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RECOMMENDATIONS FOR DESIGN, FABRICATION AND ERECTION OF STEEL BUILDING EDGE FORM

(AISC Professional Members Committee – Los Angeles Chapter)

PREFACE:

This paper was developed to serve as an aid to help the engineer; fabricator and erector better understand the significance and impact of edge-form/bent plate in the design, fabrication, erection and ultimate completion of a steel building. Decisions about edge-form/bent plate impact many other design disciplines and construction trades associated with the project. Examples include the architect, the curtain wall designer, the metal deck subcontractor, the concrete subcontractor and the stair fabricator. Since so many aspects of building design and construction are impacted by edge-form/bent plate, it is hoped that the information presented in this document will help streamline the design, fabrication, erection and ultimate completion of a steel building, or at least provide the reader with insights as to the roles and problems associated with edge-form/bent plate in building design and construction.

PURPOSE OF THE EDGE FORM

INTRODUCTION:

It is required on almost every building project. Structurally, its importance is usually minimal. Without it, the structure could not be completed. It defines the boundaries of the slab. Other trades insist on using it to determine the thickness of the floor slab, support the facia and perform other significant functions where this product is used. What is this product that is almost meaningless but significantly important? It is the edge-form/bent plate.

Edge-form is found in numerous areas of the structure but can be categorized into three major areas, the building perimeter at the floor, the building perimeter at the roof and interior openings. It can be straight or curved. Both horizontal and vertical legs can vary on the same floor. Used solely as a concrete stop along the straight edge of a floor, it can be very simple in form without any attachments. By using it to be the structural support of the facia material such as metal studs and deformed bars creates additions that begin to complicate this simple product.

As gage material or plate, the role of the edge form as an important product for proper construction cannot be overlooked. However, because of its chameleon nature, its relative cost, in time and dollars can be disproportional on a project.

Through all its varied uses and forms it is evident that some standardization is possible and information could be disseminated that could help standardize the product. Our goal is to provide positive suggestions in an effort to consolidate some of the many details that exist from design office to design office with a practical approach for the use of the edge-form/bent plate.

BACKGROUND:

Why address the issue of standardization of edge-form details and material? The answer lies, like all others addressed, in the need of our industry. Development of procedures, systems and products that will ultimately provide a quality end product in less time will ultimately bring the end product on line at a better value. As such, structural steel will be more competitive with other building materials thereby creating additional projects for structural steel.

Any product that can be produced in an assembly line type system will have its relative cost reduced, provide a more uniform product and minimize errors. As a committee, we reviewed details from various engineering offices, solicited information from fabricators, erectors and detailers and consulted general contractors and metal deck producers and installers. Candidly, the information from fabricators, erectors and detailers was solicited from numerous geographical regions whereas the information solicited from general contractors, engineers and metal deck suppliers and installers were regional.

PROBLEMS:

Specifications: With the many uses of edge-form comes various tolerances or the need for various tolerances. However, project specifications, many times are not written job specific. As a result, the tolerances for edge-form could be stricter than actually required. It is the responsibility of the designer to provide a reasonable tolerance based on an understanding of project needs and production limitations.

Tolerances: Numerous tolerances exist in the fabrication and erection of structural steel, horizontally and vertically. Plumbing, sweep and camber tolerances combined with the tolerances for location of detail materials and rolling tolerances can lead to significant variations in the final position of the member. Shop attached steel pieces; the variations are at the mercy of all the tolerances noted above. Field attached pieces of steel; considerable improvement in the horizontal location can be expected. However, as in any product, the tighter the required tolerances, the cost of meeting the tolerances increases. With edge-form that is not required for facia attachment, considerable variation in horizontal alignment should be accepted, whether shop or field attached. The specifier must establish reasonable tolerances.

Allowable Variation in Camber and Sweep Tolerances (AISC 9th Edition, pages 1-149, 1-150):

Example: Beam with flange width equal to or greater than 6" in width: W18x35 (bf = 6.0")
Allowable Camber and Sweep: 1/8" x (beam total length, ft)/10
30 foot beam: tolerances = 0.125 (30/10) = 3/8" for camber and sweep individually
(also consider beam flange Out of Square - permissible range: 1/4" to 5/16")

Concrete Screed: Bent plate has numerous conditions that can affect the final elevation of the top of the vertical leg. For the plate, the vertical leg can be too long or the bend may be more or less than 90 degrees. But all still within allowable tolerance.

The flanges of steel beams ideally are perpendicular to the web. However, tolerances exist that allow variations of +/- ¼ inch. Since the bent plates rest on the flange, the out of square of the flange will affect the elevation of the top of the vertical leg of the bent plate. The affect will be a result of the flange width and the distance the vertical leg is from the beam centerline.

All steel beams have some amount of natural camber. By specification this natural camber is always up. Once in position, the steel beam will begin to develop a down camber or deflection, a result of dead loads imposed on the members. Also, the engineer may specify a camber in the beam. This camber is normally designed to come out when all dead loads are on the beam. Any camber will affect the final elevation of the bent plate.

The beam end connections, regardless of type, all have vertical tolerances for in place fit. Columns have tolerances for length and base elevation. Beams have tolerances for depth. All contribute to the final elevation of the top of the vertical leg of the bent plate.

Architects and engineers must be aware of these tolerances and the affect on the structure when writing the specifications. The concrete subcontractor must be aware of the specification requirements and the affect on the slab thickness and flatness. Since the elevation of edge-form follows the elevation of top of steel, using the edge-form as a concrete screed should be at the risk of the concrete contractor.

The placement of the concrete topping slab is an art form and highly dependant upon the original design of the framing members. Are the steel beams relatively shallow for their intended span with no camber, which will lead to more beam deflection when placing of the topping slab? Do the specifications call for a "Dead Level" floor, which is difficult to achieve at best on an elevated steel beam and deck floor system due to the tolerances of fabrication and erection of steel beams mentioned previously? Is the steel deck depth and gauge for the intended span reasonable?

To achieve a relatively flat floor the steel framing must be of reasonable depth, camber and beam spacing. Steel beams should be slightly under cambered for dead load anticipating some deflection of the beams since cambers do not always come out. The amount of added camber should be small and dependant upon beam span, but probably not more than an 1-1/2" for steel beams used in floor systems again incase not all of the camber comes out under dead load deflection. Beams with greater camber may be an indication of a floor system, which may have problems with floor vibrations. Larger cambers can be accommodated at the roof due to the sloping requirements for drainage. Beams with camber requirements of less than 1/2" should probably not be cambered at all.

Required heights for the screed elevation need to be tack welded to the framing members to help assure that excessive concrete is not placed over the steel deck, not using the edge form as a guide. The use of laser screeds needs to be done by experienced personnel. Use of target elevations, instead of fixed elevations measure off of the steel framing, when using laser screeds should be approached cautiously as both the steel deck and beams will deflect under the weight of the wet concrete and continue to deflect as additional concrete is added and never achieve a level floor. Limits to the height of the concrete topping over the metal deck must be established to prevent overloading of the steel beams and deck. The shallower purlin beams in the center of the typical framing bay can be expected to deflect more at mid-span than the shorter deeper girders on the framing bay perimeter when attempting to achieve a relatively level floor. The expected deflections will increase the concrete topping thickness in these localized areas, but limits should be specified to prevent overloading. The actual amount of deflection is hard to predict, since the beam camber may not drop out.

Terminology: The term continuous, as it relates to edge-form should be defined so that it is not necessary to weld abutting joints. At columns, it should be acceptable by drawing or specification to seal small openings where wet concrete can seep through with products other than structural welds.

GAGE ALTERNATIVE:

Designers should consider using gage material, as thick as 7 gage, as edge-form material and having it installed by the decking contractor. Depending on application, the material usually does not need to be galvanized, regardless of thickness. The advantage in having the edge-form specified as gage material as much as possible and assigning the work to the decking contractor lies in the similarity of work performed with similar tools. The similarity involves:

A. Layout and cut and fit operations performed to provide the concrete form.
B. The Shielded Metal Arc Welding (SMAW) as the process for securing the materials to the structural members.
C. Required dimensions for installation of the final products.

