#### **SECTION 2: TYPES AND METHODS OF MEASUREMENT:**

Quantifying structural beam and column connections involve measuring the components in **SF**(square feet), **LBS**(pounds) or **TONS**. Welds and cuts are measured in **LF**(linear feet). Bolts and anchors are counted in **EA**. (each).

The connections will have typical detail drawings or section plans, showing the profiles and dimensions for each type of connection. The number of each connection type can then be counted on the floor framing plans, often using different symbols to represent each type of connection. Steel components are usually measured in SF and LF but can be easily converted to LBS by referencing the steel properties of the members in any of the widely available published materials. To use these references, the member sizes or sections have to be available. Wide Flanges (WF), I-shaped, H-shaped and channels designate the weight in the sizing such as W12x16, S8x23, HP8x37 and C10x30,

where 16, 23, 37 and 30' represent the weights in lbs. For channels, angles and for hollow steel sections (HSS), the sizes will need to be referred to a steel table to determine the weights. An angle with size L4x4x1/2 has a weight of 12.8 lbs per linear foot. A tubesteel with a size of HSS6x6x1/2 has a weight of 35.24 lbs. per linear foot. Plates are usually measured by the area but more importantly, the thickness has to be known to determine the weight. A plate with the thickness of 1/2" and 3/8" are 20.42 lbs. and 15.31 lbs, respectively.

#### SECTION 3: SPECIAL FACTORS – EFFECTS ON TAKEOFF AND PRICING:

The first thing to consider is whether the project is new-build or retrofit. Structural retrofit jobs require much more labor to install primarily because of the onsite preparation for the connections to be installed. Unlike new-build projects where the steel can be prepared in the shop, retrofit jobs require preparation for the existing structural members to be performed in place. Drilling and cutting are necessary to install new member to existing structure. Most of the steel members, if not all, are fabricated onsite to fit actual conditions which contribute to the difficulty and duration of the task.

Project size is always a factor to consider for all projects. A larger project simply allows the contractor to spread the overhead costs more effectively over the scope of work, including mobilization and demobilization costs, which result smaller unit costs. The contractor can offer lower profit mark-ups with larger projects since this will yield higher profit margins based on the larger direct costs. Installing structural connections requires the use of equipment and specialty labor. The same economies of scale principle apply to equipment rentals. Lower rates are offered to equipment that are rented for longer periods of time. These lower rates then translate to the cost of installing the structural connections. Specialty labor such as a welder usually have half-day or one day minimums set, regardless if the actual work takes an hour or a day. This also flows over to the structural connection cost.

Workflow is another factor to consider. If workers can work continuously without have to demobilize and then remobilize for the next task, this helps lower the construction cost. Phased construction is more expensive since multiple mob and demob costs need to be considered. Labor efficiency has to be optimized to yield lowest rates.

The commonly used materials for structural members are steel, concrete and timber and they can be interconnected to one another through different connections. Most of these connections are made of steel. These connections are

engineered and are unique for each project. So determining the type of structure can affect the type of connections being used in a project.

The steel material and finish are other factors that can affect the cost. The commonly used steel material is hot-rolled or cold formed carbon steel, but some projects require stainless steel which is substantially heavier and more expensive than carbon steel. Some projects that have some exposed steel members may require the steel to be 'Architecturally Exposed Structural Steel' (AESS). AESS is more expensive because the steel is fabricated as a structural and architectural element at the same time. The finish of the steel is also a factor. Most projects require the steel to be primed and painted, but projects that are in corrosive environments, require the steel to have protective coatings such as hot-dipped galvanizing, PVC wrapping or epoxy coating.

Another important factor to consider is whether a system is a proprietary system like "Sideplate". These systems are engineered for faster installation by the system developer and require licensing fees for the utilization of their system. This substantially increases the cost of a connection but potentially reduces the installation time for the contractor to build the entire structural frame.

#### SECTION 4: OVERVIEW OF LABOR, MATERIAL, EQUIPMENT, INDIRECT COSTS AND MARK-UP:

Material costs are based on measured quantities and quotations from vendors and suppliers. Sourcing out these costs is important specially if they are specified. Take chemical anchors for example, Hilti offers several types of anchors and adhesives to be applied in different load applications and conditions. Cost is also dictated by the sizes of the bolts that would then dictate the amount of chemical adhesive to be used. Since steel is the main material used for structural connections, it is important to source out actual prices. The estimator must also consider freight costs to the project site, material handling and taxes.

