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Carnegie Steel Company

I·BEAM·LOK

Armored

BRIDGE ROADWAY SLABS

and HEAVY DUTY FLOORS



CARNEGIE STEEL COMPANY
Subsidiary of United States Steel Corporation
PITTSBURGH

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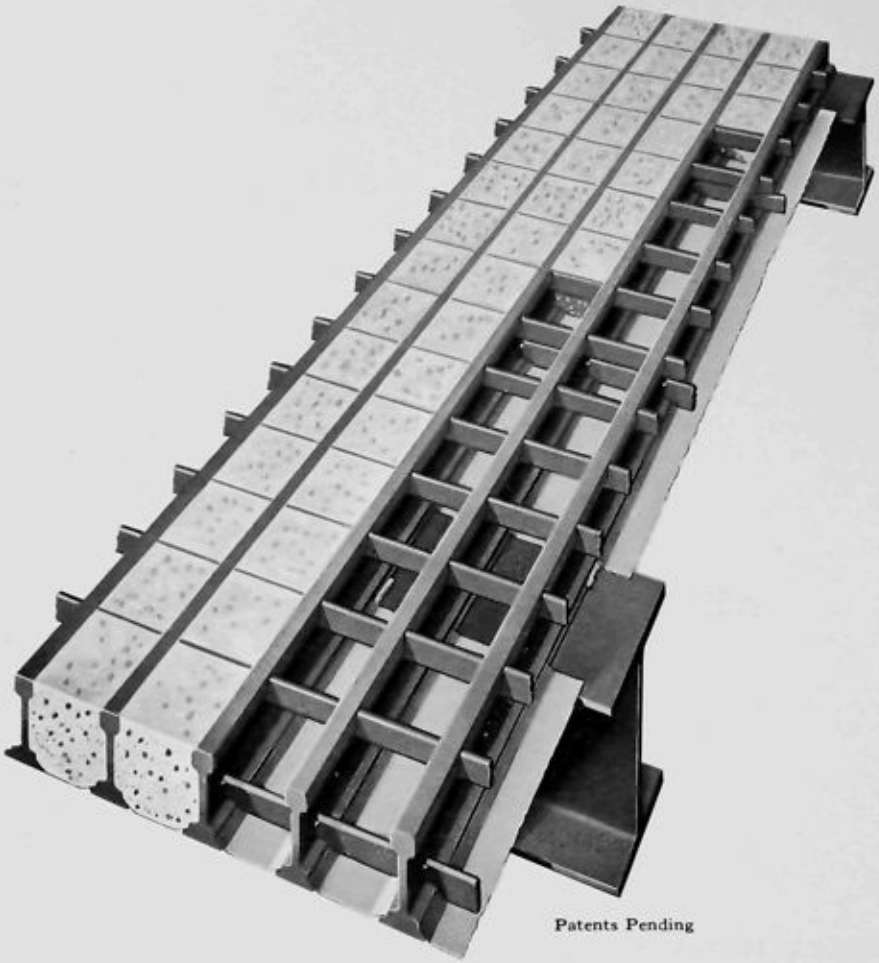
I-BEAM-LOK
ARMORED
BRIDGE ROADWAY SLABS
AND
HEAVY DUTY FLOORS

Patents Pending

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Research to develop a lighter, more rugged, less costly, and highly efficient combination steel and concrete bridge roadway slab or heavy duty floor, has led to the production of the I-Beam-Lok Armored construction by Carnegie Steel Company. As shown in the illustrations, the construction takes advantage of the well-known principle of the strength of the I-Beam.

In addition to use on large bridges, the lightweight of I-Beam-Lok Armored Slabs and the savings possible through their use will permit their application on many small beam and girder bridges, as well as on heavy duty factory floors, garages, ramps, wharves, docks and similar structures.



Patents Pending

DESCRIPTION

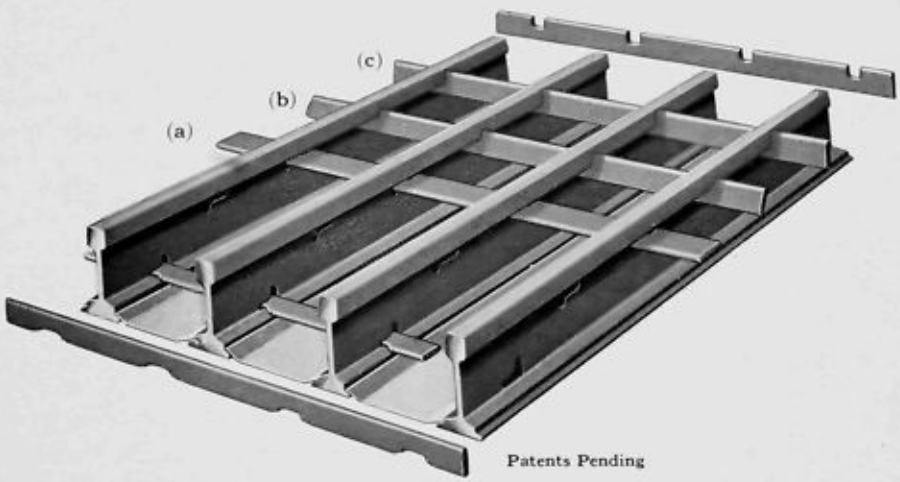
The construction is a series of alternating I-Beams and concrete ribs thoroughly tied and locked together by an adequate number of notched cross bars near both the top and bottom surfaces of the slab, providing sufficient reinforcement for lateral distribution of loads; and in addition, the top bars form a part of the integrally armored surface. Metal form strips, closely fitted between the lower flanges of the I-Beams, provide a tight form work for the concrete. These strips are omitted over the top flanges of supporting beams or girders, permitting the concrete to come directly in contact with the bearing areas. The gap in the form strips over the supports, and the open space between the I-Beams, facilitate the welding of the I-Beams to stringer flanges.

It will be noted in the illustrations that *only the webs* of the I-Beams are punched or pierced for the insertion of the cross bars. Both the top and bottom flanges of the I-Beams are intact throughout their entire length. The slab is so designed as to have constant moment of inertia for resisting both positive and negative bending moment stresses. The notched cross bars are first inserted flat in the L-shaped web holes, then turned through an arc of 90 degrees, and tack-welded in their final position. These bars hold and lock the I's rigidly at uniformly spaced intervals. As shown in the tables, I-Beam-Lok Armored units are at present available in two depths. When demand warrants, deeper sections with greater strength will be produced.

I-BEAM-LOK

COMBINES ALL OF THE FOLLOWING FEATURES:

1. *Very light unit weight, thus reducing weight and cost of entire bridge.*
2. *Armored road surface, minimizing wear and skidding.*
3. *Smooth, hard surface for high-speed traffic.*
4. *More strength as compared with other floors of comparable weight.*
5. *Greater rigidity of entire roadway. Solid connection between slab and stringers.*
6. *Ease of erection, with no concrete forms necessary.*
7. *Substantial saving of time required for completion.*
8. *Low maintenance cost. Easy repairs when necessary.*



Patents Pending

METHOD OF ASSEMBLY

1. Form strips placed on beads or projections on bottom flanges of I-Beams.
2. Lower locking bars inserted in slots and rotated to vertical position.
   (Note lower locking bar partially inserted.)
3. Upper locking bars inserted in slots and rotated to vertical position.
   (Note upper locking bars (a) inserted, (b) partially rotated, (c) fully rotated to vertical position, thus locking, spacing and holding I-Beams.)
4. In the final operation the intersections of I-Beams and upper locking bars, also I-Beams, lower locking bars and form strips, are tack-welded into integral solid units.

PRINCIPAL ADVANTAGES

Lightness

When filled with ordinary concrete, I-Beam-Lok Armored Slabs weigh only 47 pounds per square foot in 3-inch depth, and 53.5 pounds per square foot in 3½-inch depth.

The cumulative savings which are possible through reduction in sizes of stringers, floor beams, trusses, and piers, through the use of such extremely light-weight slabs, are well-known to the engineering profession.

In order to take full advantage of the light weight, no over-fill should be used. The armored floor will not only resist the internal stresses resulting from the most severe traffic conditions, but will at the same time provide an ideal roadway surface which will have a long life. However, if so desired, an over-fill of concrete, asphalt or other material may be installed at any time.

In cases where a wearing surface such as asphalt composition is applied, the dead weight of the structural slab itself can be further reduced through the use of Haydite concrete so that it weighs only 36.8 pounds in 3-inch depth and 41.5 pounds in 3½-inch depth.

Strength

While this construction has strength equal to or greater than other comparable types for the same depth of slab, it requires only 15.5 pounds of steel per square foot in the 3-inch depth, and 16.4 pounds in the 3½-inch depth.

The high ratio of strength to weight of steel is due to the very efficient utilization of steel in the design. The shape of the I-Beams produces a construction which has a constant moment of inertia for resisting reversals in stress such as occur from positive and negative bending moment in continuous slabs.

Safety

The armored surface of rectangular blocks of concrete provides a smooth, hard, anti-skid floor for present day high-speed traffic.

Long Life

The integral surface armoring of I-Beam-Lok Armored Slabs reinforces the surface of the concrete so that wear is retarded to a minimum. Unsightly cracks are avoided, progressive failure can not occur. They require virtually no maintenance except painting underneath. Armored types of surfaces installed at various times during the past five years show practically no wear. The strips of dense concrete adhere to and are locked so rigidly between the webs and flanges of the I-Beams that it is practically impossible for moisture to work its way down between the concrete and steel.

Economy

Lower initial cost per square foot, f.o.b. plant, less freight, smaller hauling and placing charges, no expensive form work to construct in the field, easier field welding, all combine to produce a finished armored slab at a much lower cost per unit of area than has heretofore been available. The resultant lower unit price plus the savings possible in the balance of a bridge structure will make it feasible to adopt I-Beam-Lok Armored Bridge Roadway Slabs in structures where the cost of other armored types of slab has heretofore been considered prohibitive.

