Prestressed Bridge Design under German Normative

Treball realitzat per:
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Dirigit per:
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Grau en:
Enginyeria de la Construcció

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Departament d’Enginyeria de la Construcció
Voldria agrair la gran predisposició i ajuda prestada dels professors Frank Jesse i Hagen Schulz de la Branenburgische Technische Universität de Cottbus per a la correcta interpretació de les normatives alemanyes, a la meva gran amiga i arquitecte M. Muela Amorrich per la gran col·laboració a l'hora de realitzar els plànols i per últim, al tutor del projecte, prof. Ignacio Valero de la Universitat Politècnica de Catalunya.

Cada una de les parts ha fet que hagi sigut possible la realització d'aquest projecte i tenen tot el meu respecte.

Carla C. Casas
Document 1:

Project Report
# Table of Contents

1. Aim of the Project.............................................................................................................. 4
2. Introduction....................................................................................................................... 5
3. Motive behind the project............................................................................................... 6
4. Actual Situation ............................................................................................................... 7
5. Information of the Study area ....................................................................................... 8
   5.1. Topography and cartography .................................................................................. 8
   5.2. Urban Planning ....................................................................................................... 8
   5.3. Geology and Geotechnic ...................................................................................... 8
   5.4. Climate .................................................................................................................. 8
   5.5. Traffic assessment ............................................................................................... 9
6. Studying the alternatives ............................................................................................... 10
   6.1. The alternatives ..................................................................................................... 10
       *Theory and Design of Bridges - Petros P. Xanthakos, John Wiley & Sons, 1994*........ 10
       Design criteria .......................................................................................................... 11
       Structural criteria ..................................................................................................... 11
       Aesthetics ................................................................................................................ 13
       Economic evaluation .............................................................................................. 13
       Alternative 1 ........................................................................................................... 14
       Alternative 2 ........................................................................................................... 15
       Alternative 3 ........................................................................................................... 16
6.2 Assessment ..................................................................................................................... 17
       Design ...................................................................................................................... 17
       Structural criteria ..................................................................................................... 17
       Economic ................................................................................................................ 17
       Aesthetics ................................................................................................................ 17
7. Chosen alternative .......................................................................................................... 18
   7.1. Definition ................................................................................................................. 18
       Cross section ........................................................................................................... 18
       Top view ................................................................................................................ 18
       Side view ................................................................................................................. 19
   7.2. Data ......................................................................................................................... 19
   7.2 Soil ............................................................................................................................ 20
   7.3 Road Layout ............................................................................................................ 20
   7.4 Signaling .................................................................................................................. 21
8. Classification of the contractor ....................................................................................... 21
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Construction planning</td>
<td>21</td>
</tr>
<tr>
<td>10</td>
<td>Affected services</td>
<td>21</td>
</tr>
<tr>
<td>11</td>
<td>Expropriations</td>
<td>21</td>
</tr>
<tr>
<td>12</td>
<td>Study of the Environmental Impact</td>
<td>22</td>
</tr>
<tr>
<td>13</td>
<td>Study of Safety and Health</td>
<td>22</td>
</tr>
<tr>
<td>14</td>
<td>Justifying the prices</td>
<td>23</td>
</tr>
<tr>
<td>15</td>
<td>Revision of prices</td>
<td>23</td>
</tr>
<tr>
<td>16</td>
<td>Budget</td>
<td>23</td>
</tr>
</tbody>
</table>
The aim of the project is to design and calculate a Prestressed Bridge under German normative.

As it is being already two years living in Germany and one of them in Berlin, as a Civil Engineer I have wanted to get in contact with the normative I will probably work with.

During the Erasmus year in Cottbus (BTU Cottbus, Brandenburg, Germany) I coursed the master lecture of Prestressed Bridges. As a result, I had the opportunity to work with the normative obtaining the necessary skills and knowledge to be able to face the design of a Prestressed Bridge working under German normative.

Thus, the aim of this project is not to provide the fully information and description to carry out the entire construction of the project but to focus on the calculation and the design of the bridge deck. Henceforth, the main weight of the project lies in going deep in the analysis of the German normative concerning the bridges to provide an accurate calculation and analysis of the forces that will suffer the bridge in either load or unload stages. Furthermore, the attention has been focused to the design of the cross section of the deck following several directives. As a result, three alternatives for the cross section and the corresponding basic calculations have been developed. Afterwards, the project focuses on the detailed calculation of the chosen alternative and the design in ULS and SLS.