With the edge-form field installed, the designer should consider welding and spacing of welds that will provide a structurally sound product that is economical to provide in the field. Figure 1 is provided as a guideline. With longer horizontal legs on the edge-form some form of support will be required to minimize deflection. Figure 2 is provided as a suggested detail to minimize deflection.

FABRICATION AND ERECTION

Problems with Shop Installation: Why is field installation of gage metal edge-form proposed over the traditional shop installed bent-plate? Not all shops are the same and not all shops operate the same but the following can well exhibit what usually occurs to varying degrees for most fabricators.

After receiving a new project, a fabricator must start the shop drawings and order materials. Both of these operations depend on the steel detailer. Proper and complete dimensioning on the design drawings is mandatory for the steel detailer to provide accurate and complete information and drawings to the fabricator.

Simultaneously, the fabricator is communicating with the steel erector, either internal or subcontracted, on erection sequencing of the project. Regardless of the terminology, the erector will desire that all structural members within a given sequence, bundle, area or whatever a designated subdivision of the structure is called, be provided together on one or several trucks as required for the subdivision. Undoubtedly, some members within the subdivision will ultimately require some sort of edge-form. This edge-form may be for perimeter beams or interior openings for stairwells, elevators or mechanical ducts. Each will require that the designer have accurate information on the design drawings for the location of the edge-form. If the information is not available numerous potential conditions arise.

The detailer must delay the final detailing of affected beams if the edge-form is shop installed. Depending on the detailer, shop drawings will range from showing members partially drawn with various dimensions left blank to not detailing the member at all until all information is received.
In either case, the potential exists for delays in the project. Project delays, additional costs, change order meetings, confrontations between contractors and designers simply because a few very meaningful dimensions were not available in a timely manner. No one is happy. The owner does not understand how a few missing dimensions can delay his project and cost him money. The architect and general contractor understand the problem but the suppliers who need to provide the information are not on board and neither will commit to a guess. Maybe the contract is let but the supplier may not be able to provide the information because the project is way down in his schedule and his shop drawings are not yet completed or even started.

Field Installation: However, if the edge-form is field installed, the dimensional information will be quickly determined and provided so that floors can be poured and other contractors are not held up. If this scenario has even the slightest resemblance to reality, plan for it and consider field installation of the edge-form. Why? Consider the following.

For the detailer, depending on the fabricators requirements, the drawings are more complex. If the fabricator has a beam line or just likes to punch holes and uses double angle connections, none of the beams require sections to show the detailing of shear plates. The only need for sections for a beam might be for the edge-form. Yes, you can use computer drafting or “sticky backs”, but it is more time, however small, and it does have to be detailed and checked and don’t’ cut the section backwards! You can use left and rights or “opposite hand” unless the fabricator doesn’t like it and it is not part of his standards. So look for more checking and additional printing. Also, look out for copes at columns, additional fill-in pieces at the backs of columns or beams with full penetration flange welds and pieces in the middle of the beam for floor openings due to stairs, mechanical openings and elevator shafts. All of the above goes away if the metal deck supplier provides the edge-form. And when the fabricator does provide the edge form, which the detailer has already detailed, sections are cut to indicate the welding and dimensions are provided to indicate the location of the edge-form from the grid line or centerline of a beam, dimensions normally provided anyway!

Fabrication Concerns: For the fabricator, if the bent plate is shop attached what needs to occur? You can have the detailer coordinate the dimensions with the designers or your staff can do the legwork. In either case, it is time that can be better-spent producing drawings and other necessary documents that are required for the shop to produce beams and columns. The material control and purchasing departments want all the bent plate information at one time so that it can be bought at one time to minimize their effort. Piece-meal information on bent plate means numerous purchase orders, requisition, etc., all of which takes staff time.

In the shop, receiving will want to receive the edge-form as required for production. For some shops with plenty of space, this may be all at once. For other shops with little storage, it may mean delivery in a specific sequence.

In either case it will need to be distributed for production. Receiving, sorting and distribution simply put means handling. And the largest waste in a shop is-----handling! Minimize handling and minimize costs!

How is the edge-form attached? Bolted or welded layout operations are required. Some shops inspect the layout before fit-up. Others inspect the fit-up. In any event, each is an operation that takes time. How much time? Our poll provided no real answer. There is considerable variation from shop to shop. You be the judge, but for sure it is time. We know that to weld the edge-form to the toe of the beam flange and the toe of the edge-form to the beam, the beam must be rolled at least once, maybe twice. Handling time that provides no value!

When shop attached, the edge-form must be welded to the toe of the beam and the toe of the horizontal leg of the edge-form. This occurs because during shop handling, shipping, etc., the welds to the beam toe keep the edge-form in place. The welds to the toe of the horizontal leg of the edge-form serve the same purpose during handling and perform the additional function of a structural weld for the slab and facia. As a field attached product, the weld to the beam flange toe can be eliminated.

When completed in the shop, the assembly must be removed from the skids and stored. Is it easy to handle with the edge-form attached? Does it nest well with other members? When hoisted does the edge-form get bent from the chokers or chains? Does it take more time to load on a truck for shipment? Does it cause loads to shift as the load bounces down the road requiring the trucker to stop and retighten the chains? Do small pieces fall off as the chains slacken and the trucker does not catch the problem? The answer to all of the above at some point in time is yes. All of the above adds to cost without a derived benefit.

In addition to the above, has your shop ever installed edge-form on the wrong side of the beam? Missed copes? Welded the edge-form out too far or in too close? How happy is your erector about this situation? There goes more time for your PM (Project Manager), more opportunities for back-charge confrontations with the erector, shop and/or detailer.

For the erector, having received a trailer with beams that have bent plate shop attached, does is take more time to off load? Have you ever received a trailer where the load has shifted and when the binders are released the beams unload themselves! Is your shake out time increased for the beams with bent plate? When you choke the beam to erect it, does it go up straight or lay over at some angle making the job for the connectors more difficult?

We know the bent plate is never on the wrong side, always straight and true and never missing a cope. But if it had one of the problems noted above, what is the true cost to you? With a five man raising gang and a crane, figuring the crane cost equal to the cost of the five men, considering 5 minutes to raise the beam find the problem, lower the beam, temporarily solve the problem and finally erect the beam in place, what is the cost? Does 50 man-minutes or .84 m-hrs sound reasonable? The temporary fix still needs a permanent fix! What is the real cost? Do you ever recover the true cost?

Finally, like it or not, the erector fields all the concerns of the general contractor/construction manager once erection begins. Do you really need to be in conversations about the alignment of bent plate that is shop attached? Did your bid price really include fixing and handling kinks in the bent plate? As a detailer, fabricator or erector, if none of the above applies to you, the above is a nice bit of fiction. If any of the above has a hint of reality, read on.

Most engineers require as much shop assembly of the steel product as possible. This is based on the principal of better quality control is available in the shop at less of a cost. In general, this is valid. However, there are exceptions. The straightness of shop attached bent plate is at the mercy of column plumbness, at least. Unless specified otherwise a plumbness of 1/500 with a maximum of 2 inches out from and 3 inches in towards the building line creates considerable variations vertically and horizontally up the side of a building.

For a three-story building with a column height of 40 feet, the tolerance is approximately 1-inch +/-. With columns at forty feet center to center, for three columns in a row the column can be +1, 0 and –1 or a total of 2 inches in 80 feet as an example. Other combinations are available and do occur! However, is this what you expected? Does it matter?

Some engineers show the bent plate shop attached on their drawings but are indifferent as to shop or field installation. Other engineers insist on shop attachment if that is what is shown on the designs. All parties, fabricators, erectors, detailers, inspectors, etc., can only bid, produce and inspect to the information provided on the plans. If you are an engineer who allows flexibility on installation, make a note to that affect on the plans. Bidders can now price the product in a manner that best suits their capabilities.