Labor and Equipment costs are measured in time, hours and in days. It should also be determined if a project is subjected to Prevailing Wage rates, Davis-Bacon rates or Merit Shop rates. This should be based on the location of a project. Different cities have different rates. This determination also affects the equipment costs since this includes the operator's wages.

General Conditions is the contractors site overhead cost to run the project. This would cover site supervision and staff, site office and facilities, hoisting, utilities, mobilization and demobilization costs. This also includes miscellaneous items such as temporary fencing, traffic control, clean-up, small tools, etc.

Overhead and Profit would cover the contractor's home office overhead costs to support the project and the profitability of the contract.

Bonds and Insurance is the markup that protects and ensures the owner that the project will be completed within bid price and time.

Design contingency is used to compensate for the lack of detail in earlier stages of design. This accounts for items missing as a project goes through design evolution until it reaches the final stages of design such as Construction Documents (CD) level. The design contingency is often reduced to zero when drawings reach CD level, since the assumption is that at this level, everything should already have been designed and represented in the drawing set. The design contingency simply reflects the estimator's confidence on the documents provided for estimating the project based on things that may have been missing during design.

Escalation is included in the cost estimate to account for material and labor price inflation. Escalation rates are based on past and current market studies to forecast the pricing changes at the scheduled time of construction. It is represented as a percentage of the overall construction cost and usually calculated to start or midpoint of construction. This somewhat protects the contractor from material cost fluctuations.

## **SECTION 5: SPECIAL RISK CONSIDERATIONS:**

Steel cost fluctuation is a major risk consideration when a contractor is locking-in a bid. Steel cost fluctuates with the price of oil, supply demand for developing countries. China has been the largest consumer for steel for the past years, in quantities which increased material prices throughout the rest of the world, due to the rapid economic growth the country has experienced. This 2015, this growth slowed down and the Chinese consumption of steel has been decreased in demand and has been forecasted to continue to reduce pace through to 2016., this will result in cost reduction of steel in the world market.

### SECTION 6: RATIOS AND ANALYSIS - METRICS AND REVIEW FOR PROPER QA/QC:

Since structural connections are usually not quantified and priced separately from the structural steel framing components, metrics are not readily available for this element for estimating QA/QC, though current practices allow carrying 15% allowance to cover the premium costs of bolts and connections.

### **SECTION 7: MISCELLANEOUS PERTINENT INFORMATION:**

The estimator should also be aware if the project requires purchased materials to be manufactured in the United States under the "Buy American Act" of 2009, especially for government project. This should be part of the General Requirements in the project manual (Specification). However, there are exceptions to this Act to allow the contractor to waiver this requirement, which will not be discussed in this paper.

In order to avoid conflicts with existing reinforcing in concrete structures, X-ray must be considered in the cost estimate, if the connection installation involves drilling the existing concrete members to anchor or attach the new members. The actual locations of existing reinforcing can affect the design of the connection. This can dictate the number and size of anchors, the size of steel plates, thickness of welds and sizes of main members.

Another aspect to consider is whether the project is a healthcare project in California. The steel component may be subjected to OSHPD requirements and inspections, which adds on a premium to the steel cost.

# **SECTION 8: SAMPLE DRAWINGS, SCHEDULES AND SECTIONS:**

### **RETROFIT PROJECT:**

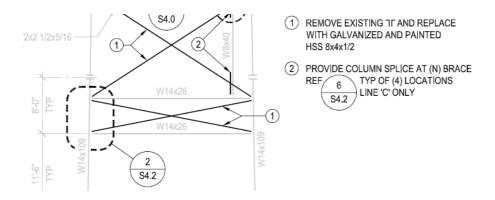


Figure 1.0:

On this figure, we see a partial elevation of a typical steel framing drawings. This shows the main member sizes of the structural frame. The connection detail is referred to detail 2 on sheet S4.2.