The normative used for the calculation of the bridge are:

- DIN 100. Zusammenstellung von Beton
- DIN 101. Einwirkung auf Brücken
- DIN102. Betonbrücken
- DIN103. Stahlbrücken
- DIN104. Verbundbrücken

The main directives for the design of the cross section are:

- RiZ-ING. Richtzeichnungen für Ingenieurbauten
- ZTV-ING. Zusätzliche Technische Vertragsbedingungen und Richtlinien für Ingenieurbauten

Although the normative used for the design of the bridge in ULS and SLS is German, the UE normative for bridges is basically a translation of the German normative and only some coefficients may vary. Thus, in order to follow the calculations the UE normative can be consulted.

The project provides all the documents necessary to define the constructive project but those parts not concerning the calculation and design of the deck are more superficial. Lack of more detailed information can be found by the reader but it must be understood that that is not the aim of the project.
2. Introduction

This Project aims to provide the necessary information to define and carry out the execution of the project “Design of a Prestressed Bridge under German normative”.

The infrastructure designed jointly with other actuations will alleviate the forecasted traffic of the area and will provide continuation and bring together the main streets that run through the neighborhood and articulate the city.

The project is located at the East side of Berlin, next to Ostkreuz train Station, in the neighborhood of Lichtenberg and consists on the design of a prestressed bridge on Kynaststraße Street that will run parallel to the Deutsch Bahn Railways that belong to the Ring-Railway that circle the city. The bridge will cross over the railways of the S-Bahn (Speed trains) and the Street Hauptstraße and will connect at the end of Kynaststraße with Marktstraße.
3. Motive behind the project

The constructive project of study is located right in between the neighborhoods of Friedrichshain and Lichtenberg and both neighborhoods are characterized by its residential and quiet atmosphere. Both belong to the oldest East side of Berlin and due to its proximity to the West side, for many years the closest area to the river was mainly abandoned. However, after the Fall of the Wall in 1989 and specially Friedrichshain, found itself in the very heart of the city. As a result, nowadays Friedrichshain is a concurred area that usually suffers from traffic jams.

That contrasts with the natural rhythm of the inhabitants of the area. Here it must be pointed out that Friedrichshain and its homolog on the west side, Kreuzberg, perform the most alternative neighborhoods in Berlin. Moreover, these two districts have become one of the reference music spots in Europe. Thus, the inhabitant profile can be defined as young-well-formed and low incomes citizen. Musicians, painters and people from the “art world” in general live together with a generation of young generation where most accomplish the requirements for university or have obtained a university graduate.

As the neighborhood of Friedrichshain is mainly residential and only in the last few years big companies have settled on the banks of the river, the aim of the actuation that this project defines relies on the idea of decreasing the traffic flow that runs through Friedrichshain thus reinforcing the connection of the main streets that articulate the city and defining high paths so both the inhabitants do not have to bear the traffic and the drivers do not have to deal with a net that is certainly not settled to articulate large amounts of traffic efficiently.

For a better understanding of the problematic, a major scale spatial vision is needed. The map below shows the actual high paths settled in the city. The red line highline Stralauer Alle (parallel to the river) and Warschauer Street (perpendicular) that gather up the traffic precedent from the west side and the west south. The green line shows the connection that is expected to be improved through the project.
4. Actual Situation

Kynaststraße arises as a continuation of Stralauerstraße and runs parallel to the Ring Train Railways that circle the city internally to end up connecting with Hauptstraße. Stralauerstraße collects the traffic coming from the west and the south side of the river through Elsen Bridge and directs it to Warschauer Street that at its time bring the traffic to the main street Frankfurter Alle / Karl-Marx Allee.

Nowadays the alternative option to avoid the route Stralauer Allee – Warschauer Straße and henceforth drive through the neighborhood is to take Markgrafendamm Street, which arises from the intersection between Elsebrücke and Stralauer Allee, and farther on becomes Hauptstraße. The map below shows the route to be followed in case one wants to continue in a northern west direction.

Hauptstraße and Kynaststraße are connected by a give way sign. Hauptstraße is a two-track set unidirectional road. The intersection that follows and redirects northerly is usually an overcrowded spot. Turning left on the intersection and driving through small streets one bump into the important intersection between Boxhagener Steet and Gürtelstraße. The latter direct the traffic to the north connecting with Frankfurter Allee which is a main entry and exit to the city center.