The idea of attaching all bent plate in the field is currently practiced by numerous fabricators.

CLOSING:

It is recognized that the manner that a product is produced can vary from manufacturer to manufacturer. It can vary by the needs of the consumer and the design considerations. There is no absolute right or wrong end product. There are definite values from uniformity, consistency and creativity.

A fabricator/erector applied some considerations noted in this document to a large project and determined that the dollar savings on paper was minimal, but there was a savings. However, through creativity, 75 tons of material was eliminated through the use of a new perimeter structural member supported by outriggers from the columns in lieu of outriggers and bent plate supported by the beam shown in the original bid documents. On a square foot basis this amounted to .2 lb/sq. ft., nothing that would catch anyone's attention but significant nevertheless.

Recent national engineering documents are pressing for the elimination of welding or any type of connections in the area of the plastic hinge zone of steel moment beams. Edge form and steel deck still needs to be attached to the building. The building designer must include this concern in his product when steel moment frames occur at the building perimeter or adjacent to other floor openings. Suggestions presented in this document may assist and encourage possible solutions, such as cantilever elements from the moment frame column.

ENGINEER GUIDELINES

These guidelines have been developed to assist the engineer and help facilitate conformity in the design of edge form/bent plate. The following are the typical floor systems used in commercial buildings of Type I construction. The terms metal deck and steel deck are used interchangeably in this document. All metal deck is assumed to be steel deck in this guideline.

Metal Deck Selection:

Typical floor and roof design usually consists of a concrete fill over the steel deck. The thickness of the concrete topping is usually dependant upon the required fire rating for the floor system, the most common being a two-hour rated floor or roof assembly. The following are some practical rules of thumb:

Floors and Roofs:

- 3" x 20 gage decks are the typically the most economical for multiple 10-foot spans.
- 3" x 18 gage may be required at single 10-foot span conditions.
- 22 gage may be damaged easily during construction, therefore, consider using the following floor assemblies:

- 2" x 20 gage w/ 3 ¼" lt. weight concrete fill over top of decking
- 3" x 20 gage w/ 3 ¼" lt. weight concrete fill over top of decking
- 2" x 20 gage w/ 2 ½" normal weight concrete fill* over top of decking
- 3" x 20 gage w/ 2 ½" normal weight concrete fill* over top of decking

*Note: Must spray deck with fireproofing to achieve 2-hour fire rating

Roof Decks without Concrete Fill

In large warehouse buildings, department store buildings and other low-rise buildings it is common to use just a bare metal deck with no structural concrete fill. This is often done as a cost saving to the project. There are proprietary composite roof systems that provide good diaphragm shear values and insulation. The trend in recent years though has been to design the roof metal deck system independent of the insulating concrete fill, which allows more independent insulating concrete manufactures to competitively bid the project instead of being tied into a proprietary composite roof system.

The recommendations for appropriate roof decking are as follows:

- 1-1/2" x 20 gage (B deck)
- 3" x 20 gage (N deck)

Since the roof deck is now non-composite, more care is required in selecting appropriate design criteria for the metal deck system to support construction and permanent gravity loads. The design criteria should include construction loads and future maintenance personal working on the roof years after the building is completed. An area of particular concern is cantilevered deck.

Cantilever Deck Design Criteria:

- Use 250# point load at end of cantilever/overhang plus the weight of wet concrete (where exists)
- Limit deflection for metal deck to L/180 or ½" maximum. (If you calculate the maximum cantilever length based on stress, the workers may be at risk.)
- See Figure 3 for examples of metal deck cantilever spans and deflections

General Design Issues:

- Vented decks should be used where lightweight concrete fills are placed (due to problems with water based glues), in areas subjected to moisture (exposed to weather), and at parking areas.
- If the steel contractor shop installs edge angles/bent plates, they may not be straight enough (due to mill standards of beams). The concrete contractor should not set their screed on the top of the bent plate/angle. It should be set off the top of the beam(s). Use 10 gage "black iron" (not galvanized) bent plate rather than 12 gage galvanized bent plate. When necessary, #4 bar can be welded to 10 gage and thicker. The black iron is more weldable and there are also less toxic fumes since not working with galvanized material.

Relative Deck Costs (in 2001):

- 20 vs. 22 gage $0.08/sf more; 18 vs. 20 gage $0.20/sf more; 16 vs.18 gage $0.25 to $0.30/sf more (main difference in costs is due to weight of materials – handling in manufacturing plants and in the field)
- Vented decks vs. normal decks $0.01/sf more.
- 10 gage "black iron" bent plate costs about 15 percent more than 12 gage galvanized bent plate (see above for advantages)

BUILDING PERIMETER

Metal Deck Direction:

The direction of the metal deck span impacts the design of the edge-form/bent plate closure and structural support at the perimeter of the building and around floor/roof openings.

1. METAL DECK PERPENDICULAR TO SUPPORT:

The design of the metal deck perpendicular to the support varies depending whether you have concrete topping over the metal deck. When the metal deck is perpendicular to the support there is a tendency to cantilever the metal deck beyond the edge of the steel beam. Deflection of the bare metal deck needs to be considered during construction or if the design involves hanging or supporting the curtain wall at the cantilever tip of the metal deck. The following are recommendations to consider.

A. FLOOR / ROOF DECK WITH CONCRETE FILL

Deck perpendicular to support (slab edge perpendicular to deck)

- **Overhang < 10" – use 10 – 20 gage single closure attached to steel beam flange**

  Issues:
  - Stop metal deck at edge beam; provide gage closure as required for cantilever span, but not less than 20 gage. Typical gages for various spans and concrete fill thickness provided by deck manufacturers in their catalogs.
  - If hanging steel studs or other building skin from edge of slab, closure gage needs to be further investigated, probably not less than 1/4" bent plate. May require rebar welded to vertical leg of bent plate.
  - If unclear at time of floor design as to method of building skin being attachment, may be beneficial to use heavier bent plate as oppose to light gauge material to allow for possibility of welding.
  - Construction cost differences between gage closures. Example, for 7" girth with two breaks, increase coast $0.15/lineal foot from 20 gage to 18 gage, $0.15/foot from 18 ga. to 16 ga., $0.15/foot from 16 ga to 14 ga.

- **Overhang between 10" to 1'-4" -- Cantilever metal deck using standard end closure plates (Preferred, see below) or 12 gage single piece closure**

  Issues:
  - Gage – 22 gage end closure for 1-1/2" metal deck and 20 gage end closure for 2 and 3 inch deck. 18-gage edge form above deck typically used (two part system). Use of two pieces of edge form is the most economical as opposed to using a single piece. The lower piece closes off the ends of the metal deck flutes, while the upper piece is adjustable in height to accommodate the required thickness of the concrete topping.
  - Fastening – are "tack welds" burnt through bent plate and overhanging deck OK?
  - Height – use concrete fill height with return bend at top of gage end closure (end form) -- may depend on Contractor preference for finishing concrete, floor flatness requirements, etc.
  - Typically no special rebar required in concrete topping for cantilever condition (May require rebar if have heavy building skin; thin shell panels, precast panels, etc.).
  - Deflection may be a problem depending upon length of cantilever, metal deck height (1-1/2" deck, 2" deck, 3" deck), gauge and amount of concrete topping.

- **Overhang between 1'-4" to 2'-0" – use standard closures (see above)**

  Issues:
  - Gage and height – see above
  - Special rebar required for cantilever in concrete for negative moment over top of steel beam.
  - Temporary shoring of metal deck cantilever may be required to prevent permanent deflection at end of cantilever due to weight of wet concrete.
  - Consider the use of an additional structural member, supported at ends by outriggers from the columns, to eliminate the cantilever of the metal deck (Preferred).

