



### Introduction to Cambering

Cambering is the process of creating an intentional slight curvature in a beam

Image courtesy of CAMBCO Inc.

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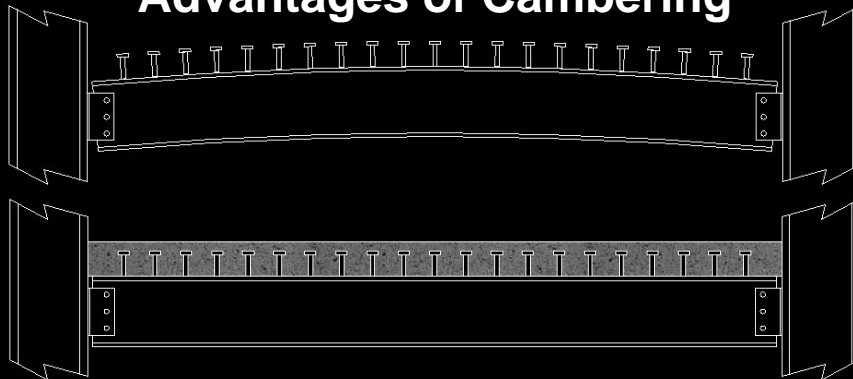
## Introduction to Cambering



- Camber in a beam can be designed to compensate for either:
  - A certain percentage of the dead load deflection
  - The full dead load deflection
  - The full dead load deflection as well as a percentage of the live load deflection (Ricker 1989)
- Camber is usually designed to compensate for deflections caused by pre-composite dead loads

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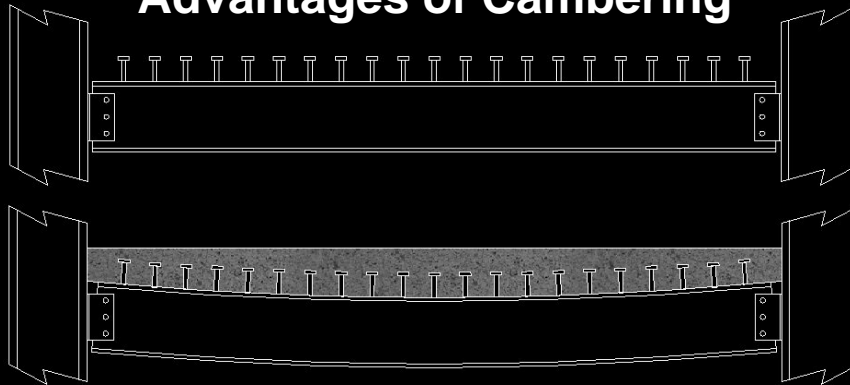
## Advantages of Cambering



- Supporting beams will deflect under the load of concrete being placed
- This deflection can be exaggerated in a composite floor system where the full strength of the system is not achieved until the concrete has cured
- Cambered beams (top diagram above) should deflect to a straight line (bottom diagram above), if load and deflection are predicted accurately and camber equals deflection
  - This allows the floor slab to be flat while maintaining a consistent thickness (Larson and Huzzard 1990)

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## Advantages of Cambering



- If beams are not cambered (top diagram above) the deflection under the load of the wet (plastic) concrete will result in a ponding effect in the concrete (bottom diagram above)
- To create a flat floor in this situation the concrete will need to be thicker at the center of the bay where the deflection is the greatest
- The volume of concrete used will typically be 10-15% more than if the floor is a constant thickness (ASCE 2002)

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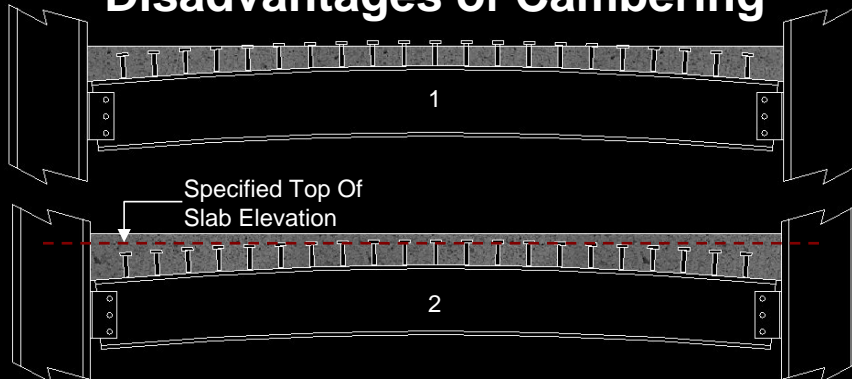
## Disadvantages of Cambering



- The use of cambered beams will, to a certain degree, be limited by other aspects of the design for a structure
- Due to the complexity in detailing, fabrication, and fit-up associated with moment connections (above left), camber should not be used in moment connected beams
- Beams with simple framing connections (above right) may be cambered because the end rotational resistance of a simple connection is small in comparison to that of a moment connection

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## Disadvantages of Cambering