The construction of the bridge aims to provide an alternative option to Stralauer Allee – Warschauer Straße, bringing together Elsenbrücke, which connects with the west part of the city, and the main intersection between Boxhagener and Gürtelstraße in an attempt to alleviate the traffic through the middle of the neighborhood.
5. Information of the Study area

5.1. Topography and cartography

The cartography and topography maps of the area have been provided by the Brandenburgische Technische Universität of Cottbus (BTU-Cottbus).

From the plans provided the following data is obtained:

- Cross slope Kynaststraße is constant at 4.0% over the entire bridge area.
- Intersection angle with the Hauptstraße the Railway lines is 98.403 gon.
- Railway lines and Hauptstraße are considered to run parallel.

Intersection points between the Topographic Station and Kynaststraße are:

- Railway 1 axis: 0 +283.681
- Railway 2 axis: 0 +289.380
- Hauptstraße axis: 0 +301.381

The detailed maps can be found in the Document nº2: Plans of the project.

5.2. Urban Planning

The last Urban Planning date from 2004 approved by the Berlin Senate Department of Urban Development classifies the ground concerned by this project as:

- Gemischte Baufläche M1 (Mixed Construction Area)

The detailed map is located in the Document 2: Plans of the project.

In order to carry out the construction of the bridge the Urban Planning must be modified and the subsequent formalities with the Senate Department of Berlin have to be done.

5.3. Geology and Geotechnic

Geotechnical information of the soil has not been possible to obtain. Thus, it has been considered the following directives:

- Groundwater not observed in the soil of the area
- The structure’s foundations will be settled in a flat area
- The maximum permissible pressure of the ground is 300 kN/m²

5.4. Climate

No atmospheric agents are expected
5.5. Traffic assessment

The area of study collects directly the traffic volume of the Federal Road 96a. The connection Warschauer Straße – Stralauer Allee belong to the federal road that runs through the city northerly.

The Mobility Plan date from 2010 “Mobility in the City – Berlin Traffic figures 2010” provides the estimated value of 25.000 vehicles per working day on 96a road before it reaches the Elsenbrücke. The value for the bridge achieves the 50.000 vehicles per day. When it turns to Stralauer Allee and Warschauer Straße the rate decreases until the 25.000 vehicles a day again.

The detailed plans can be found in the Document 2: Plans of the project.

The actuation that concerns this project looks forward to provide an effective alternative route to alleviate the elevated use of the path Warschauer-Stralauer Streets reducing the value until the range of 15.000 vehicles per day.

Thus, the construction is expected to bear traffic of 10.000 veh/day.

Detailed explanations of the traffic design can be found in the Annex 4: Road Layout
6. Studying the alternatives

6.1. The alternatives

This project contemplates three possible alternatives. As it has been pointed out previously, the project focuses on the calculation and the design of the desk. Hence, the provided alternatives consist on three different designs of the bridge’s deck.

Two different lengths for the deck are contemplated. Both the total width of the deck and the total length of the bridge for the three sections is the same being the total width 11.10 meters and the total length 49.25 meters. All three alternatives propose a bridge simply supported at its ends. Thus, the bridge works as a statically determined system.

Additionally, a basic calculation of the loads to bear for each bridge provides an approximation of the amount of tendons required. The calculations related to the latter can be found at the Annex 1: Calculation of the Alternatives.

For the selection of the design has been taking into account the following points:

- Design criteria
- Structural criteria
- Esthetic criteria
- Economic criteria

The information regarding this part of the Project and has been extracted from:

*Theory and Design of Bridges - Petros P. Xanthakos*, John Wiley & Sons, 1994
*Design and Calculation of Reinforced Structures, J. Calavera*
Design criteria

Geometric design of bridges relates to the location and proportioning of the visible elements of the structure, but it does not include structural design. Geometry design practices by state highway departments and other supervising agencies are not entirely uniform. Hence, considerable variation exists in the laws of each state controlling the size, weight, and distribution of traffic and motor vehicles.

For the overpass highway, a suitable structure is the deck type. The supports are underneath and out of sight. The bridge has unlimited clearance vertically, and the clearance laterally is controlled mainly by the location of curbs, parapets and railings. These are chosen to enhance the concept of safety. Deck-type bridges require less maintenance and accommodate widening if required. Prestressed deck elements allow longer spans in relation to depth. Spans of highway grade separations are rarely long enough to require through trusses, but even in this case plate girder bridges are preferred over trusses.