- **Cantilever greater that 2'-0" – use standard closures (see above)**

  Issues:
  - Metal deck standard closure gage and height – see above
  - Consider the use of an additional perimeter structural member, supported at ends by outriggers from the columns to eliminate the cantilever of the metal deck.
    - Eliminates need for "Temporary Shoring" of metal deck
    - Metal Deck spans to perimeter structural member, cantilever minimized, if any, over new perimeter structural member.
  - Possible to use cantilever HSS sections (3x3, 4x3 etc.) over steel beam and under metal deck to support cantilever metal deck. Expensive depending upon length of HSS back span to next interior beam. Still require edge member between outriggers.

B. ROOF DECK WITH NO CONCRETE FILL

Deck perpendicular to support:

The gauge of the edge form depends upon whether you are making structural attachments such as the building skin to the edge form. Light gauge bent plate should only be used when ***no*** attachments are made to the bent plate. Use 1/4" bent plate for attaching stud curtain wall to the roof. Parapet sitting on top of the metal deck requires special investigation if using light gauge material.

- **Overhang = 10" max – use gage bent plate (10 – 14 gage minimum, depending upon cantilever length)**

  Issues:
  - Gage bent plate – based on length of cantilever and loading
  - Height – depends on thickness of roof insulation
  - Could cantilever metal deck and provide end closure.

- **Overhang between 10" to 3'-0" – metal deck may be able to cantilever**

  Issues:
  - Maximum length of cantilever is based on loading, depth and gage of metal deck.
  - Deflection of bare cantilever metal deck must be considered for safety purposes; metal deck may have the bending strength (fb), but not the required stiffness, making it easy for someone to slide off the end of the cantilever deck as it deflects under the individual's weight.
  - End closure height – depends on thickness of roof insulation
  - Add channel or angle at end of long cantilevers to help distribute point loads, may consider outrigger from beams out to edge angle to help reduce deck deflection and diving board affect.
  - May be able to provide tube steel (HSS sections) under metal deck. Length of cantilever tube steel back span under metal deck to next interior beam may be large (example: 10 foot back span for less than 36" cantilever)

- Depending on architectural considerations, provide cantilever support from the columns and add a structural member spanning between the cantilevers to support the deck

- **Overhang greater that 3 feet – steel framing is required**

  Issues:
  - Use cantilevered steel beams from the columns or outriggers (with moment connections) and an additional perimeter structural member spanning between these outriggers. (The use of diagonally braced outriggers should be looked at very critically for all the reasons noted previously; cost and labor to install.)

  Cantilevered steel beam issues:
  - Cantilever beam connections to columns, possibly fewer connections than if used outriggers from the steel beams
  - Where seismic moment beams occur, will eliminate the concern of welding in the area of the plastic hinge since now have new perimeter structural element to support metal deck.
  - Will eliminate the notching of bent plate and support of bent plate around the column
  - Cantilever beam minimally offsets eccentric moments at the columns induced by the floor beams on the opposite column face
  - Consider not specifying full penetration welds of the flanges of the cantilever beam. Cantilever member flanges are usually thin enough to allow fillet welding to develop the flange to the column
  - Since the span between the cantilevered beam and the perimeter beam is usually small, consider a 3 x 3 or 4x4 angle welded to the top flanges of the beams at the appropriate spacing to support the metal deck. This would be similar to the angle detail used at the columns to support the metal deck when it is cut around the column.

  Braced outrigger issues:
  - Installation of diagonal brace to steel beam web/flange and the possibility of kickers on the opposite side " *is expensive*".

2. METAL DECK PARALLEL TO SUPPORT:

A. FLOOR / ROOF DECK WITH CONCRETE FILL

1. Deck parallel to support (slab edge parallel to deck)

- **Overhang = 10" max – use bent plate**

  Issues:
  - Gage (of bent plate) – based on length of overhang and loading
  - Height (of bent plate) – may depend on Contractor preference for finishing concrete, floor flatness requirements, etc. (Note, because of tolerances in the fabrication and erection of structural steel, the practice of using the edge form to determine the finish floor elevation is discouraged.)
  - May require rebar attached to bent plate depending upon building skin attachment to floor edge

- **Overhang between 10" to 2'-0" – use either horizontal outriggers from beam or cantilever supports from the columns and add a perimeter structural member (Preferred)**

  Bent plate issues:
  - Gage and height – see above
  - Can use gage material as either a continuous cantilever element with outriggers for support or use gage material as a perimeter structural member at end of outriggers for edge support of metal deck spanning between outriggers.

- Gage depends upon length of span between outriggers. Bent plate used as a perimeter structural member should have a horizontal leg of about 3”-4” for edge support of metal deck spanning between outriggers.

Potential Advantages:
- Architectural appearance (thin only if used with horizontal outriggers contained within the slab or a nominal dimension below the slab). (See comments below on disadvantages)

Potential Disadvantages:
- Additional rebar required in concrete slab for bending over top of beam, depends upon spacing of outriggers and bent plate gage.
- Limited cantilever span of bent plate with outriggers welded on top of bent plate as opposed to outrigger under bent plate and attached to steel beam flange and web.

<u>Parallel Beam outrigger issues:</u>
- Spacing of outriggers based on deck gage, length of overhang and loading (recommend 5’ O.C. maximum)
- Outriggers, usually angles, can be placed on top of bent plate under metal deck, or under the bent plate and attached to steel beam. When under bent plate can also use channels for outriggers.

Potential Advantages angles:
- Schedule (shoring not required) to support metal deck.
- Allows for thin eyebrow appearance required by architectural design.
- Helps reduce the diving board spring effect by stiffening the cantilever metal deck/edge form.
- Costs probably greater than adding an additional perimeter beam supported by cantilevers from columns

Potential Disadvantages angles:
- Must bend deck down or trim horizontal leg of angle outrigger if flush with top of beam flange
- Limited outrigger cantilever span when attached on top of bent plate
- Depth of outrigger may not work architecturally.

- **Overhang greater that 2’-0” – steel framing is required**

- Use cantilevered steel beams from columns (with moment connections) to support an additional perimeter structural member. Provide infill beams (angles) between additional perimeter structural member and girder on gridline to support metal deck.
- Use either standard closure plates with edge beam or angle spanning between outriggers

<u>Cantilevered steel beam issues:</u>
- Similar to metal deck perpendicular to steel beam
- Cost for Cantilever Moment Frame beam Connection

<u>Braced outrigger issues:</u>
- Similar to metal deck perpendicular to steel beam
- Not recommend due to cost and reliability of temporary installation methods

B. Roof Deck without concrete fill

Deck parallel to support:

- **Overhang = 10” max – use gage bent plate (10 – 14 gage minimum, depending upon cantilever length)**

  Issues:
  - Gage – based on length of cantilever and loading, including building skin attachment
  - Height – depends on thickness of roof insulation?

- **Overhang between 10” to 2’- 0” – use bent plate perimeter structural member with horizontal outriggers from beam**

  Issues:
  - Spacing of outriggers based on deck gage, length of overhang and loading
  - Bent plate height – depends on thickness of roof insulation
  - Consider use of cantilever steel beams from columns with moment connection and an additional perimeter structural member (provide infill angles between perimeter member and steel beam to support metal deck). Preferred.

