# ANNEX C
# TECHNICAL STANDARDS FOR THE DESIGN AND CALCULATION OF RAILWAY BRIDGES

The Contracting Administration may approve the design of bridges made with other technical standards that are accepted in other countries, after careful analysis.

## I.CONCRETE

## II.METAL

# I. CONCRETE BRIDGES

## CONTENT

# TECHNICAL STANDARD FOR THE DESIGN AND CALCULATION OF CONCRETE RAILWAY BRIDGES

## 1. PURPOSE

This standard is to establish the technical provisions to be taken into account for the design and calculation of armed and prestressed concrete railways bridges.

## 2. OVERVIEW

The bridge project should be complete in itself, with all the details and specifications for the scheduled work, so as to allow, without further clarification, clear and concise interpretation of the proposed work in every detail. It shall also include the entire footage of the intended work adjusted to the set items according to the required specifications.

## 3. LENGTH OF THE BRIDGE

The designer shall ensure, according to the studied layout, location and length of the bridge and the drain required by the crossing watercourse. Unless stated otherwise, the bridge and its accesses will be unsinkable. The drain supplied for the bridge must be the minimum necessary to ensure adequate performance of the work, without causing excessive backwater or uncontrollable erosions due to the defense works scheduled, nor excessive water speeds that may cause harmful interference. The designer may, however, establish a different work schedule based on duly justified economic considerations or of any other kind.

## 4. SEAROOM

Searoom between the maximum estimated watercourse rising tide and the bridge superstructure, shall be determined by the designer according to the particular conditions of the work. The points to be considered are the potential floating items being washed away, navigation possibilities and the degree of accuracy for the maximum estimated rising tide in the project. In any case, searoom will never be less than 70 cm.

## 5. TRACK GAUGE AND SUPERELEVATION

### 5.1 Straight track gauge

the track gauge, free cross-sectional area, shall not be less than that indicated in Figure 1.

### 5.2 Track gauge and superelevation on curve

In curved plane bridges, in addition to the specifications in art. 5.1, a superelevation of the outer rail over the inner rail must be provided for, which is given by the expression:

$$h = 0.741 \frac{V^2}{R}$$

where:

h: superelevation in cm, with a maximum of 15 cm.
V: top train speed in km/h.
R: curve radius on the bridge, in meters.

In this case, furthermore, the size of the track gauge, 1.70 m, according to fig.1, will be replaced with a size of 2.10 m, unless otherwise specified.

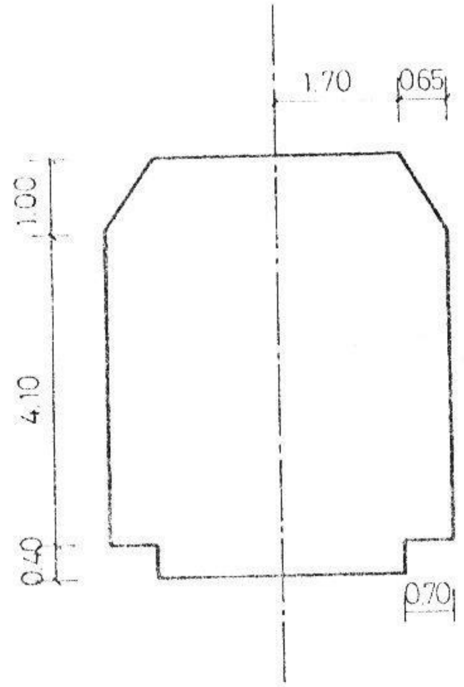



Figure 1.

## 6. TYPE OF STRUCTURE AND CLEARANCE

The designer will adopt the kind of structural solution that is more convenient from the functional, structural, economic and aesthetic point of view: assuming that above all, the bridge must have capacity and strength to accommodate and support traffic.

## 6. MATERIALS

The bridge structure must be designed in accordance with the guidelines set out in these regulations, to be built in simple, reinforced or prestressed concrete, with selected materials complying with the specifications set out in Section III of the National Roads Office Bidding documents for the construction of bridges and roads.

## 7. LOADS

The design and calculation of the bridge structure will take into consideration the following loads and stresses:

A) Main external:
8.1: permanent Load
8.2: moving load
8.3: Impact of moving load
8.4: moving load balancing
8.5: centrifugal force

B) Secondary external:
8.6: wind pressure
8.7: longitudinal forces
8.8: friction on supports
8.9: deviation and seating of abutments and piers
8.10: thrust forces
8.11: water underpressure
8.12: pressure of the water stream
8.13: mounting side effects and special effects.

C) Internal:
8.14: temperature variations
8.15: setting contraction and concrete slow flow

D) Other loads 8.16: special loads

8.1 Permanent Load

The permanent load consists of the weight of the structure and all fixed overloads.

8.1.1. Specific weight of the materials

In weight estimations, the following unit values will be used:

| | |
|---|---|
| Iron or rolled steel | 7850 kg/m$^3$ |
| Foundry | 7300 " |
| Unreinforced concrete | 2300 " |
| Reinforced or prestressed concrete | 2500 " |
| Cement of asphalt mortar | 2200 " |
| Bituminous concrete coating | 2400 " |
| Sand, gravel or ballast | 2000 " |
| Wood | 1300 " |
| Brick masonry, solid | 2100 " |
| Granite or limestone masonry | 2800 " |
| Compacted embankment or "in situ" land | 1800 " |
| Clay or earth filling, wet | 2000 " |
| Clay or earth filling, dry | 1600 " |

8.1.2. Weight of track materials

To estimate the loads produced by the set of track materials, the following values are used:

| | |
|---|---|
| Wooden sleepers | 200 Kg/ track linear m |
| Rails and little railway material | 150 " " " " |
| Check rails, re railers, etc. | 100 " " " " |

For the set of rails, sleepers, check rails and accessories, 450 kg per linear meter is the value used for each track.

8.1.3 Thickness of the ballast layer

If ballast is used for the construction of the track on the bridge, its layer thickness must be greater than or equal to 25 cm under the sleeper.

Conversely, if ballast is not laid, elastic supports will be provided between the track and the concrete to guarantee conditions of elasticity similar to those in the normal railway on the ballast.

## 8.2 Moving Load

### 8.2.1 Moving load on the track

Moving load for each railway shall be as shown in Figure 2, located in the most unfavorable position. For each project, the P value specified may not be less than 20 tonnes per axle.

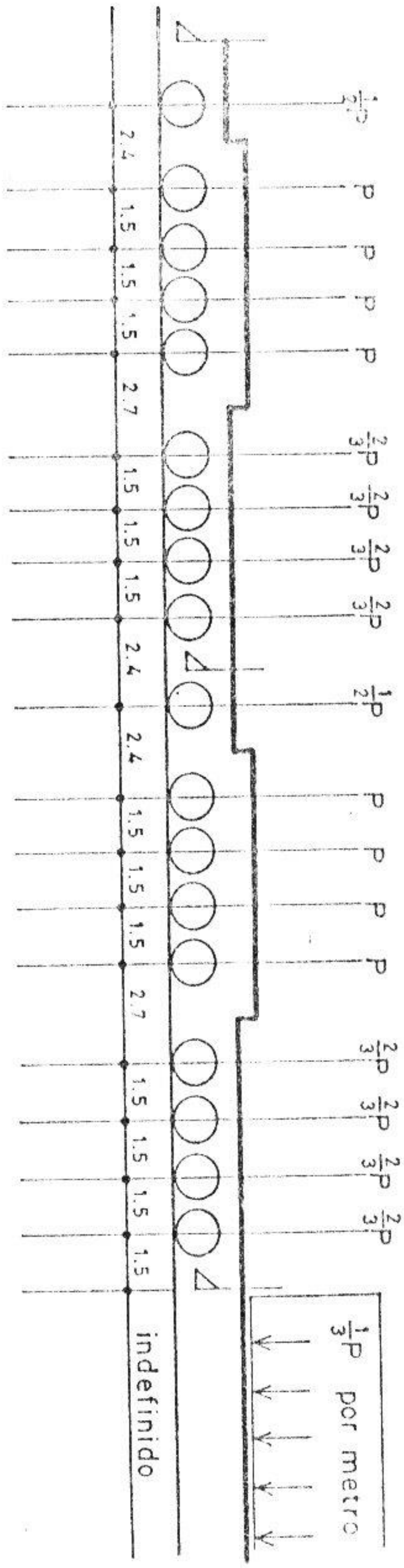



FIGURA 2 (Escala 1:200)

Figure 3 shows the weight loads corresponding to empty wagons, or otherwise, a uniformly distributed load of 1.7 tonnes per meter.