Adaptability

In addition to its particular suitability for use on steel framed structures, it may also be used to form the floor system of a reinforced concrete bridge, as the I-Beam-Lok Armored Slab will function as the flanges of a T-Beam.

HIGHWAY BRIDGE DESIGN

In designing new bridges the use of these lightweight slabs usually reduces dead loads sufficiently to permit very substantial savings in the cost of the entire structure due to reduced dead loads which justifies inclusion of I-Beam-Lok Armored Slabs in the bridge specifications.

In reflooring existing structures it is sometimes possible to take out the old heavy slabs of a bridge originally designed for H-15 loading and through the application of the light-weight slabs the permissible live load capacity of the bridge may be increased to take care of an H-20 loading without any other alterations or modifications in the structure.

Investigation of many bridges will show that I-Beam-Lok Armored Slabs may be used for reflooring even where the original floor may have been of wood. In most cases the trusses of existing bridges are adequate, with only slight changes required in the floor beams and stringers in order to bring the bridge capacity up to requirements of present day traffic. Where a wood floor has an ultimate life of perhaps three years, an I-Beam-Lok Armored Floor will have a presumable ultimate life equivalent to that of the bridge itself.

When we consider the tremendous advantage, particularly on long spans, of being able to use a structural floor slab whose weight may be as low as 36.8 pounds per square foot, it is quite apparent that this light-weight bridge floor construction is one of the most vitally important developments that has taken place since the very beginning of motor transportation.

RAILWAY BRIDGE DESIGN

The application of I-Beam-Lok Armored Slabs is much broader than merely for highway bridges. To designers contemplating the construction of a railroad bridge we submit this rugged light-weight steel and concrete deck. A timber deck laid on a steel structure is no longer considered adequate. The fire hazard, even with treated or sheet metal protected timbers, presents many difficulties, is expensive and in spite of all precautions several disastrous fires within recent years with the resultant interruption to traffic, have convinced many railroad bridge engineers that fireproof ballasted deck bridges are destined to come more and more into general use. I-Beam-Lok Armored Slabs will be found remarkably well adapted to such structures owing to the continuity of structure, ease of application, impervious condition of slab and good lateral distribution of concentrated loads which would be an important factor in cases of derailment.

The application of these slabs is not complicated. Distributing beams 10 or 12 inches deep spaced 3 to 4 feet on centers are placed on top of the stringers. I-Beam-Lok Armored Slabs are then welded to the distributing beams, filled with concrete and the solid deck thus formed is then ready for ballast and track. The distributing beams are arranged with a slight slope for drainage and due to the imperviousness of the slab, waterproofing between the ballast and the deck is not required. The solid deck also furnishes protection against the weather to supporting members. In the case of double-track structures the distributing beams may be crowned at the center with top of slab sloping down to the sides. In the case of new structures the slab is an important factor in providing lateral bracing to the bridge.

Investigation of many existing structures will show that the timber deck may be replaced by I-Beam-Lok Armored Slabs and distributing beams without increasing stresses above safe limits due to the great reduction in vibration and impact as well as to the fact that higher unit stresses are now considered permissible than was the case a few years ago.

The use of light weight I-Beam-Lok Armored Slabs in railway bridges offers the following decided advantages which fully justify their use:

1. *Greatly reduced vibration and impact;*
2. *Lower maximum stresses;*
3. *Greater rigidity of the entire structure;*
4. *Elimination of all fire hazard;*
5. *Solid waterproof deck;*
6. *Use of ballasted track construction;*
7. *Reduced wear and maintenance on the entire structure.*

ENGINEERING FEATURES

Design

Utilization of an I-Beam section in which the flanges remain solid the full length of the bar, with the cuts or holes for cross members restricted to the web, gives an arrangement equivalent to a series of steel I-Beams with concrete fillers. The cross members provide the necessary reinforcement for lateral distribution of loads, and at the top of the slab they also form a portion of the armoring system. The construction can be analyzed by commonly accepted methods of calculation, and it is proportioned to resist the full negative as well as the positive moment in continuous slab construction. Neither the form strips nor the projecting beads on the edges of the bottom flanges are considered in computing the properties of the slabs. Examination of the tables of properties will reveal that the section moduli for both concrete and steel, for both positive and negative moments, are practically balanced.

Furthermore, the section modulus or bending moment resistance of the I-Beams without concrete filling is almost as much as when filled with concrete. The steel I-Beams alone are able to take over 90% of the moment stresses. The concrete is required mainly for lateral load and shear distribution and to provide the roadway surface.

Load Distribution

Wide lateral transmittal of transverse shearing stresses in this construction is facilitated, because, in addition to the normal bond of concrete to steel, the rectangular concrete strips are locked mechanically between the flanges of the I-Beams.

Rigid Connection to Stringers

Solid uniform bearing and full contact with carrying surfaces are secured and the surfaces are protected against corrosion because the concrete is poured monolithic, down to the top of supports. Uniform bearing on the stringers also eliminates secondary stresses in their top flanges. The form strips between the I-Beams extend only about an inch onto the edge of support, and are omitted over the balance of the width of the support. Ample welds hold the I-Beams to the stringer flanges.

Dense Hard Concrete

Soundness of concrete is assured through the design of overlap of the form strip over the continuous beads or shelves on the sides of the bottom flanges of the I-Beams, which provides very tight formwork so that there is no excessive drip, loss of cement mortar, or honeycombing of concrete.

Imperviousness

Water-tightness is induced, because the concrete and steel are so intimately locked together in this structure and in addition, the long line of contact around the flanges and webs of the I-Beams provides an effective water seal.

Corrosion Resistance

Corrosion is minimized by making all material in I-Beam-Lok Armored Construction out of copper-bearing steel. As stated before, neither the beads at the sides of the bottom flanges of the I-Beams, nor the form strip between the I's, are considered in computing the properties of the combined sections. These component parts of the construction could, therefore, be eliminated entirely through corrosion, without affecting the security of the construction. However, it is well-known that strip as thick as No. 20-gauge, when backed up by material such as concrete on one side, has a very long life.

With the ordinary maintenance by painting, such as is usually given a bridge at regular intervals, it is expected that the entire metal undersurface of the slabs will have a useful life as long as the other component parts of the bridge.

Fire or Rust Proofing

Fire or rust proofing may be accomplished as illustrated on page 21 by hanging inexpensive form-work at $^3/_4$-inch to 1-inch below the I-Beam units, so that concrete completely encases the bottom of the I-Beams. In this case, the metal form strips would be omitted, and their cost would offset about one-half the expenditure for separate form work.

ENGINEERING FEATURES

Light-weight Concrete

In localities where it is the practice to use an asphalt or similar wearing surface over bridge slabs, advantage may be taken of a light-weight concrete such as Haydite, which can be used to good effect in the structural slab. Due to uniform distribution of steel in the top and bottom flanges of the I-Beams, which alone have nearly the full strength of the slab without the concrete fill, the light-weight concrete is needed mainly to secure lateral distribution of shearing and moment stresses.

COMBINED T-BEAM ACTION IN REINFORCED CONCRETE CONSTRUCTION

As shown in drawing on page 21, the space between the I-Beams is sufficiently wide to permit the placing of stirrups and the pouring of concrete to form the stem of a reinforced concrete T-Beam, the I-Beam-Lok Armored Slab acting as the flange of the T-Beam. In this case the span of the slabs can be taken as the clear distance between sides of concrete beams.

COMBINED T-BEAM ACTION IN STRUCTURAL STEEL CONSTRUCTION

As discussed in detail on page 14, considerable savings in stringer sizes and weights may be made by considering the I-Beam-Lok Armored Slab as acting in combination with the stringer, thus forming a composite T-Beam. The general arrangement of I-Beam-Lok Units makes them particularly adaptable for this purpose.

Erection

I-Beam-Lok Armored Slab Units are completely detailed and shop fabricated for each project. Form strips are tack-welded in place during fabrication of the units in the shop. The loose form strips filling in the space between adjacent 4-foot units are furnished with sheet metal straps, for temporary use, to hold forming strips in position during erection, as shown on the drawings. Openings in the I-Beam system over supports facilitate their location and give ample clearance for field welding. With any unusual conditions of crowning, considerable flexibility is possible when detailing the arrangement of stringers under the I-Beam-Lok Armored Slab Units. The fact that the concrete is poured monolithic down to the top of the stringers insures full solid bearings. Concrete is deposited, vibrated, and finished in the same manner as for other types of thin armored composite steel and concrete slabs. If ordered, the units will be shipped with one coat of paint brushed on the bottom surfaces.

Field painting is simplified because the tight fit of the form strips reduces leakage during pouring operations of concrete to a minimum, so there is very little to be scraped off the underside of the floor or the supporting girders before painting. Where required to retain plastic concrete, end dams will be welded on to the units in the shop as called for on the plans and specifications, or as specially ordered.

I-Beam-Lok units, after being welded to the stringers, will provide a temporary floor over which traffic may move, thus expediting the delivery of material for the bridge, such as curbs, sidewalks, handrails, tools, and miscellaneous equipment; as well as all of the concrete for the roadway slabs, which can be delivered to the exact spot desired in transit mixers.

DESIGN DATA

The subject of distribution of wheel loads on bridge floor slabs is one to which considerable intensive study has been given by various recognized authorities during the past twenty years.

The term "effective width" of distribution is one about which there has been considerable confusion, and which has not had a universal meaning in the minds of many engineers. We quote a good definition of this term from Bulletin No. 80, "Concentrated Loads on Slabs", by Prof. Clyde T. Morris, published November, 1933, at Ohio State University, as follows: —"The term 'effective width' has come to be recognized as that width of slab used in designing over which a concentrated load may be considered as uniformly distributed, on a line through the load parallel to the supports, which will give the same calculated moment in the slab as is actually produced by the load".