- **Overhang greater that 2 feet – steel framing is required**

  Issues:
  - Use either cantilevered steel beams from columns (preferred) or outriggers from beams with moment connections.
  - Use either standard closure plates with edge beam or angle spanning between outriggers

  Cantilevered steel beam issues:
  - Similar to metal deck perpendicular to beam

  Braced outrigger issues:
  - Similar to metal deck perpendicular to beam
  - Want to eliminate diagonally braced outriggers if possible (unless architecturally acceptable and structurally detailed)

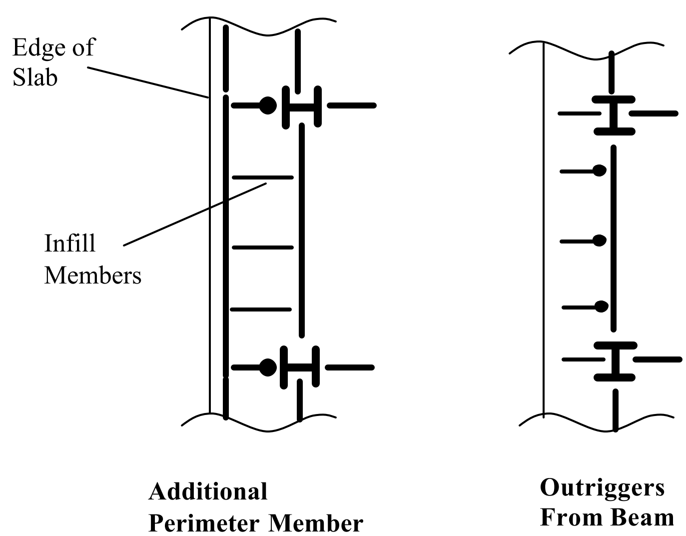


Figure A: Building Perimeter Edge Conditions (Plan View)

SPECIAL CONDITIONS

There can be many special conditions that occur along the building perimeter depending upon both the architectural features and various types of exterior cladding used and are to vast to cover all in one publication. The use of precast concrete panels, curtain walls with mullion systems and their attachment to the building are examples of such special cases. These can be proprietary systems, and it is recommended that the manufactures be contacted to determine the appropriate type of connections to use.

Edge of Metal Deck with Concrete Fill

1. Metal stud curtain wall conditions to consider:
   - Is wall on top of slab
   - Is wall running past slab edge (wall supported from floor below or hung from edge of slab)
   - What are acceptable tolerances for placement/attachment of curtain wall

2. Curved Conditions

   The width of the bent plate closure will vary along the length of the steel beam support. When installing the edge form, keep the height of the vertical leg the same as the floor thickness. Additional temporary forming can be added above to make the curb. Where required add deformed bars shot directly through the metal deck and edge form to provide the vertical reinforcing for the concrete curbs. The horizontal leg of the edge form will usually be cut and the vertical leg then bent to form the required curved shape. Edge form when cut should not be used as structural support for curtain wall attachment; use of bent plate should be used for structural support/attachment of curtain wall.

Edge of Metal Deck without Concrete Fill

1. Metal stud curtain wall conditions to consider:
   - Is wall sitting on top of metal deck (Is web crippling of metal deck a problem?)
   - Is wall running past deck edge (supported from below or to be hung from edge of metal deck)
   - What are acceptable tolerances for placement/attachment of curtain wall to metal deck
2. Curved Conditions, similar to when have concrete fill.
3. How are curbs to be attached, is a steel beam or structural member required directly under the curb.

Interior Openings

A. Stairs

The stairs are generally installed as soon as possible, prior to any concrete placement over metal deck, since the stairs can provide the mandatory egress routes for the construction workers as required by OSHA. In some cases, such as tenant improvements, the concrete fill may be placed prior to the installation of the stair, which usually requires block outs in the floor for the attachment of the stairs to the steel framing.

The problem is during the building design phase the actual opening size and location is often not readily known to put hard dimensions on the framing plans. Architectural and fire rating issues are involved in sizing the floor opening and include the following:

1. What is the width of the stair stringer flanges? Typically either steel plate or channels are used for the stair stringers. Often it will be overlooked as to the flange width of the stringers that can be 1-1/2” to 3” in width for each channel stringer as opposed to plate stringers, which only may be 1/2” thick or less. The stringer flange width can add several inches to the required width of the stair opening,

especially when you consider two flights of stairs (four stair stringers) and intermediate landings between floors.

2. A one hour rated stair shaft enclosure requires two layers of ½” gypboard on each face of the stud wall. This requires that at least 2 layers of the gypboard extend up past each edge of the stair floor opening where the stair stringers do not connect to the floor. Typically this adds another two inches to the required minimum width of the stair opening in the floor.

To allow for the uncertainty in stair opening dimensions, it is recommended that the toe of the steel beam be held back from the edge of the opening eight inches to allow for the fireproofing and steel stud to pass by the steel beam and attach directly to the under side of the edge form. Eight inches clear of the opening edge should allow enough room to still squeeze in the steel studs in case there have been some oversights as to the required opening dimensions. Using eight inches clear will require the centerline of the steel beam to be at least 10 inches from the opening edge for a W12x beam and further for larger beams.

If the steel beam supporting the stair stringer is set back to far from the edge of the opening, this can be resolved by putting a horizontal dogleg in the stair stringer so that it extends to the supporting steel beam. A full height stiffener plate is recommended at the steel beam where the stair stringer intersects.

It is strongly recommended that the opening edge form be field installed instead of installed in the shop. This allows for more flexibility to adjust the opening dimensions, especially since the required opening dimensions may not be known at the shop drawing stage or delay the shop drawing process.

Installation procedures / construction sequencing can be an issue. Example: Attach stairs to steel framing prior to placing concrete fill.

B. Mechanical

Mechanical typically can be divided into two categories; duct penetrations and pipe penetrations. Mechanical duct opening in the floors are no different than for any stair opening and generally will require only edge form for the closure.

Often the opening for pipes may be the same as for a duct if the pipes are all bundled together. Where pipes are spread out, at the various pipe penetration locations it is recommended that reinforcing methods be per the deck manufacturers requirements. Recommendations for reinforcing the deck are also provided by the Steel Deck Institute (SDI) and specify minimum distances between openings. The reinforcement needs to be sufficiently wide enough to reinforce the deck beyond the pipe hole diameter. Individual pipe holes are preferred instead of bundling a series of pipes through a single opening since it allows for the pipe riser clamps to sit directly on the floor. Holes can be cored after pouring concrete.

Roof top equipment often requires some form of continuous curb support for the piece of mechanical equipment around the opening as is common with HVAC package units. Framing members should be placed under the curbs while angles can be used to support the metal deck around the actual penetration.

C. Elevator Floor Opening

This is a commonly overlooked floor penetration. The same guidelines apply as are used for stair openings. The one additional requirement is the addition of a floor angle at the elevator door opening to support the elevator door. The elevator door shelf angle is attached to the floor edge form which in this case should be a 1/4 “ bent plate and not a lighter gauge material. The 1/4 “ bent plate should run the length of the door opening and have deformed rebars attached to the vertical leg to help prevent the vertical leg from prying away from the concrete floor fill.

D. Skylights

The edge form installation used around a skylight opening is usually no different than for any other roof opening in the metal deck. The engineer is cautioned though that there may be special cases based upon the type of skylight used that will require a specific framing system and should be verified with the skylight manufacturer.

If there is concrete fill over the metal deck, usually the skylight will have its own curb support system above the slab. Therefore the metal deck closure need not be more than just light gauge edge form if the steel beam is located near the edge of the opening. If the opening is less than 24” x 24” than steel angles can usually be used to support the metal deck in lieu of adding additional steel beams. A simple light gauge closure can be added to the top of the angle to close of the edge of the metal deck.

If there is no concrete fill over the metal deck, than the framing becomes more critical. Often to speed up the construction installation, the openings are cut in the deck after all the metal deck has been placed as this eliminates the need to provide construction guard rails around the opening until the openings have been made.

Cantilever Metal Deck Deflection:

The purpose of the metal deck deflection table is to illustrate the impact of various design decisions or assumptions on the calculated allowable cantilever length. These are not intended as specific recommendations. The various assumptions illustrated are described briefly in the footnotes of the chart. These comparisons are based on Verco Formlok metal deck section properties. Dead load is based on the weight of the concrete fill, the deck and either 3 or 4 psf deflection allowance (for LW and NW respectively). Live loads are as described in the table. The metal deck back span length is assumed to be 3x Cantilever length.