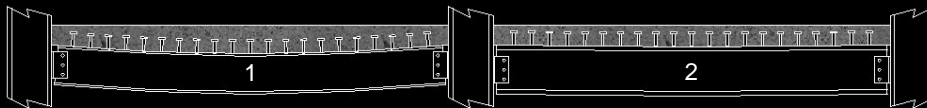


- The processes used to create camber in beams as well as the actual deflections under load of cambered beams are not exact
- Care needs to be taken in the specification and fabrication of camber to ensure that a beam, once in place and under load, will perform within tolerances
- Levelness and consistent floor thickness can be a problem (ASCE 2002)
- The diagrams above show two possible results of cambered beams not deflecting as predicted under the load of the wet (plastic) concrete

1. Stud heads are exposed      2. Top of slab elevation out of tolerance

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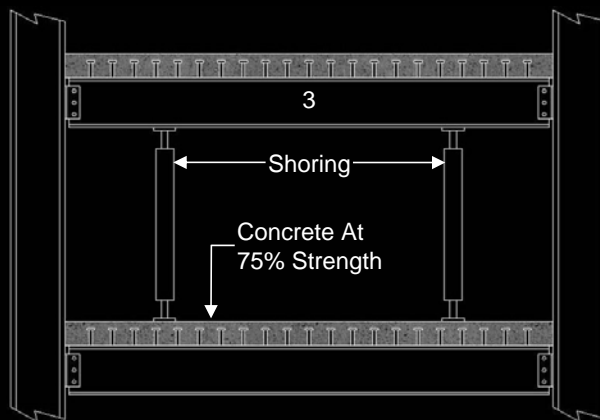
## Alternatives to Cambering



Alternative methods for achieving a level floor slab without using cambered beams include:

1. Pouring a slab of varying thickness over deflecting beams
2. Using over-sized beams to minimize deflection
3. Shore the beams before placing the concrete

(Larson and Huzzard 1990)



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## Shoring



- Shoring may be used in lieu of cambering
- The construction documents must specify the use of shoring
- There are several advantages to using shoring:
  - Lighter floor beams may be used
  - Cambers do not need to be designed or fabricated
  - Less beam deflection allows for better control of the slab thickness
  - Shoring can accommodate a contractor's special loading requirements

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## When to Camber



- Girder Beams
- Filler Beams
- Members with uniform cross section
- Composite Floor Beams

(Ricker 1989)

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## When Not to Camber



- Cantilevered Beams (above left)
- Crane Beams
- Moment Connected Beams



- Braced Beams (above right)
- Spandrel Beams (above right)

(Ricker 1989)

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## When Not to Camber



- Beams with moment connections (above left)
- Beams with non-symmetrical loading



- Beams under 20 feet in length (above right)
- Beams with end plate connections

(Ricker 1989)

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## Heat Cambering



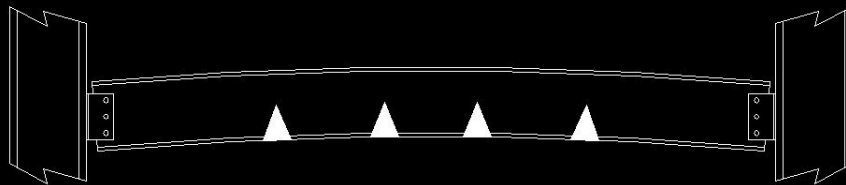
- Beams may be cambered by applying heat to small wedge-shaped areas at specific increments along the beam (Ricker 1989)
- The beam is placed upside down on supports so the "bottom" flange can be heated
- The heated flange expands under the heat and contracts as it cools
- Camber is induced in the opposite side of the beam as the heated flange cools
- Advancing this slide will begin an animation which shows the expansion and contraction that occurs in a heat cambered beam



The animation will repeat after several seconds

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## Installation of Heat Cambered Beams



- A heat cambered beam should be erected with the heat marks on the bottom side of the beam (see top diagram above)
  - This places the beam in a camber up (or concave down) orientation
- Heat marks can be seen on the beams in the bottom picture above

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## Cold Cambering



- Cold cambering methods are more widely used and generally more economical than heat cambering
- The beam is mounted in a frame and force from a ram(s) is used to bend the beam to create camber

(Ricker 1989)

Image courtesy of CAMBCO Inc.

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## Creating Camber



- Cambering is most commonly done at the fabricator's shop after the connections are fabricated (AISC 2000)
- The fabricator may mark cambered beams to ensure proper installation