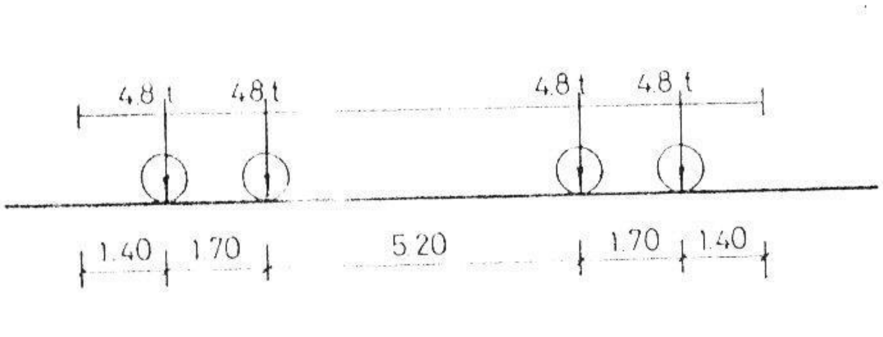



FIGURA 3 (ESCALA 1:125)

8.2.2. Moving loads on sidewalks and railings

In case of building footbridges, they are calculated with a moving overload of 400 kg/m$^2$ of sidewalk, without regard to the impact coefficient.

Sidewalk handrails and their studs will be designed to withstand a vertical force of 100 Kg per linear meter applied on their top and a horizontal force of 200 kg per linear meter applied to any level, chosen for each element so that it is the most unfavorable position.

The influence of the loads on the rail on the other elements of the structure is considered as that produced by a horizontal load acting at 90 cm above the level of the sidewalk, with a magnitude equal to 100 kg per linear meter.

## 8.3 Impact of moving load

To calculate the stresses of all the elements of the superstructure the dynamic effect of moving loads shall be taken into consideration, multiplied by a factor of impact. Calculations without considering the impact factor include: centrifugal force, balancing, braking, startup and footbridges overload.

The abutments, pillars, if not rigidly attached to the superstructure, foundation and ground pressure are calculated without considering the dynamic coefficient.

For the calculation of support and joints, whether concrete, steel, neoprene or any other accepted material, the impact coefficient corresponding to the part of the construction supported or suspended, will be considered.

The impact coefficient will be calculated using the following formulas:

for bending moments: $I = \dfrac{2.16}{(L_0)^{1/2} - 0.2} + 0.73$

for shear stresses: $I = \dfrac{1.44}{(L_0)^{1/2} - 0.2} + 0.82$

Always meet $1 \leq I \leq 2$

$L_0$ is measured in meters and it is the length of the influence line for the bending of the element considered. For asymmetric influence lines, $L_0$ is twice the distance between the point of maximum deflection and the nearest end of the influence line. In the floor elements, 3m will be added to the length of the influence line to take into account the load distribution on the tracks.

The most appropriate recommended values for $L_0$ are the following:

] Simply supported ……….. clearance for beam calculations.
MAIN BEAMS [ Continuous two-span … 1.2 x L*
] " " three-span … 1.3 x L*
[ " " four-span … 1.4 x L*
] " " 5-span and more 1.5 x L*
[Arches and gantries …… 1/2 of the clearance

where L* is the average clearance of the span calculations

| | | |
|---|---|---|
| FLOOR BEAMS | [ rail supporting beams | Separation over crossbeams plus 3 meters. |
| | [ Crossbeams loaded due to ] rail supporting beams | Twice the separation over main beams plus 3 meters. |
| | ] end crossbeams | 4 m |
| | ] Crossbeams loaded by [continuous deck elements ] and any other elements | The least clearance of the main beams or twice the separation over the main beams. |

These dynamic factors are applied to all types of tracks.

For arch bridges and solid bridges of any kind, with a filling height greater than 1m, the dynamic coefficient can be reduced by the value 0.1 x (Hc - 1), where Hc is the filling height including the ballast, up to the sleeper upper level, in meters.

8.4 Balancing of moving load

Due to balancing effects and side impact against the rail, a single horizontal force will be considered, perpendicular to the axis of the bridge and applied at any point in it, at the height of the rail. Its value will be equal to 1/3 P, without impact coefficient, and vertical effects will be disregarded. The P value is indicated in art. 8.2.1.

8.4 Centrifugal force

In curved plane bridges, a centrifugal force will be considered, applied horizontally to 1.80 m above the rail, perpendicular to the axis of the track and whose value is given by the formula:

$$Fc = \frac{P.V^2}{R}$$

where:

Fc: centrifugal force produced by an axial load P in an axle, in tonnes.
P: axial load transmitted by the heaviest axle in tonnes (without impact coefficient).
V: top train speed in km/h.
R: curve radius in meters.

This force will not be added to that of balancing, considering only that of the two which is most unfavorable.

8.5 Wind pressure

Generally speaking, unless the characteristics of the structure require other considerations, it is admitted that wind acts horizontally and in two main directions: parallel and perpendicular to the bridge axis.

Two situations are considered:

a: bridge without load ……… wind pressure = 250 $Kg/m^2$

b: loaded bridge …………… wind pressure = 150 $Kg/m^2$

The area of action of these pressures is determined according to the actual dimensions of the components of the structure, using the following criteria:

8.6.1 Crosswind on the superstructure

The surface of the wind perpendicular to the axis of the bridge, on the superstructure is:

a: in bridges without load

a.1 - In closed section beam bridges: the anterior surface of the main beam and the protruding surface of the deck.
a.2 - In bridges with shed beams: the deck surface and the parts of these beams exceeding the upper or lower part of the deck.

b: in loaded bridges

b.1 - In closed section beam bridges: the anterior surface of the main beam and the protruding deck surface and running train.
b.2 - In bridges with shed beams: the deck surface and the parts of these beams exceeding the upper or lower part of the running train. The arches protruding the deck are treated as shed beams.

8.6.2 Longitudinal wind on the superstructure

The surface wind action parallel to the axis of the bridge over the superstructure shall be obtained by taking the following percentages of the values in art. 8.6.1, both for bridges without load and loaded bridges.

1. - In closed section beam bridges …………………… 25%
2. - In shed beam bridges……………………………..…. 50%

8.6.3 Wind on piers and abutments

For solid piers, it is considered their surface section exposed to the direction of the wind.

In the other cases, the criteria used are those in art.
8.61 a.1 and a.2

8.6.4 Wind on moving load

To estimate the effect of the wind on the train, it will be assumed the train consists of a rectangle equal to the length of the bridge, 3.40 m high, and whose center of gravity is 2.20 m above the rail.

8.6.5. Wind forces on arch bridges

The influence of wind forces need not be checked in top arch bridges when these are projected as a single continuous vault and the width of the dome is larger than 1/10 of the distance between supports.

Independent arches can be considered as a single vault, when isolated parts of the dome are mutually reinforced by transverse trusses, resulting in a combined supportive effect on the wind load.

In top arch bridges the influence of the wind must always be checked.

8.7 Acceleration, braking and startup forces

The set of effects caused by acceleration, braking and startup of the moving load is considered equal to that produced by a horizontal force equal to 15% of that, applied to 1.80 m above the rail and contained in the vertical plane passing through the center of the track, regardless of the impact coefficient.

8.8 Friction on supports

In the calculation of supports, pillars and brackets, the braking effect and rubbing effort of moving supports will be added, admitting 20% for sliding friction, 20% for running friction and 3% for the reaction in the supports, this reaction being produced by the permanent load and the moving overload without impact.

Stresses produced by deformation of the elastomer supports must also be considered.

8.9 Deviation and seating of abutments and piers

These effects should be considered when, according to the nature of the structure, they can produce additional stresses.

8.10 Thrust forces

The project will consider the pressures that may be caused by the land masses supported by certain parts of the structure, such as the brackets. When the moving overload reaches a distance from the top of a retaining wall less than or equal to half its height, the overload transmitted must be considered, without impact coefficient.

The moving overload may be replaced by an equivalent ground load of height h above the top edge of the sleepers, which will correspond to the train type adopted.

1.8 t/m$^3$ will be taken as the specific weight of the ground and the angle of internal friction between wall and ground will be $\varnothing = 0°$. The pressure due to the train load is distributed over a width equal to the length of the sleeper, with slopes of base 1 and height 2, (1:2).

Stability will be checked for the case in which the natural ground or embankment is waterlogged.

Security against the tipping and/or sliding value should be at least 1.5.

However, adequate drainage must be provided.

To calculate the thrust on pillars or similar elements, one will take a notional width equal to 3 times the actual width of the piece.

8.11 Water underpressure

In case of piers and brackets submerged or that may become submerged, the corresponding underwater pressure will be taken into consideration for stability calculations.

8.12 Pressure of the water stream

Piers and other elements of the structure that may be subjected to the pressure of the water stream, will be projected considering a pressure determined by the expression:

$$P = K.V^2$$

where:

P = pressure in $kg/m^2$

K: shape coefficient

with K having the following values:

K = 70: for rectangular section piers
K = 26 : for pillars with triangular abutment at its apex forming an angle no greater than 60 sexagesimal degrees.
K = 35 : for circular section piers

8.12 Mounting side effects and special effects

Where appropriate, the influence of secondary stresses induced by previous loads will be calculated, verifying the loads at different stages of the construction process as well.

8.13 Temperature variations

To calculate stresses and deformations, a temperature variation of ±15°C will be considered. This temperature variation may be decreased to ±10°C for parts whose minimum size is greater than 70 cm or due to fillings or other provisions, are less exposed to temperature variations.

In establishing the minimum dimensions there is no need to deduct fully enclosed spaces (e.g. hollow sections in box-shaped beams) provided they do not occupy more than 50% of the corresponding total section.