Metal Deck Deflection; Comparison of Cantilever Design Criteria

3 ¼" LW (110 pcf) CONCRETE OVER DECK

		1	2	3	4	5	6
		MAXIMUM CANTILEVER (feet)					DEFLECTION
	LOADING:	(Uniform Dead Load- Cantilever only)			(250#)	(DL + 150#)	(DL + 200#)
	CRITERIA:	L/180	L/120	? = 1/4"	? = 1/2 "	f_b	
PROFILE	GAGE						(inches)
B-FORMLOK	20	2.14	2.45	2.46	1.77	2.38	1.20 in
	18	2.38	2.73	2.67	1.98	3.01	1.82 in
	16	2.55	2.92	2.81	2.13	3.55	2.49 in
	20	2.60	2.97	2.85	2.21	3.19	1.60 in
W2-FORMLOK	19	2.75	3.15	2.97	2.35	3.71	2.17 in
	18	2.83	3.24	3.03	2.42	4.04	2.64 in
	16	3.03	3.47	3.20	2.61	4.72	3.56 in
	20	3.22	3.69	3.35	2.84	4.23	1.96 in
	19	3.41	3.91	3.50	3.02	4.83	2.55 in
W2-FORMLOK	18	3.54	4.05	3.59	3.14	5.22	2.97 in
	16	3.80	4.35	3.79	3.38	6.05	3.92 in

2 ½" NW (145 pcf) CONCRETE OVER DECK

		1	2	3	4	5	6
		MAXIMUM CANTILEVER (feet)					DEFLECTION
	LOADING:	(Uniform Dead Load- Cantilever only)			(250#)	(DL + 150#)	(DL + 200#)
	CRITERIA:	L/180	L/120	? = 1/4"	? = 1/2 "	f_b	
PROFILE	GAGE						(inches)
B-FORMLOK	20	2.09	2.40	2.42	1.77	2.35	1.16 in
	18	2.33	2.67	2.62	1.98	2.97	1.76 in
	16	2.50	2.86	2.76	2.13	3.45	2.40 in
	20	2.52	2.88	2.78	2.21	3.12	1.52 in
W2-FORMLOK	19	2.67	3.05	2.91	2.35	3.62	2.05 in
	18	2.74	3.14	2.97	2.42	3.94	2.50 in
	16	2.94	3.37	3.13	2.61	4.60	3.36 in
	20	3.10	3.55	3.23	2.84	4.09	1.82 in
	19	3.29	3.77	3.40	3.02	4.66	2.36 in
W2-FORMLOK	18	3.41	3.91	3.49	3.14	5.04	2.75 in
	16	3.67	4.20	3.69	3.38	5.83	3.62 in

<u>COLUMN</u>

1. Uniform dead load only, cantilever only loaded, deflection at end of cantilever limited to cantilever/180.
2. Uniform dead load only, cantilever only loaded, deflection at end of cantilever limited to cantilever/120.
3. Uniform dead load only, cantilever only loaded, deflection at end of cantilever limited to 1/4 inch.
4. 250 # point load at end of cantilever, deflection at end of cantilever limited to 2 inch.
5. Uniform dead load on cantilever only, 150 # point load at the end of cantilever, stress limited to 22, 800 psi (0.6F_y), with no stress increase.
6. Actual deflection due uniform dead load on cantilever only plus 200# point load at end of cantilever, based on the cantilever length calculated due to stress (Column 5).

Typical Edge Form Calculations Based Upon Typical Span And Gauge

The following tables provide general information about edge form thickness based upon the common cantilever spans. The definition of “Un-reinforced Edge Form” is a simple piece of bent gauge plate or steel plate that forms the edge form for the floor slab. The definition of “Reinforced Edge Form” is the same as for the “Un-reinforced Edge Form” except additional angles at a given spacing are welded to the bent plate to stiffen the bent plate. At the end are two design examples using the reinforced and un-reinforced edge angle.

<u>UNREINFORCED EDGE FORM (TABLE #1):</u>

See Figures 1 and 2 that go along with this table

Plate	Plate	Cantilever	Slab	Conc.	Dead Load			Live	Total	Moment	Ixx	Sxx	Deflection	Bending	Lap	Weld Information				
Size	Thickness		Thickness	Weight	Concrete	Plate	Total	Load	Load	Max.				Stress		Size	Load	Length	Capacity	Load
	(in.)	(in)	(in.)	(pcf)	(psf)	(psf)	(psf)	(psf)	(psf)	(in-lb.)	(in.^4/ft.)	(in.^3/ft.)	(in.)	(psi)	(in.)	(1/16ths)	(per 1/16th)	(in.)	(lb.)	(lb.)
14ga	0.0747	7	6.25	120	62.5	3.1	65.6	20	85.55	175	0.0004	0.011	0.18	15651	2	1	87.3	2	1820	175
12ga	0.1046	10	6.25	120	62.5	4.3	66.8	20	86.77	362	0.00114	0.022	0.27	16522	2	1	180.8	2	1820	362
10ga	0.1345	12	6.25	120	62.5	5.5	68.0	20	87.99	528	0.00243	0.036	0.27	14592	2	2	132.0	2	3640	528
8ga	0.1644	14	6.25	120	62.5	6.7	69.2	20	89.21	729	0.00444	0.054	0.28	13478	2	2	182.1	2	3640	729
6ga	0.1943	16	6.25	120	62.5	7.9	70.4	20	90.43	965	0.00734	0.076	0.29	12776	2	3	160.8	2	5460	965
4ga	0.2242	17	6.25	120	62.5	9.2	71.7	20	91.65	1104	0.01127	0.101	0.24	10978	2	3	183.9	2	5460	1104
1/4in	0.25	19	6.25	120	62.5	10.2	72.7	20	92.71	1394	0.01563	0.125	0.28	11156	2	3	232.4	2	5460	1394

Notes:

1. If 10 ft or less lengths of plate are used, edges can be wrapped with no weld on the underside
2. No weld required except as a seal.
3. No weld required except to seal or tack for alignment
4. Weld spacing is approximate and can vary +/- 6 inches.
5. If seal is required, duct taping, caulking, or some other means can be used to make it.
6. Weld required if bent plate is shop welded. Required for shipping and handling.

Parameters:

A. Maximum allowable deflection at the end of the edge form = 1/4"
B. All calculations are based upon a width of 12 inches.
C. Concrete weight is based upon 120 pcf
D. Construction Live Load is considered at 20 psf (will be equivalent to 80 psf without concrete)
E. Moment max = $WL^2/2$
F. Deflection = $WL^4/8EI$

REINFORCED EDGE FORM (TABLE #2):

See Figures 3 and 4 for this table.

Plate Size	Plate thick.	Cantil.	Slab Thick.	Conc. Wt.	Dead Load Conc.	Dead Load Plate	Dead Load Total	Live Load	Total Load	Moment Max.– Plate	Ixx Plate	Sxx Plate	Deflec. Plate	Mcr	Moment Max Angle	Ixx Angle	Sxxtop Angle	Deflec. Angle	fb Angle	Lap	Weld Information Size	Weld Information Load	Weld Information Length	Weld Information Capacity
	(in.)	(in)	(in.)	(pcf)	(psf)	(psf)	(psf)	(psf)	(psf)	(in-lbs.)	(in.^4/ft.)	(in.^3/ft.)	(in.)	(in-lbs.)	(in-lb.)	(in.^4/ft.)	(in.^3/ft.)	(in.)	(psi)	(in.)	(1/16ths)	(pli)	(in.)	(lb.)
14ga	0.0747	5	6.25	120	62.5	3.1	65.6	20	85.6	668	1.520	0.486	0.01	838	446	0.962	0.4364	0	1021	2	3	191.2	3	8190
12ga	0.1046	16	6.25	120	62.5	4.3	66.8	20	86.8	2169	2.128	0.681	0.01	2297	4628	0.962	0.4364	0	10604	2	3	1986.2	3	8190
10ga	0.1345	22	6.25	120	62.5	5.5	68.0	20	88	3025	2.7364	0.876	0.01	4877	8873	0.962	0.4364	0	20331	2	3	3808.0	3	8190

Notes:

1. Vertical leg of the bent plate is to carry the load on the end of the plate between the angles.
2. Angles with longer horizontal legs will allow for greater spacing between angles.
3. Weld size of weld between the angle and beam has allowed for AWS fit-up tolerances of increasing the weld size 1/16” for each 1/16” gap over 1/16”. the Ie effective weld size is 1/8-inch weld.