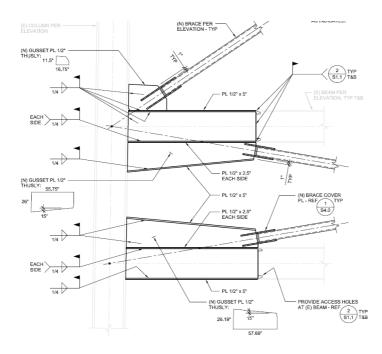


Figure 2.0:

This figure represent the connection detail referred to in Figure 1. In this figure, the connection is detailed, showing steel dimensions, type and sizes of welds, cuts to be made to existing steel

## **NEW-BUILD PROJECT:**

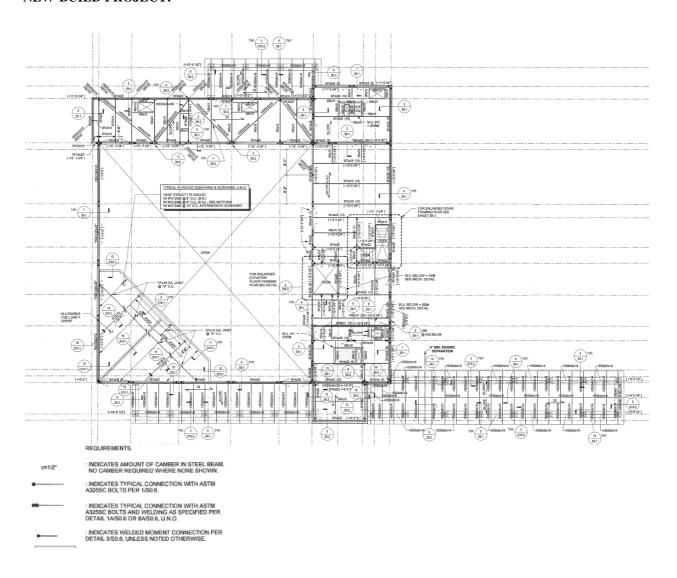


Figure 3.0:

On this figure, we see a typical building framing plan, showing the beam sizes and columns. The steel connections are represented as symbols. One dot represents typical bolted connections, double dots represent bolted and welded connections and a triangle to represent welded moment connections.

# PROPRIETARY SYSTEM: (SIDEPLATE)

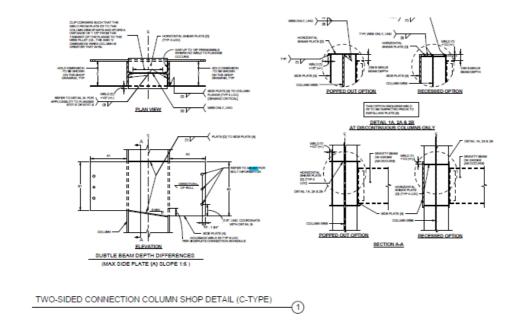


Figure 4.0:

This figure shows a typical connection detail for Sideplate connections system. These show the steel dimensions, weld type and sizes, bolt quantities and sizes.

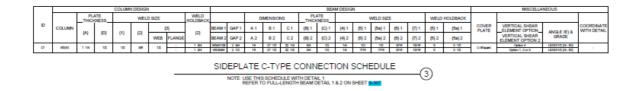


Figure 5.0:

This figure shows a typical Sideplate connection schedule which supplements the detail in Figure 4.

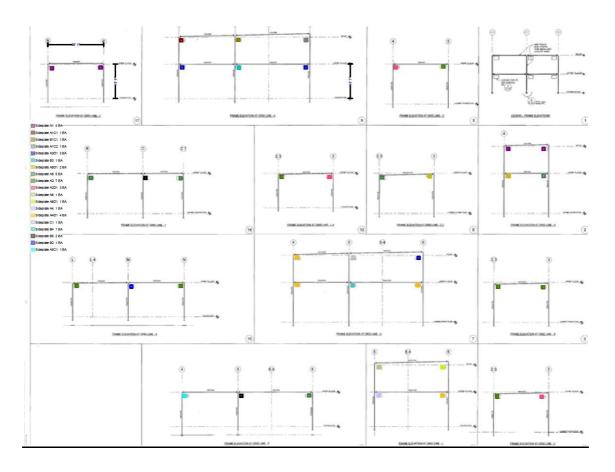
# **SECTION 9: SAMPLE ESTIMATE:**

Takeoff and Pricing: For this example, Sideplate connections are going to be used.