The uneven heating in different parts of a piece will be considered taking a difference of ±50°C.

8.14 Setting contraction and concrete slow flow

When the nature and characteristics of the structure so require, the following effects must be considered:

1: setting contraction
2: concrete slow flow

8.15 Special Loads

According to the nature of the structure, the appropriate loads and stresses must be considered.

## 9. ROLLOVER STABILITY

There must be verification of stability to overturning of all parts of the work that must be secured with a safety coefficient not less than 1.5, mainly due to wind effect.

As an exposed strip of traffic on loaded bridges, a series of empty wagons are considered in the most unfavorable position forming a continuous set with the heights indicated in art. 8.6.4 and an equivalent vertical load of 1.7 t/m. In bridges with side cantilevers the normal load in its most unfavorable position can be decisive.

## 10. SAFETY AGAINST THE LIFTING OF SUPPORTS

In continuous beams (with or without joints) and cantilevers, security against the lifting of supports shall be verified, with a safety coefficient not less than 1.5.

## 11. EFFECTS CAUSED BY CRASH OF OBJECTS, VEHICLES OR VESSELS AGAINST THE SUPPORT STRUCTURES

On the streets in the lower passages of railway bridges and in which the support structure is not protected, either by their situation or that of the vehicles traveling on the road (the curb does not offer any protection), the following forces have to be considered: a horizontal static force of 100 tonnes applied to 1.20 meters above street level acting in the direction of traffic and another static horizontal force of 50 tonnes also applied to the same height but acting in the normal direction. These shock forces are considered together with the other forces, except the wind pressure.

The armor of the reinforced concrete structure may be stressed to runoff limit and plain concrete structures to double the allowable stress.

In bridges over navigable rivers, all previous considerations are valid, but to determine the value of the force each case will be studied separately, taking into consideration river flow and type of vessels.

In bridges over non navigable rivers, effects that may be relevant in the calculation of structures will be taken into consideration.

## 12. EXISTENCE OF MULTIPLE TRACKS

In bridges with several tracks, the following reduction in moving overload can be applied:

1) For the construction of one or two tracks, the load scheme is fully applied to each track.
2) For the construction of more than two tracks, the most unfavorable case will be taken between:
   a) Two tracks loaded using the whole scheme, in the most unfavorable position and the other tracks without load.
   b) All tracks loaded using 75% of the load scheme in the most unfavorable position.

## 13. CALCULATION REPORT

Calculations must have enough data about:

a. Loads serving as the basis according to load hypotheses;
b. Weights of all the essential parts;
c. Impact coefficients serving as bases for calculations;
d. The type and characteristics of the building materials to be used and the planned foundation soil under the soil survey carried out. The soil and foundation survey report is part of the calculation report;
e. The shapes of the sections and dimensions of all essential construction parts;
f. Allowable and maximum tensions or safety coefficients calculated for all major sections. Resistance calculation must also be extended to support pieces, ground compressions and possible joints;
g. Most unfavorable tension limits or safety coefficient values for all major sections. Resistance calculation must also be extended to support pieces, ground compressions and possible joints;
h. In cases where prefabrication techniques are used, the different parts of the structure, the joints, the assembly sequence, the link between the prefabricated elements and the precast concrete as well as the spatial stability of the whole set, shall be provided;
i. Description of the construction method providing the load capacity, stability and steepness of the formwork or the special building aids adopted, concreting process, stripping and assembly.

## 14. CALCULATION DETAILS

### 14.1 Calculation method

Structural calculations and their dimensioning must be clear and presented in a simple way to check, with the designer choosing the methods and standards to use so that each structural calculation and dimensioning will be a complete set in itself.

### 14.2 Origin of formulas

The origin of formulas or special calculation procedures will be provided when they are in the general domain, otherwise, formulas will be developed to be reviewed for accuracy.

### 14.3 Computer-based calculations

In the event that structural calculations have been made by computer, the origin and designation of the program must be provided as well as its elastic and numerical methods; assumptions and simplifications taken into account in the preparation of the program; assumptions and simplifications of the program itself for the case in point; etc.

### 14.4 Most unfavorable loads position

The most unfavorable positions of the moving loads are determined by lines of influence or other procedures. Moving loads that produce an unload effect and all axle loads of vehicles leading to a favorable effect are suppressed. For gantries or similar monolithic structures the influence of uneven ground compressions shall also be taken into account as a result of a unilateral moving load. However, this can be disregarded for great filling heights. The maximum and minimum possible active compression of the land and, if necessary, the lifting force in the piers and abutments will be examined.

## 14.5 Calculation conditions

In any concrete bridge calculation of the following conditions must be met:

a) Tensions caused by the major internal and external loads will not exceed the allowable stresses.
b) Tensions of the whole load will not exceed those obtained by multiplying the allowable stresses by a 1.2 factor.

## 14.6 Variable efforts

If efforts at some point of the structure may change sign by some combination of the various loads, that is, it is subject to alternative efforts, basic allowable stress of the steel at that point will be obtained dividing the allowable stresses used in accordance with the adopted Dimensioning Standard, by the following value:

$$\delta = 1 + 0.5\ \varphi$$

where: $\varphi = \dfrac{\text{minimum effort in absolute value}}{\text{maximum effort in absolute value}}$

## 14.7 Distribution width for moving loads

Regarding deck slabs, the concentrated forces caused by the moving load can be uniformly distributed considering the width of the sleeper and the thickness of the ballast. Under the above, the concentrated loads may be considered distributed over the deck, in rectangular sections defined as follows:

Lengthwise: 0.90 m + the thickness of ballast under the sleeper. At most, separation between loads will be considered.

Transversely: 4.00 m for each track, except for structural restrictions. For fillings over 1.50 m, this value can be increased to 2.50 m plus the filling depth.

For bridges without ballast, the wheel load will be taken as divided into the support structure through the sleeper at 45°.

PROJECT PRESENTATION

The original project will be presented on canvas drawn with ink, with 1.10 x 0.50 m sheets, besides all other details necessary to complete the project, and it must include:

1) A view of the bridge projected on a vertical plane parallel to the axis and a foundation layout drawn to a scale not less than 1/200. The important elements of the structure will be planimetrically and altimetrically located.
2) The drawings have to show the details of the structure and its accesses, indicating reinforcements, detailing the location of the splices allowed, the position of the various parts, their surfacing, etc. The working joints allowed in the construction will also be established.
3) The necessary complementary specifications will be described according to the Bidding Documents.

All sheets and other requirements to present must bear the designer's signature.

# STANDARD FOR THE CALCULATION OF METAL RAILWAY BRIDGES

INDEX

# 1. GENERAL

## 1. 1 Purpose

This standard is intended to codify the technical provisions concerning both the project and the strengthening of metal railway bridges.

## 1. 2 Track gauge and superelevation

a) The track gauge, free cross-sectional area, shall not be less than that indicated in Figure 1.2.1.

b) In curved plane bridges the outer rail superelevation is given by the expression

$$S = a \frac{V^2}{R}$$

where a = 0.725

where:

S : Superelevation in cm with a maximum of 15 cm.
V: Top train speed in km/h.
R: Curve radius on the point, in meters.

In addition, in this case the dimension 1.70 meters of figure 1.2.1 for the gauge will be replaced by 2.10 meters unless otherwise specified.

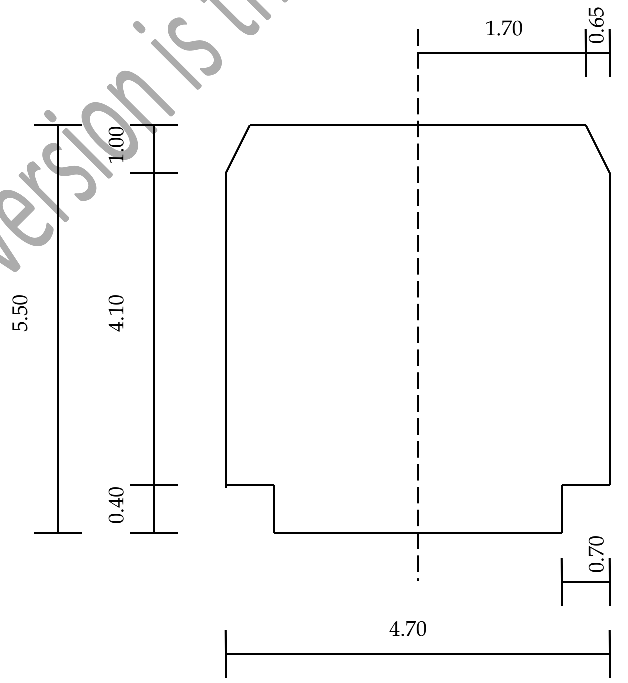



Figure 1.2.1

1. MATERIALS

2. 1 Project materials

The materials used must comply with the proper UNIT standards.
While these standards are not drawn up, the following are adopted:

a) Structural steel: A.S.T.M. : A – 7 for profiles and A – 141 for rivets.