Parameters:

A. Maximum allowable deflection at the end of the edge form = 1/4 inch.
B. All calculations are based on a width of 12 inches
C. Concrete weight is based upon 120 pcf
D. Construction Live Load is considered at 20 psf (will be equivalent to 80 psf without concrete)

Formulas:

A. Moment max = $WL^2/8$ for vertical leg of plate where L = span between the angle outriggers
B. Moment max = PL for the angle outrigger where L = the cantilever and P = WL/2
C. Deflection for the bent plate between the outriggers = $5WL^4/384EI$
D. Deflection of the angle outrigger = $PL^3/3EI$
E. Sw = $(2bd+d^2)/3$ where d = 1 inch and b = the angle leg width (Sw = 2.33)
F. Outrigger spacing assumed at 60 inches for this example.
G. Mcr = $2\pi t^3 h (EG(1-0.63(t/h))/(6Lcr))$
H. E = 29000 G = 11800

The plate thickness is limited to 10 gage since for longer cantilever spans the spacing between L3x3x1/4 outriggers must be reduced. Larger outriggers may be possible, but have limited space to weld angle to top of beam flange and may require cutting of metal deck where it conflicts with reinforcement angle.

The reinforcement of the bent plate is shown purely as a numerical exercise and not recommended for practical application due to number of pieces involved and more complexity it adds to the project. Recommendation is to provide outriggers off of column and provide an additional perimeter structural member spanning between the outriggers. Infill members spanning between the perimeter structural member and beam can be provided to support the metal deck. This simplifies the construction of the floor edge.

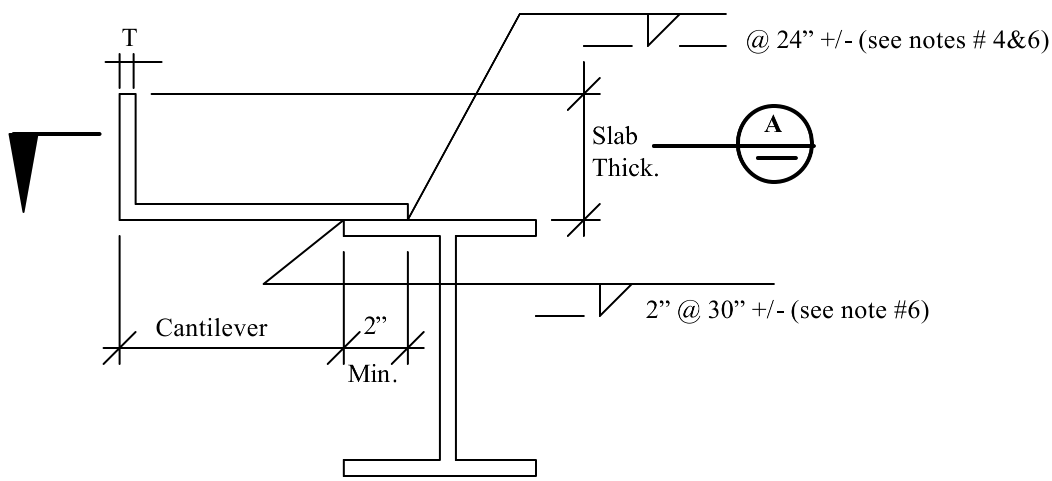


Figure 1: Edge Beam Cross Section (Un-reinforced)

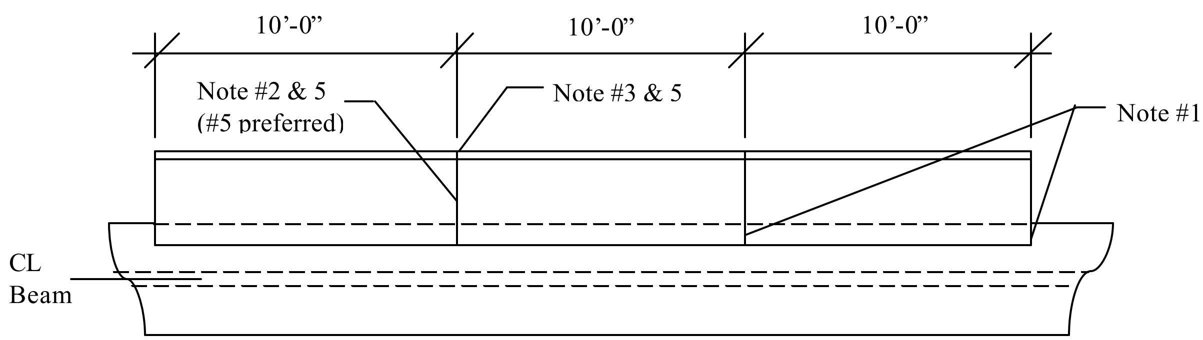


Figure 2: Plan Section A

Note numbers refer to footnotes associated with Un-reinforced Edge Form table #1

Typical Un-reinforced Edge Form Detail

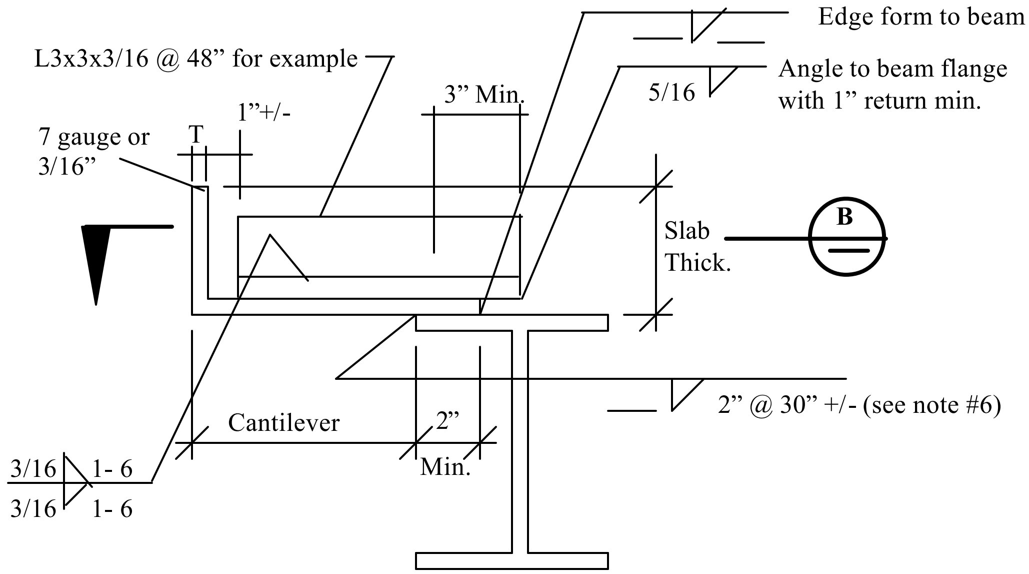


Figure 3: Reinforced Edge Beam Cross Section

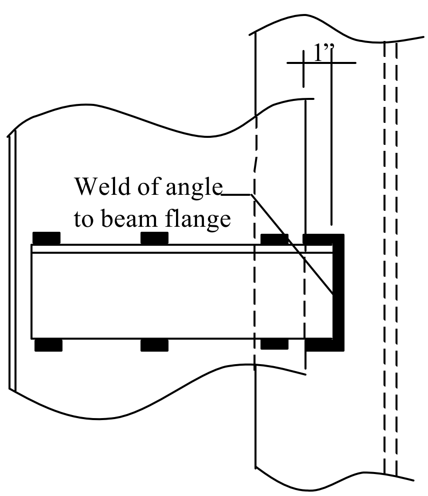


Figure 4: Plan Section B

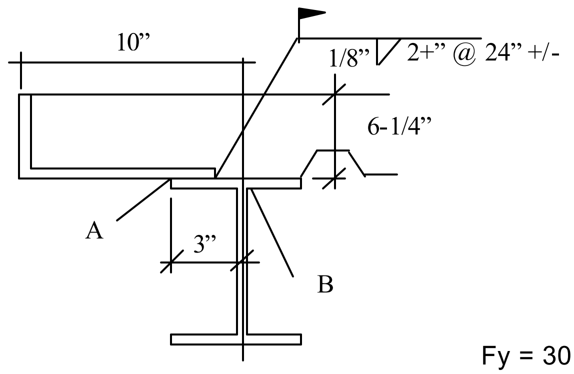
Note numbers refer to footnotes associated with Un-reinforced Edge Form table #2

Typical Reinforced Edge Form Detail

Bent Plate Design Examples:

Example 1:

Design an edge form for the detail shown below.