For a simply supported slab, certain formulas developed by Prof. H. M. Westergaard, of University of Illinois, published in "Public Roads", March, 1930, determine that the effective width of distribution is .58 S + 2 C, in which S is the span length, and C is a diameter which, for highway truck wheels, may be taken as 1 inch for each 1,000 pounds of load on the wheel, or an average value of 15 inches may be used as was done in preparing formulas for effective width given herein.

In Bulletin No. 80, Morris points out the close check given to Westergaard's theory by tests made at the Ohio State University, which gave $E = 0.68\ S + 1.7$ feet when the load was applied over an area about 5" x 9"; and that tests at the University of Illinois, by C. R. Young, as reported in the July 30, 1914, "Engineering News-Record", gave $E = 0.67S + C$. We, therefore, have close confirmation through test results of the theory developed by Westergaard, insofar as it applies to an equivalent effective width of distribution as applied to simply supported slabs of one span.

Plotting the curve of Westergaard's formula (65) $E = .58S + 2C$ indicates the desirability of modifying same for short spans, and the curve of $E = 2.41\sqrt{S}$ shows it represents a rational conservative value of effective width for spans under 4 feet. The preceding values apply for one wheel load concentration.

Where the main reinforcement in the slab is transverse to the direction of traffic, when two wheels 3 feet center to center are placed on a slab so as to produce maximum moment, the second wheel load concentration does not effect an increase in moment until the span is 5.08 feet or more. Plotting the values of Westergaard's formula (59) for M_{ox} plus formula (72) for M_x shows that a curve for an equivalent effective width for one wheel to give the effect of two wheels on span arranged for maximum live load moment is satisfied on an average conservative basis by the formula for equivalent effective width $H = 0.33S + 3.50$ for spans from 5'—3" to 10', incl.

When slabs are fully restrained, Westergaard's formula (104) $M'_{ox} = M_{ox} - 0.0699\ P$ allows a deduction of 0.0699 P from the moment per unit of width. I-Beam-Lok Armored slabs over two or more spans, when alternate I-Beams are welded in staggered arrangement near alternate edges of stringer flanges, are practically fully restrained. However, to be on a conservative, safe basis, we have decided to make a deduction of only 75% of the value computed by Westergaard, or 0.0525 P, and have prepared our tables on this basis as shown in formulas on opposite page.

Stresses shown in load tables were computed from the total design moment, M_T, as given therein.
Slabs designed for bending moment in accordance with these formulas may be considered adequate for shear without additional special reinforcement.

This design data does not provide for the effect of loads near unsupported edges. Therefore, at the ends of the bridge and at intermediate supports where the continuity of the slab is broken, the edges of the slab shall be supported by diaphragms or other suitable framing, as follows:—

The outer edges of all slabs parallel to the I-Beams shall be supported by suitable framing capable of resisting one-half the maximum moment produced by one wheel load, including impact but assuming no distribution.

The outer edges of all slabs at right angles to the I-Beams shall be supported by suitable framing capable of resisting two-thirds the maximum moment produced by one wheel load, including impact but assuming no distribution.

While the tables were prepared on the basis of I-Beams running in a direction transverse to traffic, if the I-Beams are run parallel to the direction of traffic, the unit stresses are increased slightly. The moment values, for H-20 loading which specifies a 16,000 pound wheel load, without impact, are 3,540 foot-pounds per foot of width on 6-foot span, in case of transverse reinforcement, and 3,990-foot-pounds in the case of parallel reinforcement, according to modified formulas developed along the same lines as those given herein for transverse reinforcement. Floors in which the I-Beams run parallel to the direction of traffic will occur so seldom that we suggest such cases be submitted to us for special analysis and computation.

DESIGN FORMULAS

On the basis of modifications in Westergaard's moment formulas developed as outlined on opposite page:

With I-Beams perpendicular to direction of traffic, and when C = 15″, the live load moments for one wheel on slab spans up to 5 feet, become

$$M = \frac{PS}{4E} - .0525P,$$

and, for two wheels on slabs over 5-foot span, moments become

$$M = \frac{PS}{4H} - .0525P.$$

M = Maximum live load moment per foot of width of slab.

P = Wheel load = 12,000 pounds for H-15, and 16,000 pounds for H-20 loading.

S = Slab span in feet.

E = Effective width in feet for one wheel. $E = 2.41\sqrt{S}$ for spans 1′-0″ to 4′-0″, incl. $E = 0.58S + 2.50$ for spans 4′-3″ to 10′-0″, incl.

H = Equivalent effective width for one wheel to give the effect of two wheels on slab arranged for maximum moment. $H = 0.33S + 3.50$ for spans 5′-3″ to 10′-0″, incl.

W = Dead load per square foot of slab.

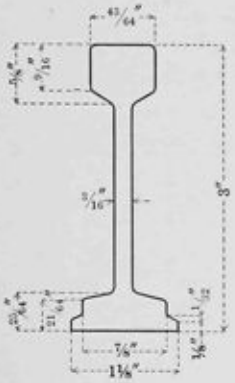
I = Impact Factor = $\frac{50}{125 + S}$

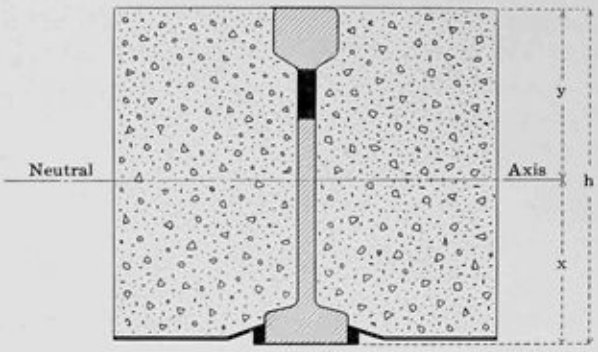
D.L.M. = Dead Load moment per foot width of slab = $\frac{1}{11} WS^2$.

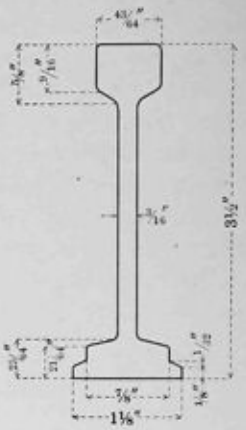
(L. + I.) M = Live Load + Impact moment per foot width of slab.

M_T = Design Moment = D.L.M. + (L. + I.) M.

PROPERTIES OF I-BEAM-LOK SLABS







All I-Beams spaced 4″ center to center

ELEMENTS OF I-BEAM-LOK SLABS

Depth	Average Weight of Steel per Sq. Ft.	*Total Weight of Slab per Sq. Ft.		I per Foot of Slab Width	x	y	Section Modulus Per Foot of Slab Width		Moment
		Ordinary Concrete	Haydite Concrete				Compression Concrete	Tension Steel	
In.	Lbs.	Lbs.	Lbs.	In.⁴	In.	In.	In.³	In.³	
3½	16.4	53.5	41.5	96.0	1.96	1.54	62.3	3.26	Positive
				99.1	1.47	2.03	67.4	3.25	Negative
3	15.5	47.0	36.8	64.2	1.69	1.31	49.0	2.53	Positive
				63.2	1.24	1.76	50.9	2.39	Negative

Areas of beads along bottom flanges of I-Beams and the form strips are not included in computations. Areas of upper slots in I-Beams deducted. Areas of lower slots in I-Beams not deducted as they do not occur in zones of maximum stress. Concrete disregarded on area in tension. Ratio, n = 15.

Section modulus of 3½″ I-Beam steel without concrete = 3.02 per foot of width.

Section modulus of 3″ I-Beam steel without concrete = 2.40 per foot of width.

*1 cubic yard of concrete will fill approximately 105 sq. ft. of 3½″ I-Beam-Lok.

*1 cubic yard of concrete will fill approximately 124 sq. ft. of 3″ I-Beam-Lok.

DIMENSIONS OF COMPONENT PARTS

I-BEAM SECTIONS								CROSS BARS		
Depth	Web Thickness	Top Flange		Bottom Flange Without Side Beads		Area	Weight per Foot	Top Bars, Size	Bottom Bars, Size	Form Strips, Size
		Width	Average Thickness	Width	Average Thickness					
In.	In.	In.	In.	In.	In.	In.²	Lbs.	In.	In.	In. x B.W.G.
3½	.188	.675	.612	.875	.365	1.23	4.17	1⅛ x 3/16	1 x 5/16	3½ x No. 20
3	.188	.675	.612	.875	.365	1.13	3.85	1⅛ x 3/16	1 x 5/16	3½ x No. 20