In no case will the strength characteristics be less than the following:

| Characteristic | Profiles and metal | Rivets |
|---|---|---|
| Breaking stress | 37 $Kg/mm^2$ | 35 $Kg/mm^2$ |
| Yield point | 23 $Kg/mm^2$ | 20 $Kg/mm^2$ |
| Ductility (5 d) | 25% | 30% |

b) Molten steel: A S T M: A - 27. Its minimum requirements are the same as the previous one.

c) Special steels: Their use as well as the increase in the basic allowable stresses, must be specifically authorized. Their features will be adjusted, as far as possible, to the following standards:

A S T M: A - 242 for low alloy steel.
A S T M: A - 94 for silicon steel.
A S T M: A - 8 for nickel steel.

Steels whose breaking stress is less than one and a half times the yield point, will not be allowed.

d) Foundry: A S T M: A - 48

e) Aluminum: Its use must be expressly authorized, taking the allowable stresses based on the tests the contractor must make in the Materials Testing Institute of the Engineering University of Montevideo. In no case will material be allowed with inferior characteristics than the following:

Breaking stress : 30 $Kg/mm^2$
Proportional limit : 25 $Kg/mm^2$
Ductility (5d) : 15%

2. 2 Reinforcing materials

If the material of the bridge to be reinforced is one of those described above, the reinforcing elements will be of the same material. Otherwise, existing material having the most similar (thermal and elastic) characteristics to the bridge material, will be used.

In this case, the calculation is performed for the most unfavorable material characteristics, taking into account the inhomogeneity.

# 3.- LOADS

## 3. 1 General

For bridge calculations the following loads and forces must be considered:

A. Main:

A - 1: Permanent Load.
A - 2: Moving Load.
A - 3: Impact of moving load.
A - 4: Balancing of moving load.

B. Secondary:

B - 1: Wind pressure.
B - 2: Centrifugal force.
B - 3: Longitudinal forces (braking and acceleration of the moving load).
B - 4: Temperature variations.
B - 5: Side effects from the main loads.
B - 6: Mounting side effects and special effects.

The stresses produced by each of these loads and forces will be placed in a separate table of stresses.

## 3. 2 Permanent load

In estimating weights to determine the stresses produced by the permanent load, the following unit weights will be used:

| | | |
|---|---|---|
| Steel | 7,850 | Kg/m³ |
| Foundry | 7,200 | " |
| Concrete, macadam | 2,400 | " |
| Sand, gravel, ballast | 2,000 | " |
| Granite | 2,800 | " |
| Wood, sleepers | 1,300 | " |

For the set of rails, sleepers, check rails and accessories, 450 kg per linear meter is the value used or each railway.

## 3. 3 Moving load

a) Moving load for each rail shall be as shown in Figure 1, located in the most unfavorable position. For each project the P value to be used is specified, which in no case may be less than 18 tonnes.

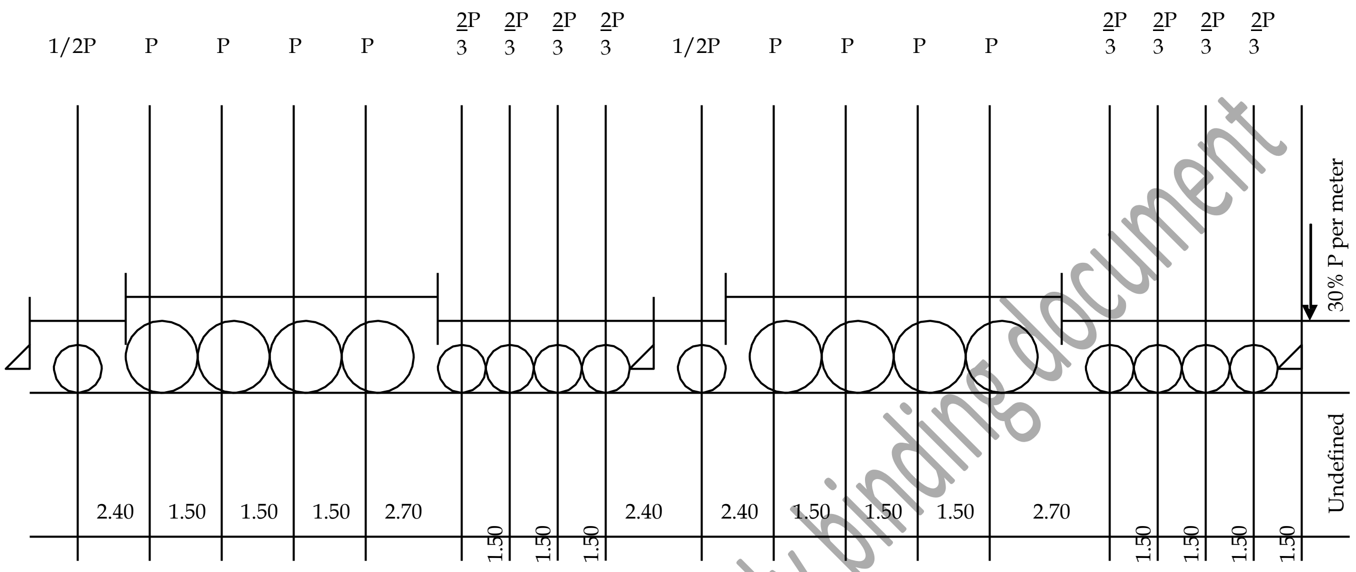



Fig. 3.3.1

b) The moving load for each track for the study of bridge reinforcement will consist of two coupled units of an expected running locomotive, followed by a linear load of 5000 kg/m.

The type of locomotive is determined so that the train formed produces the maximum effort in its most unfavorable position, including impact.

3. 4 <u>Moving load impact</u>

The effect of moving load impact (irregularities in the track, train impact, speed and hammering effect) is considered equal to that produced by a percentage of that impact given by the values shown below:

| | |
|---|---|
| a) Steam locomotives: In general: | $60 - (L^2 / 45)$ for $L < 30$ m |
| | $10 + (540 / (L - 12))$ for $L > 30$ m |
| For the calculation of trusses: | $15 + (1200 / (L + 7.5))$ for all L |
| b) Diesel, electric or mixed locomotives: | $40 - (L^2 / 48)$ for $L < 24$ m |
| | $16 + (180 / (L - 9))$ for $L > 24$ m |

L: section clearance in meters between support axes.

3.5 Balancing of moving load

Due to balancing and side impact effects against the rail, two types of loads are considered:

a) Vertical load acting downward on a rail and upwards on the other, each equal to 10% of the moving load.
b) Single horizontal force, perpendicular to the axis of the bridge and applied at any point in it, at the height of the rail. Its value will be 1/3 P and its vertical effects will be disregarded.

3.6 Wind pressure

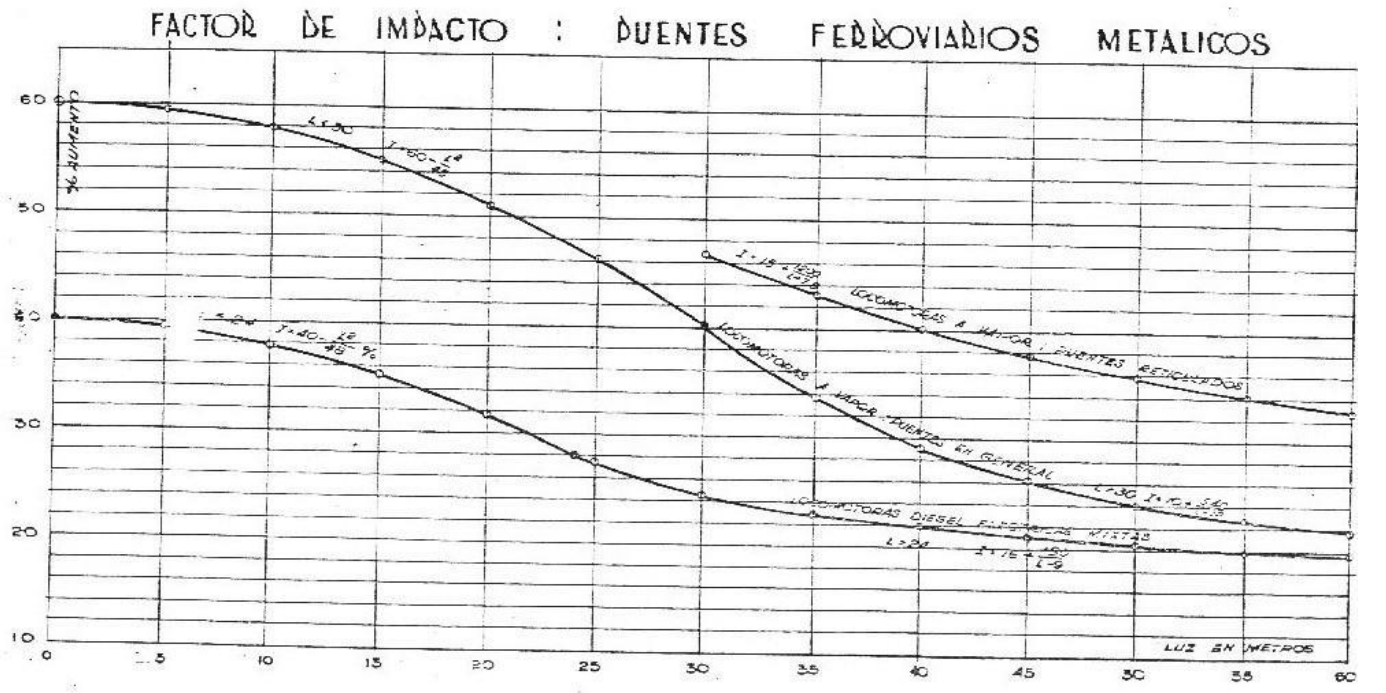
a) Loaded bridge. On the bridge a horizontal lateral pressure of 150 Kg/m$^2$ with a minimum of 300 Kg/m is considered.
On the unloaded train, a horizontal lateral force of 450 kg/m applied 2.40 m over the rails is considered.