Structural criteria

For single-span bridges, suitable structure types include:

- Simply supported deck or through girders
- Right-angle rigid frames
- Rigid-angle frames with concealed cantilevers with or without counterweights
- Simply supported girders with concealed cantilevers with or without counterweights
- Two short concealed spans (cantilever)

The simply supported structure is statically determinate and simple in design, but has in general a higher cost. Thus, when unyielding foundations are feasible, the rigid frames provide more economical solutions. The latter two options are more suitable for longer spans where small girder depth must be maintained.

Ordinarily, the overall bridge cost is higher for simple spans and lower for rigid frames. This suggests that the former should be used at sites where reasonably unyielding foundations are not attainable.

SLAB BRIDGES

Slab bridges normally require more concrete and reinforcing steel than girder bridges of the same span, but the formwork is simpler and less expensive. In Europe, where the cost of formwork is relatively low, other types of concrete bridges and simply supported slabs are feasible. Hence, slabs are seldom used for spans greater than 18 ft (6 m). The small overall superstructure depth in slab bridges is favourable factor at grade separations.

When thinking on choosing between slabs or girders the choice may be determined by the length. Here girders would constitute the most suitable option. However, slabs have the following characteristics that can replace the advantages of a girder:

- Simplified layout of the reinforcement in both the top and the bottom
- Workable formwork and smaller area of exposed concrete surface, resulting in a lower cost of surface finish
- Better distribution of live loads laterally and longitudinally, resulting in a fewer critical sections in the design.
Slab bridges have, however, certain disadvantages articulated mainly in the higher cost of materials and the associated greater dead loads.

DECK GIRDER BRIDGES
Deck girder bridges are divided into three main types according to the interaction between the girder and the slab:
- Girder-and-slab systems, where the slab spans transversely between longitudinal girders, providing the typical T-beam action.
- Girder, floor beam and one-way slab, where the slab is supported by floor beams spanning two or more longitudinal girders.
- Girder, floor beam, and two-way slab supported along the four edges.

T-beam decks consist of a vertical rectangular stem with a wide top flange, usually a transversely reinforced slab forming the riding surface for the traffic. A T-beam design that accommodates positive moments may not necessarily provide the strength required for negative moment because of some possible loss of strength by the wide compression flange in the cracked tensile zone of the section. This problem is remedied by either the thickening of the stem in the areas of negative moment or providing a partial bottom slab or providing compression reinforcement.

Based on span lengths, T-beam bridges are the next class of structures beyond the range of longitudinally reinforced slabs. Additionally, because of its continuity, T-Beams develop positive moments at mid-span and negative moments over the supports just as simply span bridges does yet the difference that T-beams will have a stretch where the compression zone will not shape as a beam to take the form of T-compression zone.

SLAB VS BEAM CROSS SECTION
- Slab:
The advantages of a plate cross-section are:
  ▪ Relatively slim and insensitive constraints
  ▪ Suitable for curved bridges ground plan
  ▪ Easy concrete placement
  ▪ Small concrete surface that is easy to inspect and maintain.

The disadvantages, however, by no means serious, may be the heat of hydration, by slab thickness above 1 meter. In case of application concrete technological measures (eg cements with low heat of hydration and the addition of additives, as well as provision for a slow heat flow) should be thus applied.

- Girder:
The advantages of a slab beam are:
  ▪ Economical weight, anyway good rigidity
  ▪ Relatively simple formwork and concrete placement
  ▪ Good economy
The disadvantages are noted:

- Generally low slenderness and higher sensitivity in forced continuous structures
- Not good for curved structures

**Aesthetics**

It is apparent that bridge esthetics is not an isolated concept, but should be examined in the context of structural requirements and budget constraints. In addition, it must be considered the utilitarian esthetics, which is a composite of physical factors and visual design aspects. These include location, alignment, roadway characteristics and details, bordering conditions, vistas and views, and the presence of open space and manufactured complexes.

Surveys about esthetic date from the seventies show that bridges with structural lightness and smooth lines, exposed and undistorted appearance, and a composition that considers harmony with the surrounding environment were the highest rated.

The design of abutment wingwalls poses a difficult aesthetic problem for grade separations as when parallel to the roadway crossing underneath can create the impression of a tunnel. Wingwalls that are parallel to the roadway above should not appear too tall relative to slab depth. Smaller, better proportioned walls can be achieved by lengthening the span. This will often, however, result in a substantial increase in cost.