LOAD TABLES FOR I-BEAM-LOK SLABS

UNIT STRESSES IN STEEL AND CONCRETE

In Pounds Per Square Inch

Span	H-20 LOADING								H-15 LOADING							
	3½" I-BEAM-LOK				3" I-BEAM-LOK				3½" I-BEAM-LOK				3" I-BEAM-LOK			
	Without Overfill		With Overfill of 25 lbs. per Sq. Ft.		Without Overfill		With Overfill of 25 lbs. per Sq. Ft.		Without Overfill		With Overfill of 25 lbs. per Sq. Ft.		Without Overfill		With Overfill of 25 lbs. per Sq. Ft.	
	f_c	f_s	f_c	f_s	f_c	f_s	f_c	f_s	f_c	f_s	f_c	f_s	f_c	f_s	f_c	f_s
2'—0"	405	7790	410	7820	515	10000	520	10040	310	5890	310	5930	390	7570	395	7620
2'—3"	445	8520	445	8560	565	10940	565	10990	335	6440	340	6490	425	8270	420	8330
2'—6"	485	9250	485	9310	615	11880	615	11930	365	7000	370	7050	465	8970	465	9040
2'—9"	520	9940	525	10010	660	12760	665	12840	390	7510	395	7570	495	9620	500	9710
3'—0"	555	10630	560	10710	705	13640	710	13740	420	8020	425	8100	530	10270	535	10370
3'—3"	585	11250	590	11290	745	14430	750	14540	445	8510	450	8600	565	10900	570	11010
3'—6"	620	11860	625	11970	785	15220	790	15350	470	8990	475	9090	595	11520	600	11660
3'—9"	650	12430	655	12540	825	15940	830	16080	490	9400	495	9520	625	12060	630	12200
4'—0"	680	12990	685	13120	860	16660	870	16820	510	9810	520	9950	650	12600	660	12740
4'—3"	705	13530	715	13680	895	17320	905	17530	535	10220	540	10370	675	13070	685	13280
4'—6"	735	14070	745	14240	930	18040	940	18310	555	10650	565	10810	705	13620	715	13840
4'—9"	760	14600	765	14780	...	.....	....	.....	575	11040	585	11230	730	14130	740	14370
5'—0"	790	15130	800	15320	...	.....	...	.....	595	11430	610	11650	755	14630	770	14900
5'—3"	880	16820	890	17030	...	...	....	.....	670	12820	680	13020	845	16400	860	16670
5'—6"	910	17410	920	17660	....	.....	....	.....	690	13210	700	13450	870	16840	890	17220
5'—9"	940	18060	955	18330	...	.....	....	.....	715	13690	730	13960	905	17470	920	17850
6'—0"	...	...	...	...	...	.....	....	.....	740	14160	755	14460	935	18100	955	18490
6'—3"	....	....	....	....	....	.....	....	.....	765	14670	785	15000	....	.....	....	.....
6'—6"	....	....	....	....	....	.....	....	.....	790	15170	810	15530	....	.....	....	.....
6'—9"	....	....	....	....	....	.....	....	.....	815	15610	835	15990	....	.....	....	.....
7'—0"	...	.....	....	.....	....	.....	....	.....	835	16050	860	16450	...	.....	....	.....

H-20 Loading 16,000-pound wheel plus impact ranging from 39.4% on 2'—0" span to 37.9% on 7'—0" span.

H-15 Loading 12,000-pound wheel plus impact ranging from 39.4% on 2'—0" span to 37.9% on 7'—0" span.

Stresses based on slabs extending continuously over two or more spans with I-Beams transverse to direction of traffic. n ratio = 15

Moments based on wheel load plus impact and dead load of slab.

Two wheel loads, 3'—0" center to center, figured on spans over 5'—0".

Concrete stresses in tables are very conservative, as the entire weight of the slab is figured while actually the dead weight of the slab is carried entirely by the steel and only live loads affect the stresses in the concrete.

Portions of tables showing stresses with 25 pound overfill are for use where specifications call for separate wearing surface. It is common practice to omit all wearing surfaces when I-Beam-Lok Armored Slabs are used. However, when their weight is included in the design, wearing surfaces may be added many years later without over-stressing any portions of the bridge.

Haydite Concrete

When 3,000 pound strength Haydite Concrete weighing 98 pounds per cubic foot is used in slabs with an overfill, stresses are reduced in 3½" deep slabs by an amount equal to $^{12}/_{25}$ of the difference in stress between values for slabs with and without overfill, and for 3" deep slabs, by an amount equal to $^{10}/_{25}$ of the difference.

For example:—

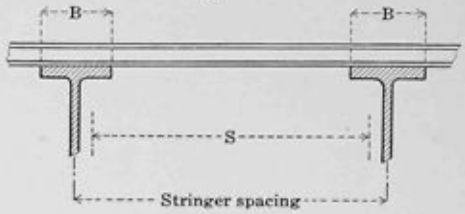
With 3½" slab on 5' span under H-20 loading, f_c without overfill equals 790 pounds, and with, 800 pounds. The difference is 10 pounds, and $^{12}/_{25}$ of same equals 5 pounds. In Haydite Concrete I-Beam-Lok Armored Slabs with 25 pounds of overfill wearing surface, the reduced concrete unit stress becomes 800 minus 5 or 795 pounds per square inch. The same procedure applies to unit stresses in the steel I-Beams.

INCREASED STRINGER SPACINGS PERMISSIBLE WITH WIDE FLANGE CB SECTIONS

The spans shown in the tables for I-Beam-Lok Armored Slabs are for center to center spacings of standard beam stringers. Where wide flange CB Sections are used, sound engineering practice indicates that the actual design span be decreased when flanges are more than six inches wide and when the effective design span does not exceed six feet.

The method of fastening I-Beam-Lok Armored Slabs to stringers with welds staggered on opposite edges of the flanges and the efficiency of the slabs in resisting negative moment due to their constant moment of inertia give assurance that the practice recommended below is very conservative.

These factors warrant increasing the center to center spacing of stringers beyond the effective design span as shown in the following table:



CENTER TO CENTER SPACING OF STRINGERS FOR VARIOUS EFFECTIVE DESIGN SPANS

Effective Design Span, S	WIDTH OF STRINGER FLANGE, B, IN INCHES									
	7	8	9	10	11	12	13	14	15	16
1′—0″	1′—1″	1′—2″	1′—3″	1′—4″	1′—5″	1′—6″	1′—7″	1′—8″	1′—9″	1′—10″
2′—0″	2′—1″	2′—2″	2′—3″	2′—4″	2′—5″	2′—5″	2′—6″	2′—7″	2′—8″	2′—9″
3′—0″	3′—1″	3′—2″	3′—2″	3′—3″	3′—4″	3′—5″	3′—6″	3′—6″	3′—7″	3′—8″
4′—0″	4′—1″	4′—1″	4′—2″	4′—3″	4′—4″	4′—4″	4′—5″	4′—6″	4′—6″	4′—7″
5′—0″	5′—1″	5′—1″	5′—2″	5′—2″	5′—3″	5′—3″	5′—4″	5′—4″	5′—5″	5′—5″
6′—0″	6′—0″	6′—1″	6′—1″	6′—1″	6′—2″	6′—2″	6′—2″	6′—2″	6′—3″	6′—3″

B=Stringer flange width in inches. S=Effective design span of floor. Example: S=4′—0″ and B=12″ Use stringer spacing of 4′—4″

DESIGN FOR COMBINED T-BEAM ACTION OF STEEL STRINGERS AND I-BEAM-LOK ARMORED SLABS

Stringers are usually proportioned for carrying full live and dead loads without assistance from other component parts of the structure.

However, where I-Beam-Lok Armored Slabs are used, which permit the concrete to come in direct contact with the stringer flanges and in which the bottom flanges of the transverse I-Beams may be adequately welded to the stringers, the welds may be proportioned so as to resist all horizontal shear between the top flanges of stringers and roadway slabs when they are considered as a composite structure. This warrants full consideration with respect to T-Beam action which will reflect substantial savings in weight of stringers and cost of structure even after considering the extra welding required.

Should the engineer desire to take advantage of this refinement of design, the following procedure is recommended:

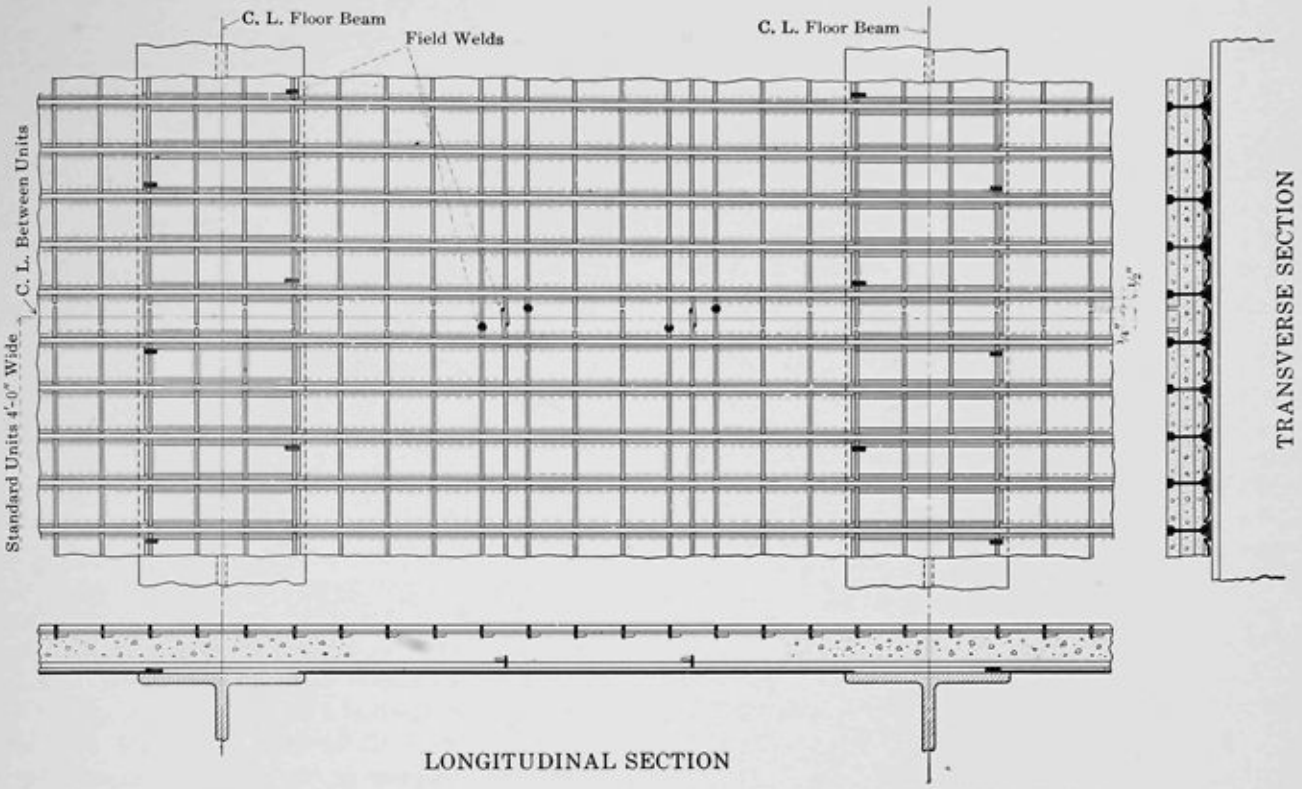
1st. Determine the stress in stringer due to dead load only.