b) Unloaded bridge. A lateral horizontal pressure of 250 Kg/m$^2$ is considered.

c) The following will be considered exposed areas:

| | |
|---|---|
| Plate beams | 1 ½ times the area of the vertical projection |
| Shed beams, trusses | 1 vertical projection beam, plus all the deck emerging part |





3.7 Centrifugal force

In curved plane bridges a centrifugal force will be considered, applied horizontally 1.80 m above the rail, perpendicular to the axis of the track, and whose value is given by a percentage of moving load equal to: $V^2/R$.

Where:

V: top train speed in km/h
R: curve radius, in meters

3.8 Longitudinal force

The set of effects caused by accelerations and decelerations of the moving load is considered equal to that produced by a force equal to 15% of that, applied to 1.80 m above the rails and contained in the vertical plane passing through the center of the track.

3.9 Temperature variations

a) To calculate stresses and expansions, a temperature variation of ± 35° C and a thermal expansion coefficient of 0.01 mm per meter and degree Celsius, will be adopted.
b) All nominally isostatic sections with clearance under 20 meters, shall have a sliding support of smooth surfaces, one of them preferably convex. For clearance over 20 meters both ends must be articulated and one of them provided with rollers or hangers.

3.10 Mounting side effects and special effects

a) Bridges will be designed in such a way that secondary stresses created by the main loads are minimal. In general, those produced by deformation of trusses will be considered only in bars where $l/a > 10$

   where:

   l: length between bar supports
   a: section width, perpendicular to the deformation plane

b) In cases where the type of structure and assembly technique so justifies, calculation of stresses and deformations have to be carried out. It should also be calculated, if necessary, special stresses produced by the interaction of the various elements of the structure or by other causes.

# 4.- STRESSES

## 4.1 Basic allowable stresses

The values given in Table I, expressed in Kg/cm², will be called basic allowable stress, regarding stress and the respective material.

| Stress | Element | Material: Structural steel | Molten steel | Special steels | Foundry |
|---|---|---|---|---|---|
| Traction | Plates and rods (net section) | 1250 | 1000 | 0.5 $\sigma_s$ | |
| | Rivet shank (nominal section) | 650 | 500 | 0.25 $\sigma_s$ (*) | |
| | Bolt rods and threaded parts (net section) | 1250 | 100 | 0.5 $\sigma_s$ (*) | |
| | Bead welding | 750 | 0 | | |
| | Butt welding | 1000 | 800 | | |
| Compression | Overall (gross section without buckling) | 1250 | 1250 | 0.5 $\sigma_s$ | 850 |
| | Bead welding | 800 | 800 | | |
| | Butt welding | 1000 | 1000 | | |
| Bending | Metal sheets and profiles end axes | 1250 | 1000 | 0.5 $\sigma_s$ | 250 (*) |
| | Hinge pins end axes | 2000 | 1500 | 0.75 $\sigma_s$ (*) | |
| | Bead welding | 750 | 600 | | |
| | Butt welding | 1000 | 800 | | |
| Cut | Beam plates (gross section) | 750 | 600 | 0.3 $\sigma_s$ | 250 (*) |
| | Machine placed rivets | 900 | 700 | 0.35 $\sigma_s$ (*) | |
| | Turned and adjusted bolts | 900 | 700 | 0.35 $\sigma_s$ (*) | |
| | Rivets placed by hand | 700 | 550 | 0.3 $\sigma_s$ (*) | |
| | Bead welding | 650 | 500 | | |
| | Butt welding | 800 | 600 | | |
| Crushing | Bolts | 1500 | 1500 | 0.6 $\sigma_s$ (*) | |
| | Machine rivets, studs | 1750 | 1750 | 0.7 $\sigma_s$ (*) | |
| | Hand rivets, turned bolts | 1250 | 1250 | 0.5 $\sigma_s$ (*) | |
| | Among hangers and their joints | 850 | 850 | 0.35 $\sigma_s$ | |
| | Rollers and convex surfaces, in Kg/cm in length for R: radius in cm | 80 R for R from 5 to 30 cm<br>440 $R^{1/2}$ for R from 30 to 150 cm | | Structural steel values by $\frac{\sigma s - 900}{1400}$ | |

Table I

(o)$\sigma_s$: yield point in Kg/cm²
(*) with express authorization

## 4.2 Variable efforts

When efforts in some bar or part of the structure may change sign by some combination of the various loads, that is, it is subject to alternative efforts, basic allowable stress of these elements is obtained by dividing the table of art. 4.1 by a coefficient:

$$\gamma = 1 + 0.50\ \varphi$$

Where:

$$\varphi = \frac{\text{minimum effort in absolute value}}{\text{maximum effort in absolute value}}$$

4.3 Stress values needed for calculations

a) In any bridge calculation, all the following conditions must be met:
   A) Tensions caused by the major loads will not exceed the basic allowable stresses.
   B) Tensions of the whole load (main and secondary) will not exceed those obtained by multiplying the allowable stresses by a 1.2 factor.

b) For the calculation of reinforcement bridges other than those considered, yield and break tests will be carried out. They may be taken as the basic allowable stresses for special steels as long as the yield stress considered $\sigma_s$ is the lesser of the following values:
   A) Minimum flow limit given by test results
   B) 75% of the minimum breaking stress given by test results

c) To calculate the masonry bearing surface, the following allowable stresses will be used:

   Pressed brick with cement mortar: 20 Kg/cm²
   Sandstone or limestone: 40 Kg/cm²
   Concrete: 45 Kg/cm²
   Granites: 60 Kg/cm²

4.4 Complex elastic states

When it is necessary to study the safety of regions subjected to complex elastic states, the following resistance criteria are used:

a) Double elastic state:
   $\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2 <= \sigma_{adm}^2$

b) Triple elastic state:
   $\sigma_1 - \sigma_2 <= \sigma_{adm}$
   $\sigma_1 <= \sigma_{adm}$
   where:
   $\sigma_x$ , $\sigma_y$: the normal stresses in two perpendicular planes
   $\tau$: existing shear stress
   $\sigma_1$, $\sigma_2$: the maximum and minimum main tensions in algebraic value
   $\sigma_{adm}$: Basic allowable tensile stress with a positive sign

## 5. GENERAL CONDITIONS

5.1 Project conditions

The project will be carried out so that all the bridge elements are accessible for inspection, cleaning and painting. Any concavity where water can be deposited will be provided with drain holes or filled with concrete or other suitable material.

## 5.2 Minimum dimensions of the material

a) The minimum thickness of the material is 10mm, except for the plate of the laminated profiles intended for coating or surfacing.
b) The minimum thickness of gusset plates will be:
   12 mm for clearance under 30 m
   15 mm for clearance over 30 m
c) Beam angular supports smaller than 75 * 75 * 10 will not be used.

## 5.2 Junctions

a) Where possible, the joints will be symmetrical regarding the axis of the joined parts and will have at least the same resistance as those parts.
b) Where possible, the bars will be arranged so that at their gusset plates their gravity axes pass through a point; otherwise, the stresses causing that deflection will be calculated.
c) In gusset plates joints, riveting or welding lines have to be distributed so that their center of gravity coincides with that of the rod; where this is not possible, the appropriate stresses have to be calculated.

## 5.3 Riveting

a) In the study of riveting the new rivet nominal diameter must be used, and all provisions concerning distance between rivets have to be taken from their center.
b) When the rivets have an effective length greater than 4 times the diameter and must transmit calculable efforts, their number will increase by 1% for every millimeter of length in excess of 4 diameters, and special care must be taken of their manufacturing and placement. Rivets exceeding 6 diameters long, must not be used.
c) The distance between rivets will not be less than 3 diameters or greater than 10 diameters.
d) A rivet distance to the nearest edge will not be greater than 4 diameters or 12 times the plate thickness.
   The rivet distance to any edge will not be less than:
   a) 1.8 times its diameter if it is a shearing edge
   b) 1.6 times its diameter if it is a laminated plate edge
   c) 1.4 times its diameter if it is a laminated profile edge

## 5.4 Welding

a) Arc welding will be used subject to the following conditions:
   A) In the bridge project, or the reinforcements made in workshop in riveting mixed joints or bolts and welding, it will be recognized that the weld alone absorbs all stresses.
   B) In riveted bridges, reinforcing by welding absorbs the stresses produced by the permanent load if such reinforcement is effected on site; welding must withstand all stresses caused by other acting loads.

b) In the study of the welding, an effective section will be that obtained multiplying the throat thickness by the effective length of the bead.
Throat thickness shall mean:
   A) In a welding bead, the minimum distance from the root to the weld face.
   B) In a butt welded joint, the minimum thickness of the bonded parts.
Effective length means the total length of the fillet minus twice its nominal side.

c) The nominal side a, expressed in mm of a welding bead section will not be lower than the value given by $a = 1.4 (e)^{1/2}$ being e the minimum thickness welded plate in mm.

d) The length of a weld bead shall not be less than 4 cm, or less than 4 times the nominal side of the bead section.
For bead lengths less than the latter, the nominal side is considered equal to ¼ of the bead length.