**Economic evaluation**

Bridge types can be identified in terms of:

- Main constituent materials (concrete, steel)
- Structural systems
- Interaction with substructure (continuous spans, simple spans, rigid frames)

Invariably, the span length for bridges that do not fall into the category of grade separation structures will articulate the bridge type (e.g., steel box girders, cable stayed bridges, and suspension bridges).

The selection of materials and structural form for the superstructure is a complex procedure because it must take into account all factors affecting design. It is also influenced by the quality and cost of fabrication and construction procedures, foundation conditions and requirements, bridge height, and erection constraints.
Alternative 1

The first alternative contemplated by the project consists of the following characteristics:

- Double T deck
- Deck length: 25.7 meters
- Deck width: 11.1 meters
- Total bridge length: 49,25 meters

The schemes below define the variant:
Alternative 2

The second alternative contemplated by the project consists of the following characteristics:

- Single T deck
- Deck length: 25.7 meters
- Deck width: 11.1 meters
- Total bridge length: 49.25 meters

The schemes below define the variant:
Alternative 3

The third alternative contemplated by the project consists of the following characteristics:

- Single T deck
- Deck length: 35 meters
- Deck width: 11.1 meters
- Total bridge length: 49,25 meters

The schemes below define the variant:
# 6.2 Assessment

## Design

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## Structural criteria

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<td>Distribution of live loads</td>
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## Economic

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<td>Totals</td>
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## Aesthetics

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<td>Structural lightness</td>
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<td>Totals</td>
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7. Chosen alternative

This section summarizes the most important characteristics of the solution adopted. All this information is greatly enlarged and justified in the various annex the project contain.

The detailed calculations and design of the alternative can be found in the Annex 2: Bridge – Structural Calculations

7.1. Definition

Cross section

Top view
7.2. Data

---

**Basic Data**

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<tr>
<th>Type</th>
<th>Simply supported at the edges</th>
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<td>Exposure class</td>
<td>XC4, XD3, XF4</td>
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<td>Concrete class</td>
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<td>Steel class</td>
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**Basic Design Data**

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<tr>
<td>Deck length</td>
<td>25.70 m</td>
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<tr>
<td>Deck width</td>
<td>11.10 m</td>
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<td>Deck height</td>
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<td>Embankment length</td>
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<td>Cross Section Data</td>
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<td>-----------------------------</td>
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<td>Side road width</td>
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<td>Road slope</td>
<td>+/- 2,5 %</td>
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<td>Footpath width</td>
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<td>Railing height</td>
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<td>Protective barrier</td>
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<td>Tendon axial distance</td>
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<tr>
<td>Tendon distance axis-edge (cv)</td>
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<td>Cladding tube ext. diameter</td>
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</table>

### 7.2 Soil

The Annex 3: Soil Calculations provides detailed information of the amount of soil that has to be replaced or that is needed for the development of the construction.

The total amount of soil to be provided is: 80285,697 m³

### 7.3 Road Layout

The Annex 4: Road Layout defines the characteristics and the design of the road in accordance with the Spanish normative "6.1 IC Road Sections, Highway Instruction (BOE of 12 December 2003)"
7.4 Signaling

To develop the signaling of the present constructive Project the following Catalan normative has been followed:

- 8.1 IC Vertical signaling
- 8.2 IC Horizontal signaling

In the Annex 5: Signs, buoys and fenders, justification and description of the intended signal is collected.

8 Clasification of the contractor

In compliance with the articles 25, 26, 27, 28, 29, 36 and 133 of the Spanish Royal Decree 1098/2001 of 12 October, which has been approved by the Spanish General Regulations of the Law on Public Administration Contracts, and the Article 54 of Law 30/2007 of 30th October Public Sector Contracts, the following classification should be accomplished by the contractor in order to be able to implement this work:

- B. Group - Bridges, viaducts and large structures
- Subgroup B3 -. Prestressed Concrete
- Category e) when the average annuity exceeds 840,000 euro and not more than 2,400,000 euro.

9 Construction planning

In compliance with Article 132 of the Spanish Royal Decree 1098/2001 of October 12, chapter 1 and paragraph e) of the Article 107 of Law 30/2007 of 30th October Public Sector Contracts, the Annex 6: Construction Planning is elaborated for the possible development of the work.

10 Affected services

No information of the services that surround the area and henceforth could be affected by the development of the constructive project has been available at the project level.