2nd. Assume as top flange of the composite T-Beam a width of slab equivalent to 12 times the thickness, but not to exceed $\frac{3}{4}$ of the stringer spacing for interior stringers or $\frac{3}{8}$ of the stringer spacing plus the outside overhang for exterior stringers. Consider that portion of slab which is assumed to act as the top flange to be entirely of concrete and compute properties of composite section by replacing the concrete by the equivalent area of steel, taking n = 15.

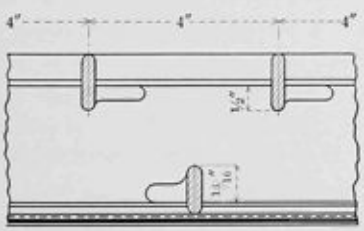
3rd. Determine stresses in the composite T-Beam due to live load only.

4th. Adjust stringer size and spacing so that the sum of live and dead load stresses does not exceed the maximum allowable values.

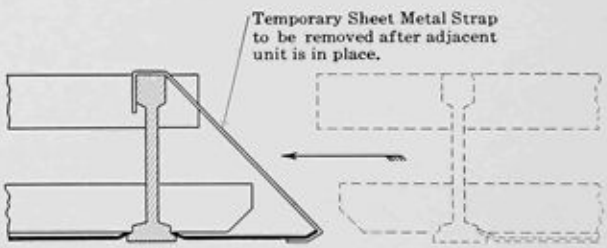
TYPICAL DETAILS OF I-BEAM-LOK CONSTRUCTION



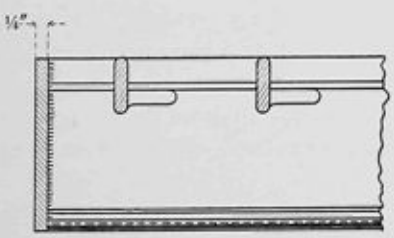
TYPICAL APPLICATION SHOWING STRINGERS AND LOCATION OF FIELD WELDS



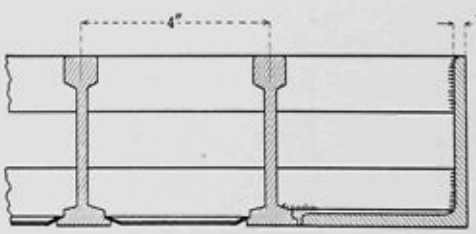
ENLARGED DETAIL SHOWING
UPPER & LOWER CROSS BARS



METHOD OF PLACING ADJACENT UNITS



TYPICAL END DAM



TYPICAL FINISHING ANGLE

SPECIFICATIONS FOR STEEL

Description

The bridge floor slab shall be composed of I-Beam-Lok Armored Bridge Roadway Slab units, as manufactured by Carnegie Steel Company, consisting of a combination of I-Beams, with metal form strips between and resting on the projections at the lower edges of the I-Beam flanges, and with rectangular cross bars inserted through slots in the upper and lower portions of the webs of the I-Beams and then rotated through an arc of 90-degrees into final position. The entire assembly shall be welded into rigid units. The depth of the finished floor and the dimensions and weight of the I's and cross bars shall be as shown on the plans. After the units are erected and welded to the supporting members, they shall be filled with concrete and finished flush with the tops of the I-Beams and cross bars to form an armored wearing surface.

Steel Material

All steel shall be furnished in structural grade of A.S.T.M. Standard Specification for Bridges A7-33T, and shall have a copper content of .2 per cent minimum.

Fabrication of Steel

All steel shall be commercially straight and be assembled in a workmanlike manner. The I-Beams shall be placed 4-inches on centers with form strips between flanges at the bottom to form units approximately 4 feet wide but not exceeding 33 feet in length. The form strips are to be placed in short lengths so as to extend only about 1 inch onto the edge of each support. Upper cross bars shall be spaced 4 inches center to center at right angles to the top flanges of the I-Beams, and when turned into final position in the slots, shall be approximately flush with the tops of the beams. The upper cross bars shall have the ends projecting through the webs of the outside I-Beams of the unit alternately long and short, so as to produce staggered joints between units. A pair of lower cross bars shall be placed 16 inches apart at about the mid-spans of the slab. See plan of typical arrangement on page 15.

Drawings

Shop detail drawings shall be furnished by the manufacturer to the purchaser for approval. Erection drawings shall be furnished to the contractor, when the nature of the project warrants it, for use in assembling and erecting material.

Field Assembly

The I-Beam-Lok Armored units shall be placed by the erector as indicated on the erection diagram, and alternate I-Beams welded to alternate edges of supports, with 1½-inch length of 5/16-inch bead weld for each I-Beam. Where units are placed with I-Beams transverse to the direction of traffic they shall be, if possible, of a length to cover the entire roadway; otherwise, the ends of I-Beams shall be welded over their full cross-sectional area to provide continuity. Where the I-Beams in the units are parallel to the direction of traffic, the ends of abutting units shall be welded over their full cross-sectional area to provide continuity. Continuous cross-bar steel in the upper surface must be maintained by welding in the field with ¾" x 3/16" cross-sectional area of weld the ends of each pair of upper bars which are near and almost directly above the lower bars. The lower bars must be lapped and welded in the field with two ¼-inch bead welds ¾-inch long.

In the erecting of I-Beam-Lok Armored units, care should be exercised to place each unit in its proper position, measuring in all cases to some fixed point, as otherwise a cumulative error in spacing is quite likely to appear, making necessary either flame cutting the final units or inserting some additional steel to fill up a gap.

SPECIFICATIONS FOR CONCRETE

Our experience with light-weight armored floors indicates that proper concrete placed under intelligent supervision is of the utmost importance. We suggest the following specifications for securing best results:

Proportions

The concrete shall be composed of one (1) part of Portland cement and five (5) parts of fine and coarse aggregate approximating a 1:2:3 mix proportioned as follows: One (1) part of Portland cement, not more than two (2) parts of fine aggregate and not less than three (3) parts of coarse aggregate.

Fine Aggregate

Sand shall consist of clean, hard, durable, uncoated grains, free from injurious amounts of dust, lumps of clay, organic matter, loam or other deleterious substances.

The grading shall be from fine to coarse with the coarser particles predominating. After being thoroughly dried, the sand shall meet the following requirements by weight:

Three-eighths (3/8) inch screen circular opening passing	100 per cent
No. 4 Sieve passing	85 to 100 " "
No. 16 " "	45 to 80 " "
No. 50 " "	5 to 30 " "
No. 100 " "	0 to 6 " "
Clay and silt removed by decantation test	Not over 3 " "
Coal	Not over 2 " "

Coarse Aggregate

Gravel or crushed stone shall be graded 3/8-inch to 3/4-inch, 95 to 100 per cent passing 3/4-inch mesh and 0 to 8 per cent passing 3/8-inch mesh.

Gravel

Gravel shall be clean, washed, free from clay or coating of any character and shall be tough and durable. Flat or elongated particles, soft stone, or shale or run of the bank gravel will not be permitted.

Crushed Stone

Crushed stone, if used as the coarse aggregate, shall be clean, sound, of uniform quality, and free from thin and elongated pieces. If obtained from gravel, only that portion shall be crushed which has been retained upon a screen with 2-inch or larger openings.

Water

The amount of water for mixing shall be approximately 5 to 6 gallons including the surface water in the aggregate for each sack of cement weighing 94 pounds. The amount of water used shall not produce a slump of more than 2 inches.

Mixing

The mixer shall not be charged until entirely emptied of previous batch. Rotation of mixer shall be 18 to 20 revolutions per minute. Timing shall not begin until all materials, including water, are in mixer, and shall continue for at least 1 1/2 minutes if mixer is equipped with automatic discharge lever locking timing device, or 2 minutes if mixer is not so equipped. No concrete shall be used which has been left in the drum of the mixer more than 10 minutes after the water has been added.

Placing

Concrete shall be placed and vibrated in place by means of a vibrating device acceptable to the engineer until all material is well settled and in close contact with the steel. The concrete shall be finished to a uniform surface even with the top of the steel without depressions or excess concrete covering the top of the steel.

If concrete is poured at a time when the temperature is 40° F. or lower, special care shall be taken to prevent freezing. The steel floor as well as the concrete shall be preheated to a temperature of 70° F. The contractor when so ordered by the engineer shall furnish and maintain a sufficient number of steam coils or other suitable heating devices together with tarpaulins to supply an adequate amount of moist heat.

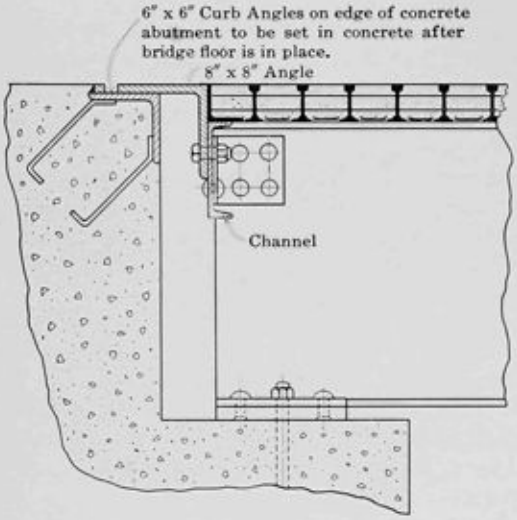
Finishing

Float at once, bringing surface to proper level as quickly as possible and then avoid further work, being especially careful to avoid unnecessary lateral movement of the mixture at the surface. Do not attempt to secure a smooth finish by floating the finer aggregate to the surface but allow as much coarse aggregate as possible to remain at the top and immediately become part of the wearing surface.