## 6.- PARTS AXIALLY LOADED

### 6.1 Slenderness

a) The slenderness $\lambda$ of the bar, length ratio of the minimum turning radius ($\lambda = l/r$), shall not exceed the following values:
   general compressed bars: 100
   compressive wind bracing beams: 120
   single trusses, main flanges: 140
   double trusses, secondary flanges: 200
   extended bars: 200

b) In composed bars the distance (d) between flanges or gussets of the truss will be such that the slenderness (d/r) of each rod element, in isolation, does not exceed 2/3 of the slenderness of the bar as a whole, both to extended and compressed bars.

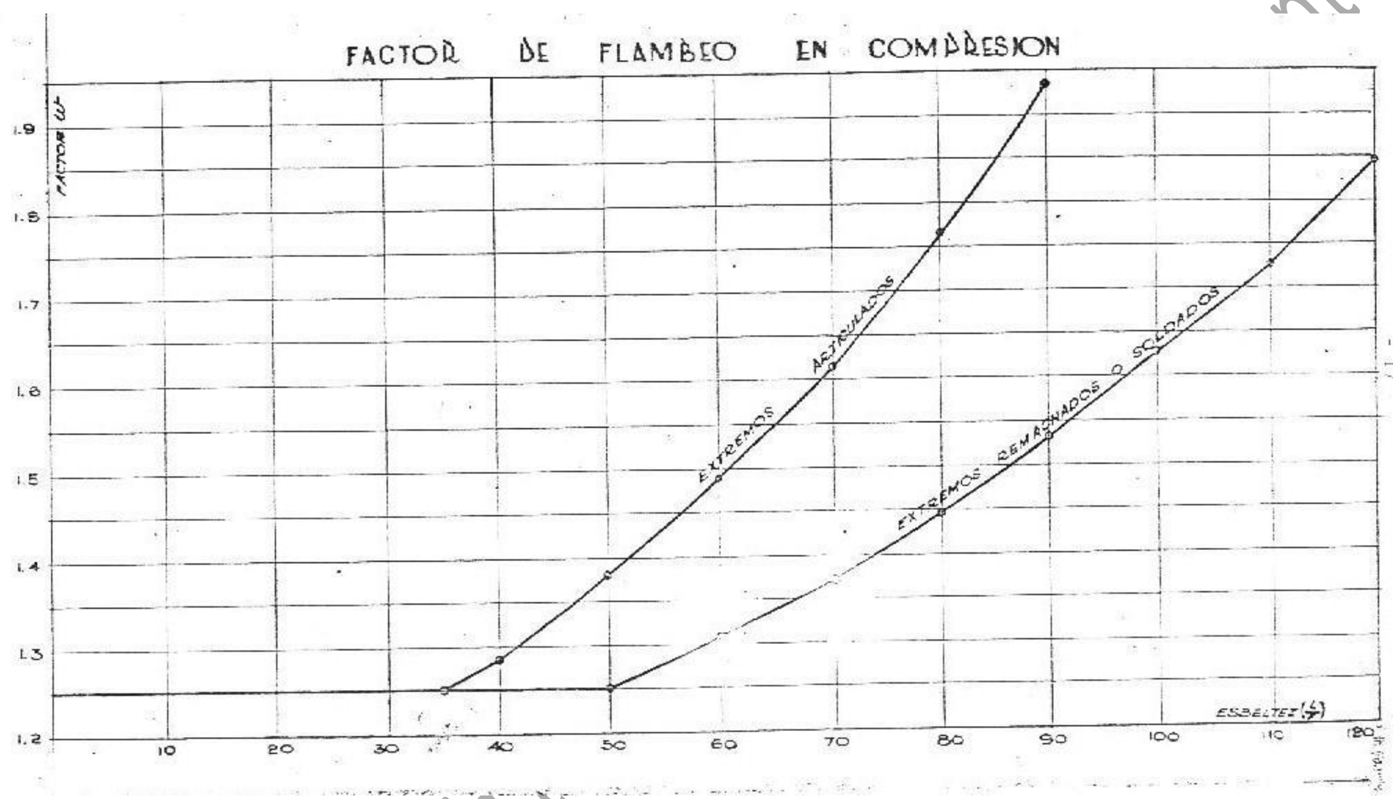
### 6.2 Calculation method

a) The tension in compressed iron, steel or cast steel structural pieces calculated with the gross section, may not exceed that obtained dividing the basic allowable compressive stress by the compressive buckling in factor $\omega$, given by the expressions indicated below:
   A) Riveted or welded ends:
      $\omega = 1.25$ for $\lambda < 50$
      $\omega = 1.125 + \lambda^2/20000$ for $\lambda > 50$
   B) Articulated ends:
      $\omega = 1.25$ for $\lambda < 35$
      $\omega = 1.125 + \lambda^2/10000$ for $\lambda > 35$

In the calculation of special steel compressed parts, the previous buckling factor is increased by a percentage given by the expression: $(\omega - 1.25)\ \sigma_s/23$

b) To calculate composite rods, the buckling factor in the plane parallel to the joints is given by: $\omega = \omega_s (\omega_u - 0.25)$

where:
$\omega_s$: buckling factor of the simple bar
$\omega_u$: buckling factor of the connecting element (flange or truss).
In the plane normal to the joints, $\omega_s$ will be used.
c) Extended parts will be calculated with the basic allowable stress, using their net area.




## 6.3 Effective areas

a) The gross area of a bar is equal to the sum of the products thickness by the gross width of each and all elements of the bar, measured normally to its axis.

b) The net area of a bar is equal to the sum of the products thickness by the net width of each and all elements of the bar, for riveted bars, as follows:
Net width of an element is obtained by calculating all possible break lines through various riveting lines, using the following expression:

$$b_n = b - d\,(1 - \Sigma K) \qquad \text{where } K = 1 - p^2/(4gd)$$

where:

$b_n$: Net width for the chosen line break.
b: Gross width of the plate or element in place.

d: diameter of the rivet hole 3mm greater than the nominal diameter of the rivet.
p, g: longitudinal distance (pitch) and transverse distance (gage) for each pair of successive rivets found to cross the break line.
ΣK: sum of the values obtained for all the rivets included in the breakline, taken 2 by 2.

The net width shall not be less than that obtained by deducting from the gross with a number of diameters equal to the number of rivet rows.

c) In bars formed by a single or two angular supports connected back to back and on the same side of the gusset plate, the effective area to be taken for those bars will be equal to the net or gross area, as appropriate, over the attached wing plus the unattached half wing. If the bar is formed by two angular supports each connected to a spacer plate, but joined by reinforcement plates, the whole section may be taken as the effective area.

6.3 Project conditions: simple bars

a) The width of the free wings compressive angular support will not exceed 12 times its thickness.
b) The thickness of the gusset plates bonded section, will not be less than 1/32 of the clearance between the beading and the laminated profile wings, or the distance between the nearest rivet lines. For the other plates making up the bar, the fraction will be 1/40. In either case, if the existing stress ($\sigma$) is lower than the admissible one ($\sigma_{adm}$), the fractions may be multiplied by $(\sigma/\sigma_{adm})^{1/2}$.
c) In the extended articulated bars, the net area of the corresponding cross section to the axis of the bolt will exceed at least 40% the net area of the rod body, and the net area beyond the existing bolt hole located along the longitudinal axis bar will be at least equal to the net area of the rod body.
Furthermore, in the case of riveted or welded and jointed bars, the net width across the bolt hole, transversely to the axis of the bar, will not exceed 8 times the corresponding thickness.
d) Axis bars will have a thickness not less than 20 mm and not less than 1/8 of the width, or greater than 60 mm.
The bolt diameter shall not be less than 7/8 the width of the widest bar reaching the gusset.
e) In simple coupling riveting for extended main bars, the distance between rivets joining both plates and profiles in a parallel and normal direction to the effort, will not exceed 8 diameters or 30 cm. In bars composed of two angular supports separated by the thickness of the gusset plate and maintained by washers or linings, the angular supports may be placed at a distance no greater than 1.20 m, but will never be less than 2 intermediate ones.
f) In simple coupling riveting for compressed bars the pitch of the rivets that attach plates and profiles shall not exceed 12 times the thickness of the thinnest plate or outer profile, or 16 times the thickness of the thinnest plate or inner profile; the gage shall not exceed 24 times the thickness of the thinnest plate or profile. In no case will pitch or gage exceed 6 or 8 diameters for main or secondary bars respectively; at the end of the bar the pitch or gage will not exceed 4 diameters in a distance equal to 1½ times the maximum width of the bar.