Below is a takeoff for Sideplate connection type A. This takeoff determines the weight of the plates utilized, based on the areas and thickness of the plates, totaling to 32.9 tons.

Side Plate ID					Plate A							
	Column Size	Beam Size	LOC	QTY	Length Dim. A (ft)	Column Depth (ft.)	Depth Dim. B (ft.)	Area/Plate (ft²)	Plate Thickness	WT/SF	WT of Plate A (LBS)	
A1	W24X131	W24X55	4.000	2.000	1.500	2.042	2.250	8.081	0.625	25.520	1,649.868	
A1C1	W24X131	W24X55	1.000	2.000	1.500	2.042	2.250	8.081	1.625	66.350	1,072.382	
A1C2	W24X131	W24X55	1.000	2.000	1.500	2.042	2.250	8.081	1.500	61.250	989.953	
A2	W24X176	W24X84	7.000	2.000	1.500	2.100	2.292	8.365	1.000	40.830	4,781.363	
A2C1	W24X176	W24X84	2.000	2.000	1.500	2.100	2.292	8.365	1.000	40.830	1,366.104	
A2D1	W24X176	W24X84	3.000	2.000	1.500	2.100	2.292	8.365	1.000	40.830	2,049.156	
A3D1	W24X131	W24X94	3.000	2.000	1.500	2.042	2.292	8.231	1.125	45.940	2,268.766	
A4	W24X146	W24X103	1.000	2.000	1.500	2.058	2.292	8.269	1.250	51.040	844.109	
A4D1	W24X131	W24X103	4.000	2.000	1.500	2.042	2.292	8.231	1.250	51.040	3,360.842	
A5	W24X131	W24X94	2.000	2.000	1.750	2.042	2.500	9.604	1.125		1,764.862	
A5	W24X176	W24X94	1.000	2.000	1.750	2.100	2.500	9.750	1.125	45.940	895.830	
A5	W24X131	W27X94	1.000	2.000	1.750	2.042	2.500	9.604	1.125	45.940	882.431	
A5	W14X283	W27X94	1.000	2.000	1.750	1.392	2.500	7.979	1.125	45.940	733.126	
A5C1	W24X176	W27X94	1.000	2.000	1.750	2.100	2.500	9.750	1.750	71.460	1,393.470	
A5D1	W24X176	W27X94	2.000	2.000	1.750	2.100	2.500	9.750	1.125	45.940	1,791.660	
A6	W24X146	W27X102	1.000	2.000	1.750	2.100	2.542	9.913	1.000	40.830	809.455	
A6D1	W14X311	W24X103	1.000	2.000	1.750	1.425	2.542	8.197	1.000	40.830	669.357	
A7C1	W24X229	W30X108	2.000	2.000	1.917	2.167	2.750	11.367	2.000	81.670	3,713.263	
A8	W24X229	W30X116	3.000	2.000	1.917	2.167	2.750	11.367	1.250	51.040	3,480.928	
A8C1	W24X229	W30X116	2.000	2.000	1.917	2.167	2.750	11.367	2.000	81.670	3,713.263	
A8D1	W24X229	W30X116	1.000	2.000	1.917	2.167	2.750	11.367	1.250	51.040	1,160.309	
B1C1	W24X131	W24X55	1.000	2.000	3.000	2.042	2.250	11.456	1.625	66.350	1,520.244	
B2	W24X176	W24X84	1.000	2.000	3.000	2.100	2.292	11.802	1.000	40.830	963.758	
B2C1	W24X176	W24X84	1.000	2.000	3.000	2.100	2.292	11.802	1.000	40.830	963.758	
В3	W24X131	W27X94	1.000	2.000	3.000	2.042	2.292	11.668	1.125	45.940	1,072.093	
B4	W24X146	W24X103	1.000	2.000	3.000	2.058	2.292	11.707	1.250	51.040	1,195.009	
B5	W24X131	W27X94	2.000	2.000	3.500	2.042	2.500	13.979		45.940	2,568.812	
B7C1	W24X229	W30X116	2.000	2.000	3.833	2.167	2.750	16.638	1.875	76.560	5,095.068	
В8		W30X116	4.000	2.000	3.833	2.167			1.250	51.040	6,793.424	
B8C1	W24X229	W30X116	2.000	2.000	3.833	2.167	2.750	16.638	1.875	76.560	5,095.068	
C1	W24X146	W24X103 W24X94	1.000	2.000	3.000	2.058	2.292	11.707	1.250	51.040	1,195.009	
									Total	for Plate A	32.926 To	ns