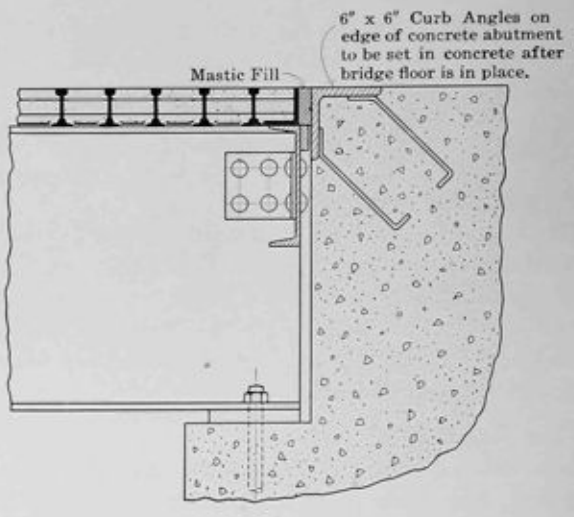
Curing

The slab shall be cured by means of a double thickness of burlap spread over the entire surface and kept moist during the entire curing period, or by other means at the discretion of the engineer, such as emulsified asphalt sprayed on immediately after concrete is placed.

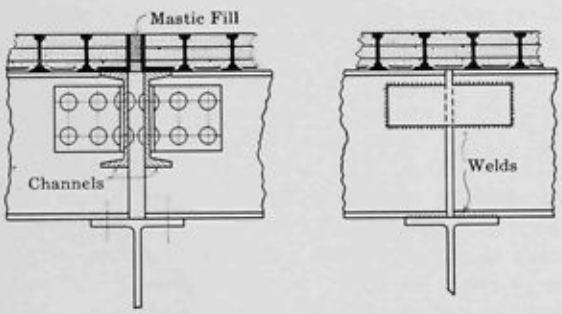
SUGGESTED DETAILS FOR SUPPORTING EDGES OF SLABS ON BRIDGES



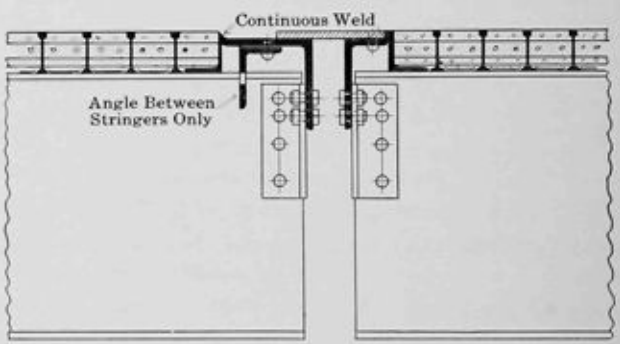
ARRANGEMENT FOR EXPANSION AT ABUTMENT*

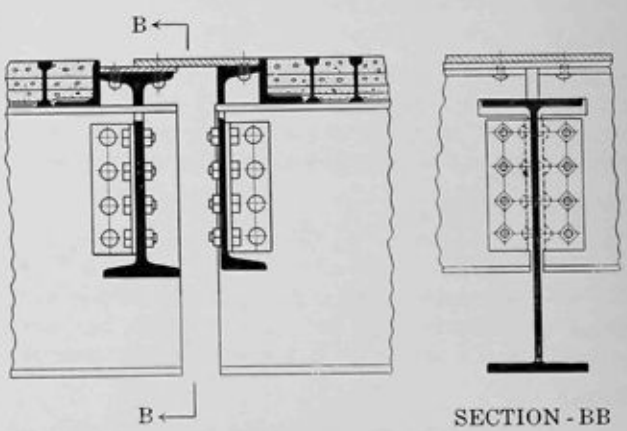


ARRANGEMENT OF FIXED END AT ABUTMENT*



ARRANGEMENT AT FIXED ENDS OF STRINGERS*

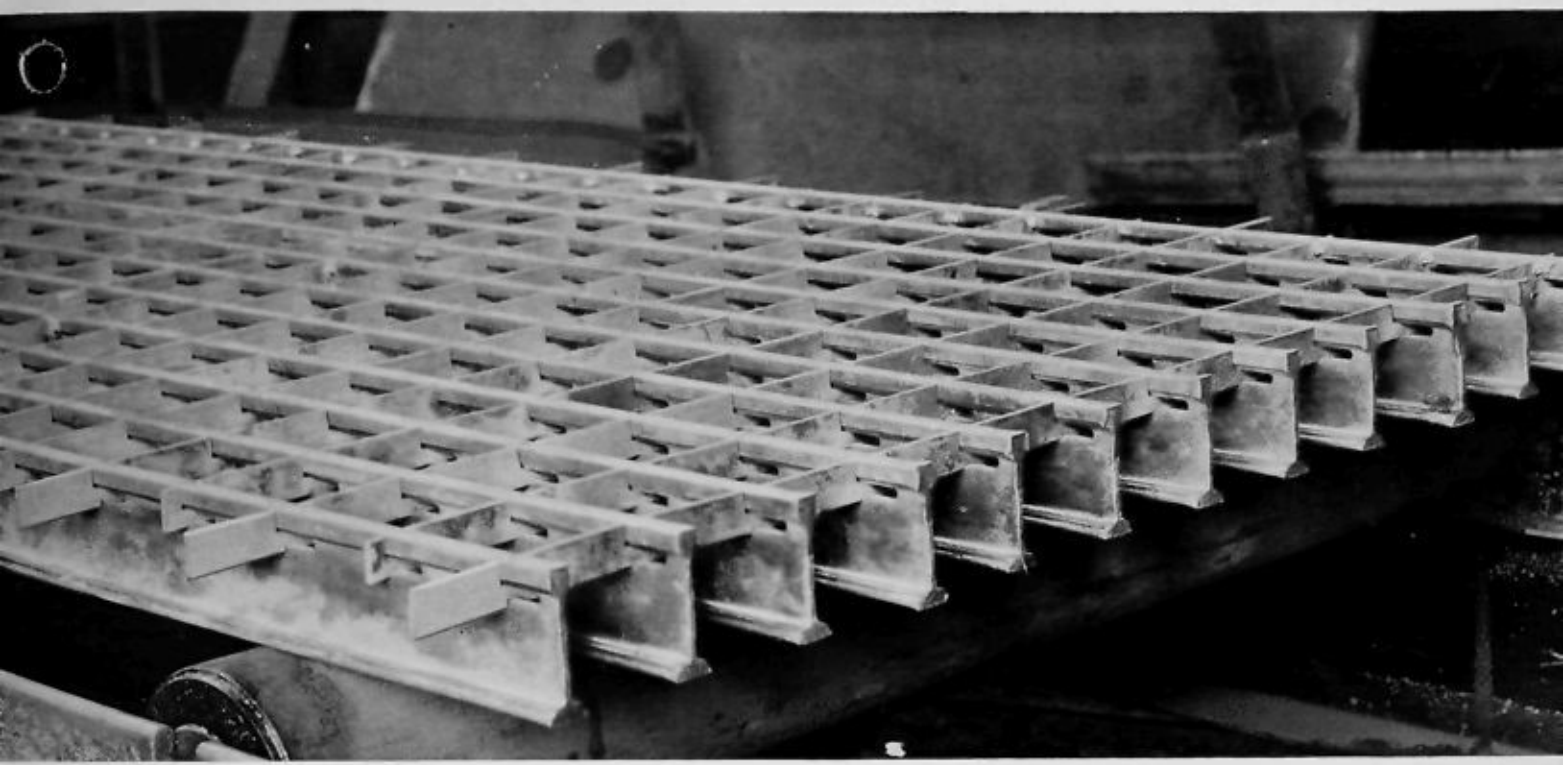




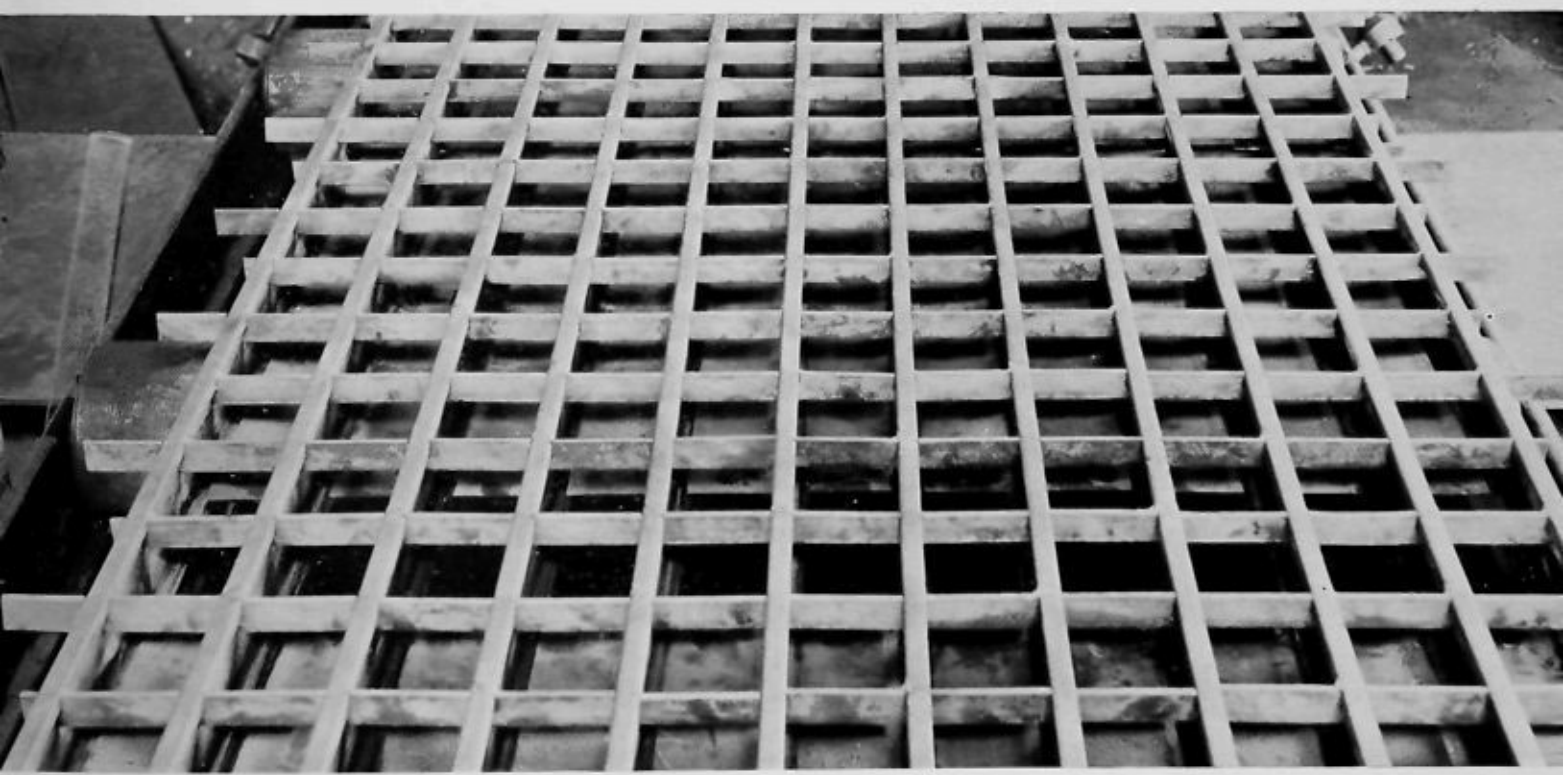
SECTION - BB

EXPANSION JOINTS*

*Where continuity is broken, framing at edges of slabs must be provided to resist one-half the moment produced by one wheel load plus impact, without considering distribution, when framing is parallel to I's in units. When framing is at right angles to I's in units, provide for resisting two-thirds of wheel load moment.