In compound bars with 2 angular supports as in the preceding subsection, the distance shall not exceed 0.70 m and be such that the slenderness of each angle is greater than 40.

g) The joints of the bars subjected to axial loads must be designed to fully convey efforts, unless the 2 parts of a compressed bar are opposite to each other for direct mutual support, in which case they can be calculated with the sole purpose of maintaining the 2 parts in place, as long as any bending stress that may overlap cannot cancel the compressive stresses.

6.4 Project conditions: compound bars

a) Normal shear stress to the longitudinal axis of the rod, which is used to calculate flanges or trusses in compressed bars, will be given by the sum of shear stress caused by the main loads and a percentage of the allowable compressive load on the bar expressed by: $100/(\lambda+10) + \lambda/100$. In extended bars only the first of those efforts is considered.
It will be admitted that the shear stress is divided equally among the various link planes parallel to the force, whether full (bonded section) or discontinuous (flange or truss).

b) The inclination θ of trusses relative to the axis of the bars is approximately 60 º for simple trusses or 45 º for double trusses.
When the distance between 2 riveting or welding lines of adjacent elements is greater than 40 cm double truss will always be used, riveted or welded at the intersection if they are laminated iron sheets.
The width of the laminated iron sheet truss will not be less than 3 times the diameter of the respective rivets; when the beads or bar elements are more than 12 cm wide at least 2 rivets will be placed at each end.

c) All compound bars will have flanges at their ends and possibly within their gussets. In compressed parts, the width of said flanges along the axis of the bar will not be less than the distance between the riveting or welding lines that join the bar elements and pieces extended 2/3 of this distance. In intermediate flanges 1/2 and 1/3 of that distance may be respectively taken.

7. BENT PARTS

7.1 Calculation method

a) The maximum tensile ($\sigma_t$) and compression ($\sigma_t$) stresses in sections subjected to simple bending, will be calculated by the inertia moment method, using the following expressions:

$\sigma_c = (M/I_B)\ c'$ $\sigma_t = (M/I_B)\ c$

$(A/A_n)$ where:

$I_B$: Gross inertia moment.
c, c': distance from the neutral line (the gross section center of gravity) to the far, extended and compressed neutral axis, respectively.
A, $A_n$: gross and net areas of the extended bead, respectively.

The maximum compressive stress may not exceed the value obtained dividing the basic allowable compressive stress by the bending buckling factor μ, given by the expressions listed below:

$\mu = 1 + \alpha/3000$ for $\alpha < 750$
$\mu = \alpha/600$ for $\alpha > 750$

$\alpha = Ld/(bt)$ is the beam lateral slenderness where:

L: Free lateral length of the beam (in brackets, take double the clearance)
d: height of the beam
b: width of the compressed bead
t: thickness of the compressed bead.

Lateral slenderness α shall not exceed 3000.

b) In bars subjected to bending and axial compression, the basic allowable compressive stress must be greater or equal to that given by the expression:

$$\sigma = \omega P/A + \mu M/W$$

7.2 Reinforcing elements

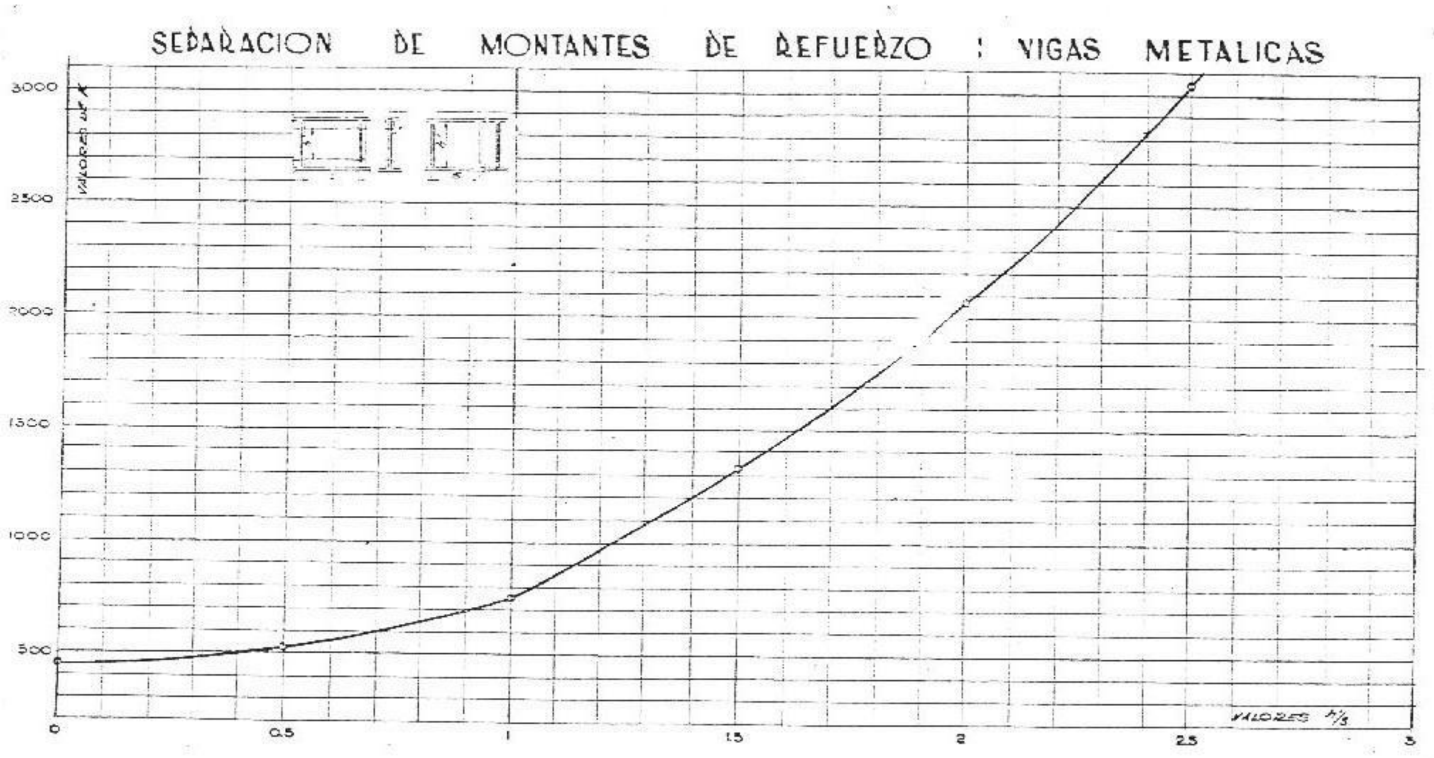
a) If the ratio (h'/t) of the headroom between beads (h') to the beam plate thickness (t) is greater than 60, the factor $K = 60\,\tau(h'/(100t))^2$ will be determined, where τ is the maximum tangential stress measured in $Kg/cm^2$, in the region concerned.
In addition, when K is greater than 440, it is necessary, for purposes of the bonded section stability, to place stiffeners separated by a distance (s) measured along the axis of the beam, given by the expressions:

$S = h'(300/(K - 440))^{1/2}$ for $k < 740$
$S = h'(440/(K - 300))^{1/2}$ for $k > 740$

The relationship h'/t shall not exceed 170.

b) In all those places with concentrated loads to a plate beam through the beads (supports, reactions, etc.), weight distribution transoms will also be placed.

c) Transoms will be calculated as fixed end columns, but the compressive buckling coefficient may be reduced by 0.25. For stiffeners, the maximum shear stress acting on the panel will be regarded as the load.