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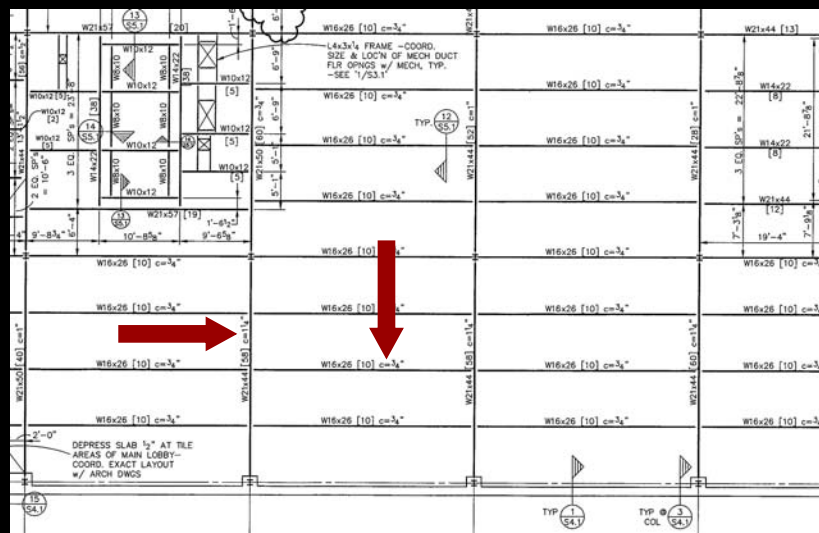
## Natural Mill Camber



- Natural mill camber, which is a slight camber present in a beam when it is received from the mill, will exist in most beams
- If the natural mill camber is at least 75% of the specified camber, no further cambering by the fabricator is required
- If camber is not specified, the beams will be fabricated and erected with any natural mill camber oriented up (or concave down) (AISC 2000)

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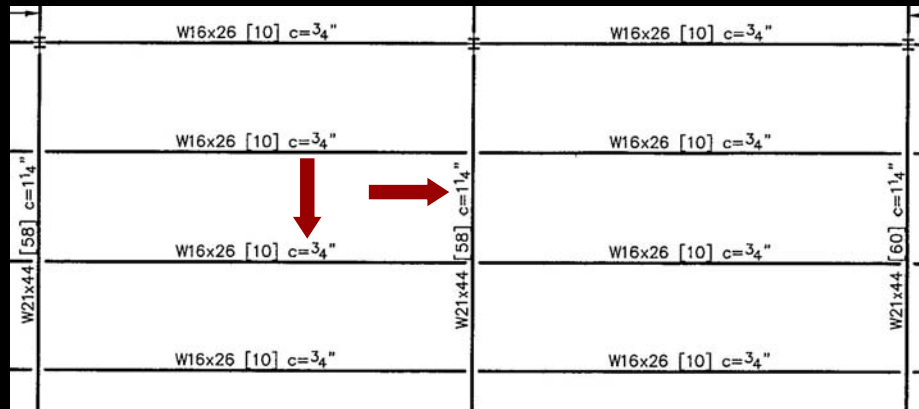
## Cambered Beams on Structural Plans



Cambered beams should be clearly marked on the structural plans (AISC 2000)

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## Cambered Beams on Structural Plans



- The structural plan above shows which beams are cambered
- The amount of camber is indicated for each cambered beam
  - c=3/4" indicates that the beams are cambered 3/4" at the center
  - c=1 1/4" indicates that the girders are cambered 1 1/4" at the center

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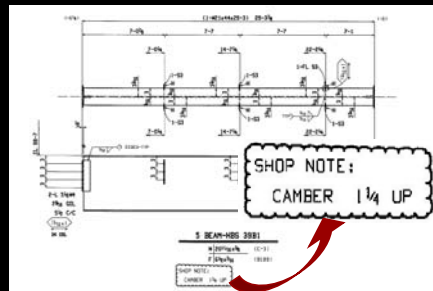
## Installation of Cambered Beams



- The installation of cambered beams is similar to that of other structural steel members
- No additional tooling, equipment, or hardware should be required

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## Quality Control



- Per the AISC Code of Standard Practice "camber shall be measured in the Fabricator's shop in the unstressed condition." (above left)
  - The amount of camber specified on the shop drawing (above right) is for the beam center line in an unstressed or unloaded condition
- Tolerances for camber are specified in the AISC Code of Standard Practice:
  - Members 50 feet or less in length = minus 0" and plus 1/2"
  - Members over 50 feet the plus tolerance is increased by 1/8" for every 10 feet over 50 feet

(AISC 2000)

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## Quality Control



- It is possible for all or part of the induced camber to come out of a beam during shipment to a jobsite
- This is acceptable under the AISC Code of Standard Practice (2000), but the fabricator's quality control procedure should provide verification that the specified camber was measured in the shop

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## Cost of Cambering



- Cambered beams require additional fabrication resources which will make them cost more than non-cambered beams
- The additional cambering cost should be compared with
  - Cost of additional concrete due to “ponding”
  - Cost of using shored construction
  - Cost of using a heavier section that does not need to be cambered

Image courtesy of CAMBCO Inc.

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## Cost Savings from Cambering



- The cost to camber beams may be less than the alternatives
- A cost comparison can reveal the savings associated with the use of cambered beams
- Larson and Huzzard (1990), in their study of cambered beams and uncambered beams found a cost savings of approximately 4%
  - A 30' x 30' bay size was used
  - Filler beams were spaced at 10' o.c.

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## Impacts on the Schedule



- There will be an increase in fabrication duration for structural steel to account for time required to create camber in beams
- The amount of time required to create camber is dependent on a fabricator's internal scheduling and fabrication methods

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## Impacts on the Schedule



Delivery, shakeout, and erection durations should not be impacted by the use of cambered beams

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