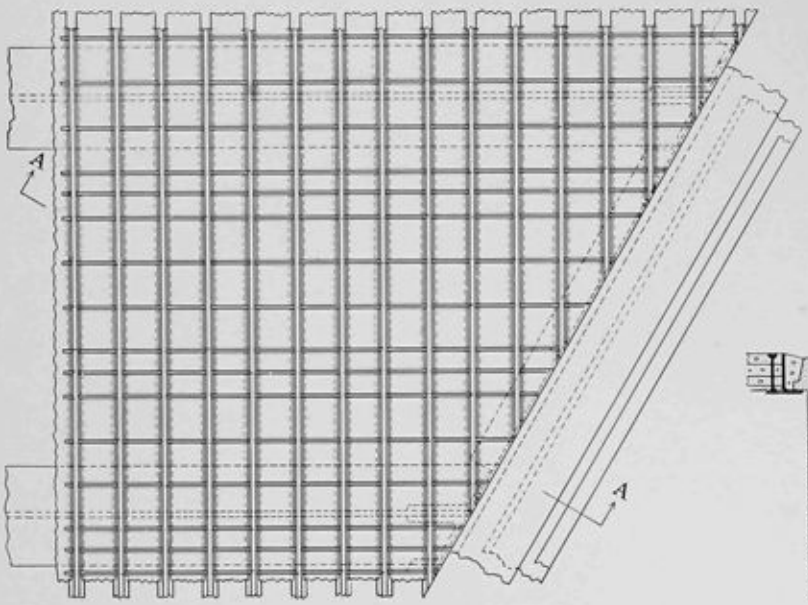


I-BEAM-LOK ARMORED UNIT READY FOR SHIPMENT

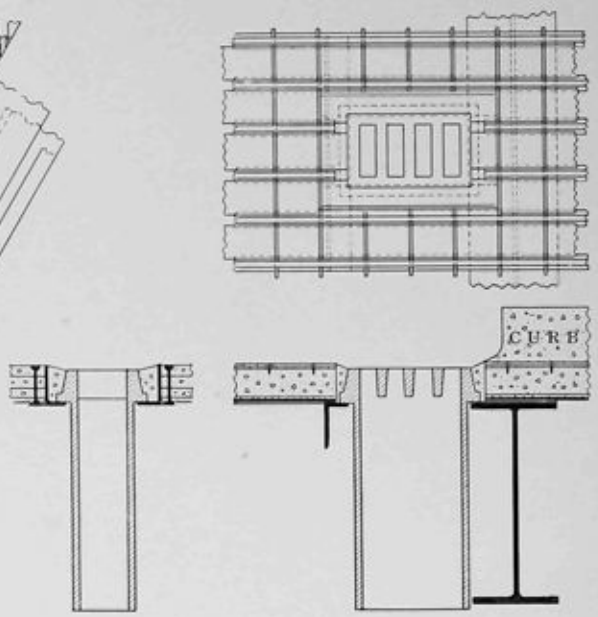


DETAILED VIEW OF TOP OF I-BEAM-LOK UNIT

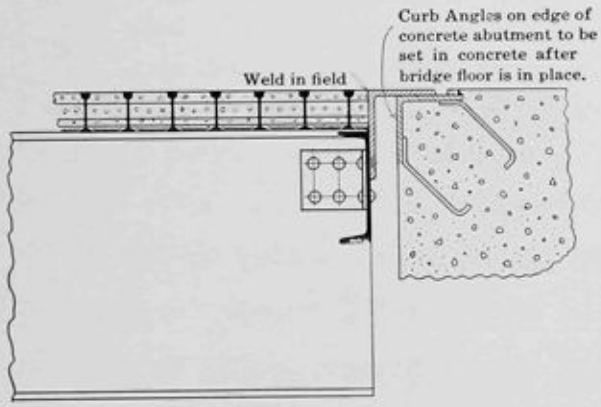
Showing Armored Surface formed by tops of I's and upper edges of intersecting cross bars. Note space where form strips are omitted to permit concrete to come into direct contact with supporting beam flange.



PLAN



DETAILS OF CAST IRON SCUPPER



SECTION A-A

SUGGESTION FOR FRAMING AT SKEWED END OF BRIDGE†

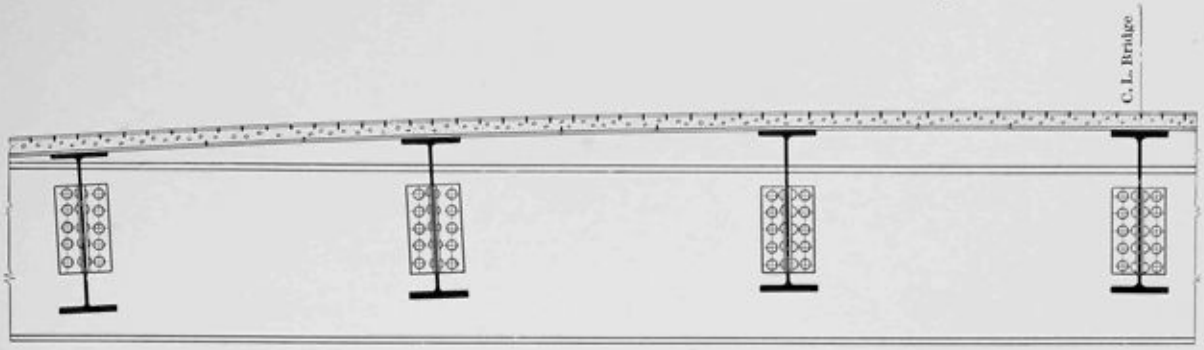


DETAILS OF STEEL PIPE SCUPPER

†On skewed ends framing must take two-thirds of wheel load concentration, including impact and assuming no distribution.

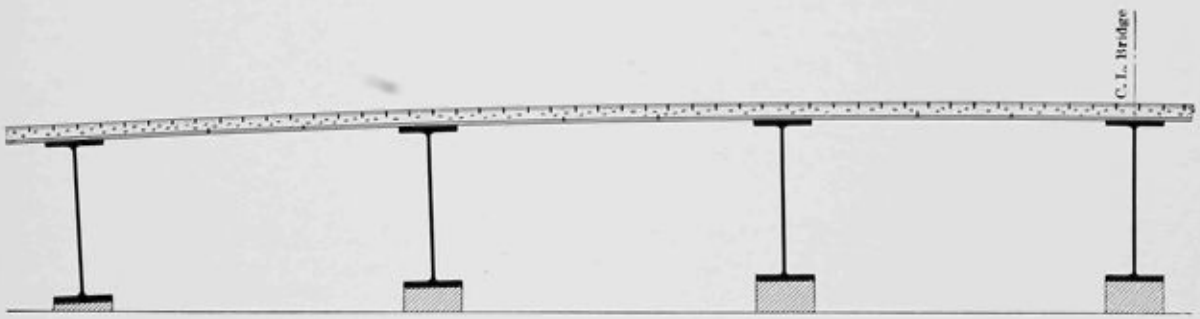
TYPICAL ARRANGEMENT OF STRINGERS FOR CROWNED OR CAMBERED BRIDGE FLOOR

Note that stringers are normal to roadway surface.
Crown or camber is shown greater than normal in illustrations in order to clarify details.