# Below is a sample takeoff sheet on the Sideplate type counts:



Below is the sample steel framing estimate including the Sideplate components:

	Quantity	Unit	Unit Cost	Total
Metals				
Structural Steel				
Steel columns, WF	149	tn	\$3,543.13	\$526,155
Steel columns, Tube Steel	17	tn	\$4,148.63	\$71,647
Floor framing	288	tn	\$4,099.28	\$1,179,199
Roof framing	160	tn	\$4,099.28	\$656,582
Side plate connections				
Side plate connection, type A	32.9	tn	4,148.63	\$136,490
Side plate connection, type B	4.4	tn	4,148.63	\$18,254
Side plate connection, type C	1.3	tn	4,148.63	\$5,393
Side plate connection, type D	2.4	tn	4,148.63	\$9,957
Bolts, 3/4"Ø	354.0	ea	12.35	\$4,372
Weld, 1/2" fillet weld	2,478	lf	6.75	\$16,727
Licensing fee	1	ls	92,000.00	\$92,000
Miscellaneous bolts and connections	32	tn	\$4,148.63	\$134,104
letals				<u>\$2,850,879</u>
Subtotal Subcontractors Cost			\$2,850,879	\$47.01
General Conditions	8.2%		\$233,683	\$3.85
Design Builders Bond and Insurance	2.2%		\$67,860	\$1.12
General Contractor Fee	4.0%		\$124,521	\$2.05
Design Builders Contingency	2.0%		\$65,539	\$1.08
Escalation to MOC, July 2016	4.0%		\$491,603	
TOTAL ESTIMATED CONSTRUCTION COST			\$ <u>3,834,084</u>	\$55.11
Total Area:	60,650	oc.		

The total cost of the connection system (Sideplate) is \$283,192, which represents 9.93% of the overall steel framing cost which translate to \$4.67 per square foot.. The total weight of the Sideplate connection is 6.67% of the total steel framing weight adding about 1.35lbs. per square foot of steel to the project.

### **SECTION 10: GLOSSARY:**

- Moment Connections: Bolted or welded connections that can provide full moment continuity, transferring bending moments, shear forces and normal forces.
- **2. Structural Retrofit:** Adding structural components to the existing structural frame to upgrade from current state to the new design.
- 3. **Productivity Rate**: This refers to the time a crew can perform a task.
- **4.** Takeoff: Quantification of elements on the plans for cost estimating.
- **5. Mobilization**: Refers to the contractor's or subcontractor's time and effort to set-up onsite, including equipment to do a task or project.
- **6. Demobilization:** Refers to the contractor's or subcontractor's time and effort remove himself and associated equipment from the project site once a task or project is complete.

### **SECTION 11: REFERENCES:**

- 1. Trading Economic website on Steel as a commodity.( <a href="http://www.tradingeconomics.com/commodity/steel">http://www.tradingeconomics.com/commodity/steel</a>)</a>
- "Steel Demand in China Dropping Through '16 as Growth Slows", a Bloomberg article by Jasmine
  Ng,Updated April 2015( <a href="http://www.bloomberg.com/news/articles/2015-04-20/steel-demand-in-china-to-decline-through-2016-global-group-says">http://www.bloomberg.com/news/articles/2015-04-20/steel-demand-in-china-to-decline-through-2016-global-group-says</a>)
- 3. SteelConstruction.info website (<a href="http://www.steelconstruction.info/Moment\_resisting\_connections">http://www.steelconstruction.info/Moment\_resisting\_connections</a>)