D.L. = 0.120 kcf
L.L. = 0.020 ksf – Const. L.L.

Fy = 30 ksi
Fb = .75 Fy = 22.5 ksi

Check 1 ft. length of Plate for bending:

DL. = $\underline{0.145\text{kcf } (6.25\text{in})}$ = 0.076ksf   LL = 0.020 ksf   Total Load = 0.096 ksf

$M = Wl^2/2 = 0.008 \text{ klf } (7)^2(1/2) = 0.169$ in-k/ft. of plate

$S_{x\ required} = \dfrac{M}{F_b} = \dfrac{.169 \text{ in.-k}}{22.5 \text{ ksi}} = 0.0075 \text{ in}^3 = \dfrac{bh^2}{6}$ b= 12in   h = 0.0613 in

Try 14 ga. Bent Plate: t = h = 0.0747 in > 0.0613 in

Check deflection:

$I_{xx} = \dfrac{bh^3}{12} = \dfrac{12}{12}(0.0747)^3 = 0.000417 \text{ in}^4$

Deflection = $wl^4/8EI = (0.0083/12 \text{ kli})\,(7)^4/\,8\,(29000)\,(0.000417) = 0.17”$ 0.17 < 3/16 ok

Check weld required: (sum moments about “A” -- $M_A = 0$)

M_A = 0.169 in –k (See above)
Weld tension = 0.169 in-k/ 3in = 0.056 k/12in
Weld size = 0.056 K/ (0.91 K/in/ 16^{th}) ($2/16^{ths}$) = 0.031 in of 1/8 weld Per 12 inch of Plate
1 in > 0.031 in O.K.

Check beam top flange for rotation:

Let beam web = 5/16”

Sum of M_B

$M = wl^2/2 = (0.0083/12 \text{ k/ft.})(10 \text{ in.}/7 \text{ in.})(10 \text{ in.})^2/2 = 0.346”^{K}$

$S_x = \dfrac{bh^2}{6} = \dfrac{12}{6}(5/16)^2 = 0.195\text{in}^3$ $I_{xx} = \dfrac{bh^3}{12} = \dfrac{12}{12}(5/16)^3 = 0.0305 \text{ in}^4$

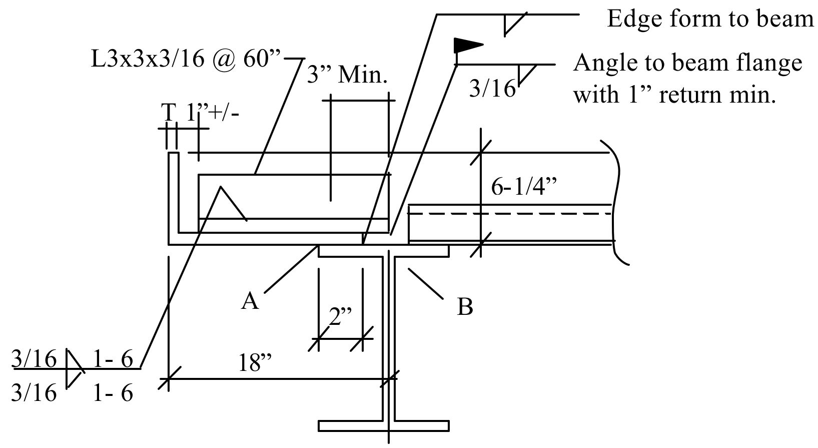
f_b = 0.346/0.195 = 1.77 ksi O.K

Deflection = $wl^4/8EI$ = ((0.01)(10)^4 /8(29000) (0.0305))3/10 = 0.042in. = L /238   say O.K.

Check beam rotation – a function of beam length

Example 2:

Design an edge form for the detail shown below.



D.L. = 0.120 ksf
L.L. = 0.020 ksf = const. L.L.

Fy = 30 ksi for Plate
Fb = 0.75 (30) = 22.5 ksi for Plate
Fy = 36 ksi for Angle
Fb = 0.6 Fy = 21.6 ksi for Angle

E = 29000
G = 11800

Check Plate between angles:

Assume the vertical leg of Plate supports D.L. + L.L. between angles-Ignore the weight of the plate.

D.L. + L.L. = (0.120(6.25/12) + 0.020) (1.25/2) = 0.052 klf
M = $Wl^2/8$ = (0.052(5)^2/8)12 = 1.93 in.-k

Check M_{cr} for bending in the plate:

M_{cr} = {2*Pi*b^3*h(E*G*(1-0.63(b/h)))^.5}/6*L_{cr}

Try 12 ga. Plate   b= 0.1046   Pi = 3.14
                    h= 6.25 L_{cr} = 5 ft. = 60 in.

M_{cr} = 2*3.14*0.1345^3*6.25(29000*11800*(1-0.63(0.1345/6.25)))^.5/(6*60)
M_{cr} = 2.29 in-k
2.29 >1.93   OK

Check 12 gauge Plate:

Span (18 in.-3 in.) = 15 in.   (Check 12 in. wide strip)

$S_x = \frac{bh^2}{6} = \frac{12*(0.1046)^2}{6} = 0.0219 in^3$

$M = \frac{Wl^2}{8} = \frac{(0.140*(15)^2)}{12*8} = 0.328$ in.-k

f_b = M/S = 0.328/0.0219 = 14.98 ksi < 22.5 ksi O.K.

Check L 3 x 3 x 3/16 angle:

Load on end of angle = 0.052 klf x 5 ft. = 0.26 kips
M = PL = 0.26 k x 15 in. = 3.9 in.-k
Sx_{top} = 0.4364 in^3
Sx_{bottom} = 1.2088 in^3
Fb= 3.9/0.4364 = 8.94 ksi O.K.

Check weld: $\frac{0.26 \text{ k} \times 15 \text{ in.}}{3 \text{ in.}} = 1.3 \text{k}$

Weld Capacity = 0.91 kips/16th / in x 3 (16^{ths}) x 3 in. = 8.19^k > 1.3 k   O.K.

Check Weld at end of angle:

Load = 0.26 k   Force on weld = .26 x 15in./13 in. = 0.3 k
Weld Capacity = 0.91 x 3 x 2 = 5.4^k
5.4 k > 0.3 k   O.K.

Check beam top flange for rotation: (Assume uniform load along the beam flange)

Let beam web = 5/16"

Sum of M_B

M = wl^2/2 = [(0.120 k/ft.)/12](18 in.)^2/2 = 1.62 in-k

$S_x = \frac{bh^2}{6} = \frac{12}{6}(5/16)^2 = 0.195 in^3$ $I_{xx} = \frac{bh^3}{12} = \frac{12}{12}(5/16)^3 = 0.0305 \ in^4$

f_b = 1.62/0.195 = 8.31 ksi O.K

Check Deflection:

Equivalent load at the end of the flange is (.083/12)(18)^2/(2*3) = 0.374 k
Deflection = wl^4/3EI = ((0.374)(3)^4 /3(29000) (0.0305)) = 0.0114 in. at the end of flange. Extrapolating to the end of the plate, the deflection at the end of the plate due to flange rotation is

(18/3)* 0.0114 = 0.068 in.   OK

Check beam rotation: A function of beam length