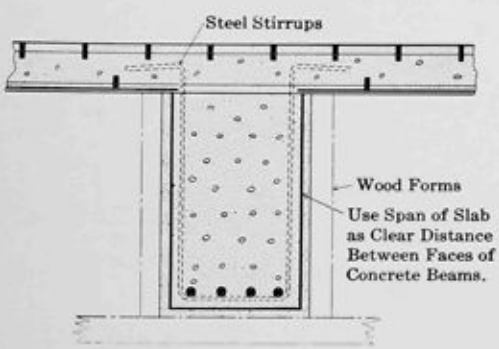


CANTED STRINGERS AND CONNECTION ANGLES

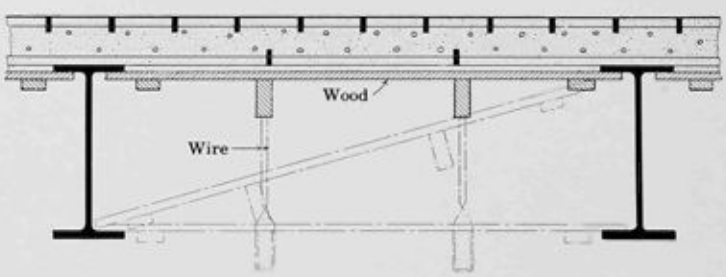
Note that rivet holes in floor beam are in both vertical and horizontal alignment.
Canting of stringers is accomplished by skewing rivet holes in outstanding legs of connection angles.



BEVELED OR STRAIGHT FILLERS UNDERNEATH

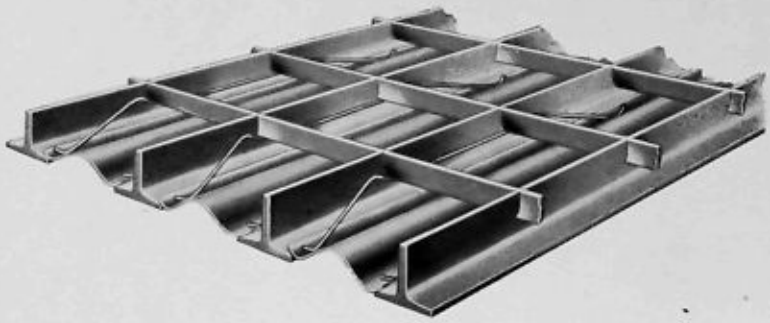


REINFORCED CONCRETE TEE BEAM, POURED MONOLITHIC WITH I-BEAM-LOK FLOOR OR ROADWAY SLAB



SIMPLE FORMWORK FOR ENCASEMENT OF BOTTOM FLANGES OF I-BEAM-LOK MEMBERS TO PROVIDE A SMOOTH ALL-CONCRETE UNDER SURFACE WHEN STEEL FORM STRIPS ARE OMITTED

BRIDGE SIDEWALK CONSTRUCTION

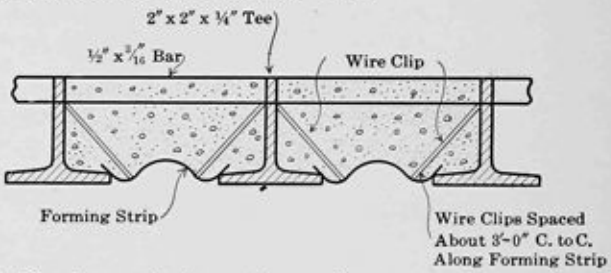


Construction for
Sidewalks, Building Floors and Lighter Roadways

For use where the strength of regular 3-inch and 3½-inch I-Beam-Lok is excessive, such as in sidewalks of bridges or over excavated areas adjacent to buildings, floors of factories or warehouses and garages, including ramps, and the decks of piers or wharves, we recommend 2-inch T-Tri-Lok construction. This light construction, weighing approximately 12.6 pounds per square foot for the steel alone, and 30 pounds for the finished slab when filled with ordinary concrete, or 25 pounds filled with Haydite concrete, offers a non-combustible, integrally armored surface slab to meet the requirements for comparatively lighter loads.

For 2-inch T-Tri-Lok, tees 2″ x 2″ x ¼″ are used with ½″ x 3/16″ cross bars, both tees and cross bars being spaced on 4-inch centers. This leaves a 2-inch opening between the edges of the tee flanges which is filled by a No. 20 gauge steel form strip held in place by No. 10 gauge wire clips.

This steel structure is shipped completely fabricated, and when filled with concrete flush with the top of the tees, produces a rigid armored slab similar to the heavier bridge roadway floor.



Tables shown below give unit stresses in steel and concrete for various spans and loads. The limiting spans are determined using the total load which is correct for total deflection. Complete details of T-Tri-Lok construction will be found in the 1933 edition of the T-Tri-Lok Booklet published by Carnegie Steel Company.

2″ T-TRI-LOK—UNIFORMLY LOADED
2″ x 2″ x ¼″ Tees, 4″ Centers. Concrete Flush.

Load, Lbs. per Sq. Ft.	SPAN IN FEET																	
	4′—0″		4′—6″		5′—0″		5′—6″		6′—0″		6′—6″		7′—0″		8′—0″		9′—0″	
	f_c	f_s	f_c	f_s	f_c	f_s	f_c	f_s	f_c	f_s	f_c	f_s	f_c	f_s	f_c	f_s	f_c	f_s
100	115	1101	145	1394	179	1720	217	2082	258	2477	303	2908	351	3372	459	4404	581	5574
150	172	1652	218	2090	267	2581	325	3123	387	3716	454	4361	527	5058	688	6606		
200	229	2202	290	2787	359	3441	434	4163	516	4955	606	5815	703	6744	918	8809		
250	287	2753	368	3484	448	4301	542	5204	645	6194	757	7269						
300	344	3303	436	4181	538	5161	651	6245	774	7432								
400	457	4404	581	5574	717	6882	868	8327										

n, ratio of modulus of elasticity of steel to concrete = 15.
Loads above heavy lines will not produce excessive deflections.

CARNEGIE STEEL COMPANY
PRODUCTS

BLAST FURNACE PRODUCTS

Basic Pig Iron
Bessemer Pig Iron
Ferro-Manganese

Ballast Slag
Bank Slag
Concrete Slag

Road Building Slag
Granulated Slag
Sand Slag

STEEL — CLASSES AND KINDS

Carbon
Open-Hearth
Bessemer

Alloy
Open-Hearth Alloy
U S S Stainless and Heat Resisting Steels

ROLLING MILL PRODUCTS

Semi-Finished Products
Ingots
Blooms
Billets
Slabs
Sheet Bars
Skelp (Wide and Narrow)

Structural Products
C B Sections
Standard Beams
Light Beams
Stanchions
Joists
H-Beams
Standard Channels
Ship Building Channels
Car Building Sections
Bulb Angles
Angles
Tees
Elevator Tees
Conductor Tees
Zees
Cross Tie Sections
Carnegie Steel Sheet Piling
Miscellaneous Sections

Plate Products
Sheared Plates—
- Rectangular
- Circular
- Sketch

Universal-Mill Plates
Base Plates for Columns and Machinery
Floor Plates

Fabricated Products
Steel Mine Timbers
Gangway Sets and Mine Props
Carnegie Steel Sheet Piling
H Bearing Piles
I-Beam-Lok Floor Construction
T-Tri-Lok Floor Construction

Railroad Track Products
Standard Rails, over 60 pounds
Light Rails, 60 pounds and under
Miscellaneous Rails
G E O Track Material
Angle Splice Bars
Fish Plates
Tie Plates
Frog Fillers
Reinforcing Bars
Screw Spikes
Track Spikes
Track Bolts and Nuts
Rail Clips
Cross Ties for Railroads
Cross Ties for Mine Track
Cross Ties for Portable Track

Wrought and Forged Steel Products
Axles—
- Untreated
- Annealed
- Quenched and Tempered
- Electric Railway Car
- Steam Railroad Car
- Locomotive Driving
- Locomotive Trailing
- Tender
- Mine Car
- Industrial Car
- Armature Shafts—Alloy
- Armature Shafts—Carbon

Wheels—
- Solid Wrought, Carbon Steel
- Untreated
- Rim Toughened
- Electric Railway
- Steam Railroad
- Industrial Car
- Mine Locomotive
- Industrial Locomotive
- Crane Track

Miscellaneous Circular Sections
Fly Wheel Blanks for Trucks
Brake Drums for Trucks
Heavy Forgings—
- Untreated
- Annealed
- Quenched and Tempered

Bar Products
Agricultural Implement Sections
Angles
Automobile Body Sections
Automobile Bumper Sections
Automobile Rim Sections
Barrel Sections
Bevel Sections
Cam Sections
Can Ring Sections
Casement Sections
Channels
Concrete Reinforcement Bars
Cooperage Steel—Tight and Slack
Crescents
Flat Blanks for Automobile Parts
Flats—Square Edge, Band Edge, and Round Edge
Grooved Flats
Half Ovals
Half Rounds
Hame Sections
Hexagons
Hoops
Key Sections
Locking Bar Sections
Magneto Sections
Neck Yoke Sections
Nut Sections
Ovals
Pipe Coupling Sections
Pole Cap Sections
Pole Sections
Round Cornered Squares
Rounds
Skelp—Bevel Edge and Scarfed
Slack Barrel Cooperage
Special Sections of Various Kinds
Spring Steel Sections
Squares
Tees
Window Sash Sections
Zees

COKE AND COKE BY-PRODUCTS

Blast Furnace Coke

Benzol—
- Industrial Pure
- Industrial 90%
- Motor

Toluol, Industrial Pure
Xylol, Industrial

Naphtha—
- Industrial Refined Light Solvent
- Industrial Crude Light Solvent
- Industrial Crude Heavy Solvent
- Industrial High Test

Ammoniacal Liquor
Ammonium Sulphate
Crude Naphthalene

Tar
Creosote Oil
Cresylic Acid
Phenol
Cresol

CARNEGIE STEEL COMPANY

General Offices, Pittsburgh, Pa. ..... Carnegie Building

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