7.3 <u>Project conditions</u>

a) Transoms will be symmetrical to the median plane of the bonded section, with contact against the beads, they will extend and not be bent, normally to the bonded section, the closest possible to the bead. For angular supports, the normal side to the bonded section shall not exceed 16 times its thickness or be less than 5 cm plus one thirtieth of the beam height.
Transoms will be joined to the bonded sections by welding or riveting not greater than 8 diameters.

b) The compound beam bonded section joints will be designed to transmit the total shear stress and bending of the bonded section where the joint is.
Bead joints shall be designed to develop the total effort for the elements cut.
Angular supports will be joined with angular supports, and splices of different elements in the same section will not be allowed.

c) The thickness of the normally compressed beam elements will not be not less than 1/12 of the respective clear width, which shall not exceed 15 cm. The total area of the laminated iron plates comprising a bead shall not exceed 70% of the total area and their thickness will not be greater than the thickness of the angular supports or profiles joining the bonded section.
Any riveting or welding joining the beads to the bonded section must be able to transmit the horizontal shear stress produced and any load directly applied to the bead.



| TRAIN TYPE P = 1 TONNE | | | | |
|---|---|---|---|---|
| Maximum stresses in simple sections | | | | |
| Section clearance (m) | Shear stress | | Bending Moment | |
| | Maximum Tonnes | Equivalent uniform load Tonne/m | Maximum Tonne * m | Equivalent uniform load Tonne/m |
| 2 | 1.2 | 1.25 | 0.50 | 1.00 |
| 4 | 1.8 | 0.94 | 1.50 | 0.75 |

| | | | | |
|---|---|---|---|---|
| 5 | 2.20 | 0.88 | 2.25 | 0.72 |
| 6 | 2.50 | 0.83 | 3.00 | 0.67 |
| 8 | 2.92 | 0.73 | 5.07 | 0.63 |
| 10 | 3.37 | 0.67 | 7.28 | 0.59 |
| 12 | 3.82 | 0.64 | 9.85 | 0.55 |
| 14 | 4.22 | 0.60 | 12.75 | 0.52 |
| 15 | 4.42 | 0.59 | 14.37 | 0.51 |
| 16 | 4.59 | 0.57 | 16.02 | 0.50 |
| 18 | 4.96 | 0.55 | 19.43 | 0.48 |
| 20 | 5.45 | 0.54 | 23.17 | 0.46 |
| 22 | 5.79 | 0.54 | 26.99 | 0.45 |
| 24 | 6.50 | 0.54 | 31.00 | 0.45 |
| 25 | 6.71 | 0.54 | 33.92 | 0.45 |
| 26 | 6.78 | 0.53 | 39.63 | 0.44 |
| 28 | 7.45 | 0.53 | 44.86 | 0.44 |
| 30 | 7.83 | 0.52 | 52.05 | 0.44 |
| 35 | 9.08 | 0.51 | 68.63 | 0.44 |
| 40 | 9.73 | 0.49 | 88.83 | 0.44 |
| 45 | 10.61 | 0.47 | 113.16 | 0.44 |
| 50 | 11.47 | 0.46 | 137.88 | 0.44 |
| 55 | 12.30 | 0.45 | 164.28 | 0.43 |
| 60 | 13.12 | 0.44 | 192.51 | 0.43 |

State Railways Administration blueprint Nº C - 8039

| State Railways | | | | | TREN TYPE P = 1 TONNE | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1/2 | 1 | 1 | 1 | 1 | 2/3 | 2/3 | 2/3 | 2/3 | 1/2 | 1 | 1 | 1 | 1 | 2/3 | 2/3 | 2/3 | 2/3 | |
| Dist. | | 2.40 | 1.50 | 1.50 | 1.50 | 2.70 | 1.50 | 1.50 | 1.50 | 2.40 | 2.40 | 1.50 | 1.50 | 1.50 | 2.70 | 1.50 | 1.50 | 1.50 | |

| Axle N° | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PARTIAL EFFORTS IN TONNES | | | | | | | | | | | | | | | | | | |
| 1 | 0.5 | 1.50 | 2.50 | 3.50 | 4.50 | 5.17 | 5.83 | 6.50 | 7.17 | 7.67 | 8.67 | 9.67 | 10.67 | 11.67 | 12.34 | 13.00 | 13.67 | 14.33 |
| 2 | | 1.00 | 2.00 | 3.00 | 4.00 | 4.67 | 5.33 | 6.00 | 6.67 | 7.17 | 8.17 | 9.17 | 10.17 | 11.17 | 11.84 | 12.50 | 13.17 | 13.83 |
| 3 | | | 1.00 | 2.00 | 3.00 | 3.67 | 4.33 | 5.00 | 5.67 | 6.17 | 7.17 | 8.17 | 9.17 | 10.17 | 10.84 | 11.50 | 12.17 | 12.83 |
| 4 | | | | 1.00 | 2.00 | 2.67 | 3.33 | 4.00 | 4.67 | 5.17 | 6.17 | 7.17 | 8.17 | 9.17 | 9.84 | 10.50 | 11.17 | 11.83 |
| 5 | | | | | 1.00 | 1.67 | 2.33 | 3.00 | 3.67 | 4.17 | 5.17 | 6.17 | 7.17 | 8.17 | 8.84 | 9.50 | 10.17 | 10.83 |
| 6 | | | | | | 0.67 | 1.33 | 2.00 | 2.67 | 3.17 | 4.17 | 5.17 | 6.17 | 7.17 | 7.84 | 8.50 | 9.17 | 9.83 |
| 7 | | | | | | | 0.67 | 1.33 | 2.00 | 2.50 | 3.50 | 4.50 | 5.50 | 6.50 | 7.17 | 7.83 | 8.50 | 9.16 |
| 8 | | | | | | | | 0.67 | 1.33 | 1.83 | 2.83 | 3.83 | 4.83 | 5.83 | 6.50 | 7.16 | 7.83 | 8.50 |
| 9 | | | | | | | | | 0.67 | 1.17 | 2.17 | 3.17 | 4.17 | 5.17 | 5.84 | 6.50 | 7.17 | 7.83 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | | | | | | | | | | 0.50 | 1.50 | 2.50 | 3.50 | 4.50 | 5.17 | 5.83 | 6.50 | 7.17 |
| 11 | | | | | | | | | | | 1.00 | 2.00 | 3.00 | 4.00 | 4.67 | 5.33 | 6.00 | 6.67 |
| 12 | | | | | | | | | | | | 1.00 | 2.00 | 3.00 | 3.67 | 4.33 | 5.00 | 5.67 |
| 13 | | | | | | | | | | | | | 1.00 | 2.00 | 2.67 | 3.33 | 4.00 | 4.67 |
| 14 | | | | | | | | | | | | | | 1.00 | 1.67 | 2.33 | 3.00 | 3.67 |
| 15 | | | | | | | | | | | | | | | 0.67 | 1.33 | 2.00 | 2.67 |
| 16 | | | | | | | | | | | | | | | | 0.67 | 1.33 | 2.00 |
| 17 | | | | | | | | | | | | | | | | | 0.67 | 1.33 |
| 18 | | | | | | | | | | | | | | | | | | 0.67 |
| PARTIAL MOMENTS IN TONNES * METER | | | | | | | | | | | | | | | | | | |
| 1 | 0.00 | 1.20 | 3.45 | 7.20 | 12.45 | 24.60 | 32.35 | 41.10 | 50.85 | 68.05 | 86.05 | 99.45 | 114.85 | 129.95 | 165.49 | 179.95 | 205.85 | 225.15 |
| 2 | | 0.00 | 1.50 | 4.50 | 9.00 | 19.80 | 26.80 | 34.80 | 43.80 | 59.80 | 76.60 | 89.25 | 103.90 | 118.25 | 152.40 | 166.15 | 191.40 | 209.95 |
| 3 | | | 0.00 | 1.50 | 4.50 | 12.60 | 18.10 | 24.60 | 32.10 | 45.70 | 60.10 | 71.25 | 84.40 | 97.25 | 128.70 | 140.95 | 164.70 | 181.95 |
| 4 | | | | 0.00 | 1.50 | 6.90 | 10.90 | 15.90 | 21.90 | 33.10 | 45.10 | 54.75 | 66.40 | 77.75 | 106.50 | 117.25 | 139.50 | 155.25 |
| 5 | | | | | 0.00 | 2.70 | 5.20 | 8.70 | 13.20 | 22.00 | 31.60 | 39.75 | 49.90 | 59.75 | 85.80 | 95.05 | 115.80 | 130.05 |
| 6 | | | | | | 0.00 | 1.00 | 3.00 | 6.00 | 12.40 | 19.60 | 26.25 | 34.90 | 43.25 | 66.60 | 74.35 | 93.60 | 106.35 |
| 7 | | | | | | | 0.00 | 1.00 | 3.00 | 7.80 | 13.40 | 19.05 | 26.70 | 34.05 | 51.60 | 62.35 | 74.10 | 92.35 |
| 8 | | | | | | | | 0.00 | 1.00 | 4.20 | 8.20 | 12.85 | 19.50 | 25.85 | 41.60 | 51.35 | 62.10 | 72.85 |
| 9 | | | | | | | | | 0.00 | 1.60 | 4.00 | 7.65 | 13.30 | 18.65 | 32.60 | 41.35 | 51.10 | 60.85 |
| 10 | | | | | | | | | | 0.00 | 1.20 | 3.45 | 7.20 | 12.45 | 24.60 | 32.35 | 41.10 | 50.85 |
| 11 | | | | | | | | | | | 0.00 | 1.50 | 4.50 | 9.00 | 19.80 | 26.80 | 34.80 | 43.80 |
| 12 | | | | | | | | | | | | 0.00 | 1.50 | 4.50 | 12.60 | 18.10 | 24.60 | 32.10 |
| 13 | | | | | | | | | | | | | 0.00 | 1.50 | 6.90 | 10.90 | 15.90 | 21.90 |
| 14 | | | | | | | | | | | | | | 0.00 | 2.70 | 5.20 | 8.70 | 13.20 |
| 15 | | | | | | | | | | | | | | | 0.00 | 1.00 | 3.00 | 6.00 |
| 16 | | | | | | | | | | | | | | | | 0.00 | 1.00 | 3.00 |
| 17 | | | | | | | | | | | | | | | | | 0.00 | 1.00 |
| 18 | | | | | | | | | | | | | | | | | | 0.00 |

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