11 Expropriations

The totality of land to expropriate is classified in the Urban Planning date from 2010 and issued by the Senator Department of Urban Planning and Territorial Development of Berlin as follows:

- Gemischte Baufläche (Mixed construction area)
Since the affected land will be obtained through forced expropriation system, emergency procedure, it has to be taken into account the compliance of the criteria and principles contained in the following documents of the Spanish law:

- Law 6/1998, 13th April, on the ground and rating system.
- Law of eminent expropriation, the 16th December, 1954 and its regulations implementation of the 26th April, 1957.
- RDL 1/1992, of 26th June.

The future boundary of the area to be expropriated is delimited as follows:

- Non-buildable: The future boundary of the area to be expropriated corresponding to the main trunk has been delimited to three meters measured in the horizontal and vertical axis from the intersection of the foot embankment or of the coronations. Similarly, in the case of the existence of a ditch foot embankment or clearing saved coronation will take into account three meters from the outermost line of these.
- Buildable: The future boundary zone is delimited by the expropriation. From the line of intersection of the work.

The amount of land to be expropriated is detailed in the Annex 7: Expropriations of the present document.

The total area to be expropriated is: 24,456,825 m²

12 Study of the Environmental Impact

In the Annex 8: Environmental Impact Assessment of this paper, the possible impacts that may result in the implementation of the project area by defining preventive measures for those avoidable impacts and remedial measures for those who are not determined are defined, thus reducing the magnitude of these to be compatible with the environment.

The issues on which the project implementation can produce any result of an environmental nature and therefore studied the annex are the following:

- Hydrology
- Landscape
- Air Quality
- Acoustic
- Flood Risk
- Heritage
- Infrastructure and other urban environment

13 Study of Safety and Health

In accordance with Article 4 of the Spanish Royal Decree 1627/1997 of 24th October, chapter 1, paragraph g) of Article 107 of Law 30/2007 of 30th October Public Sector Contracts, in the Annex 9: Study of Safety and Health of this project can be found the Health and Safety Study.
14 Justifying the prices

The justification for this project rates based on bank rates GISA 2010, performed with the costs of labor, equipment and materials market.

15 Revision of prices

According to Article 89 of the Spanish Royal Decree 3/2011, of 14 November, approving the revised text of the Law on Public Sector, is approved that as it is a work period of less than one year of implementation, there is no need to set a revision of prices.

16 Budget

The total amount of the Material Execution Budget is: 741,640,74 €

(SEVEN HUNDRED AND FOURTYONE THOUSAND SIX HUNDRED AND FORTY EURO AND SEVENTYFOUR CENTS)

The total amount of the Execution Budget by Contract is: 1,067,888,50 €

(ONE MILLION SIXTYSEVEN THOUSAND EIGHT HUNDRED AND EIGHTYEIGHT EURO AND FIFTY CENTS)

Detailed information for the understanding of the Budget can be found in Document 4: Budget of this project.
Annex 1
Studying the Alternatives
# Table of Contents

1. Alternative 2 ........................................................................................................................................... 3  
   1.1. Cross section values .................................................................................................................. 3  
       Area ............................................................................................................................................. 3  
       Inertia ......................................................................................................................................... 3  
   1.2. Load assessment: .................................................................................................................... 4  
       1.2.1. Vertical loads .................................................................................................................. 4  
       1.2.2. Horizontal loads .......................................................................................................... 4  
       1.2.3. Centrifugal loads ......................................................................................................... 5  
   1.3. Moments: .................................................................................................................................. 5  
       1.3.1. Combination of actions 1: \( t = 0 \) .............................................................................. 6  
       1.3.2. Combination of actions 2: \( t = \infty \) .......................................................................... 6  
   1.4. Preliminary design .................................................................................................................... 6  
       1.4.1. Determination of the boundary lines ........................................................................... 7  
       1.4.2. Determination of the Prestress force .......................................................................... 8  
       1.4.3. Determination of the number of tendons required .................................................. 9  

2. Alternative 3 ........................................................................................................................................... 10  
   2.2. Cross section values ................................................................................................................ 10  
       Area ............................................................................................................................................. 10  
       Inertia ......................................................................................................................................... 10  
   2.3. Load assessment: .................................................................................................................... 11  
       2.3.1. Vertical loads .................................................................................................................. 11  
       2.3.2. Horizontal loads .......................................................................................................... 11  
       2.3.3. Centrifugal loads ......................................................................................................... 12  
   2.4. Moments .................................................................................................................................. 12  
       2.4.1. Combination of actions 1: \( t = 0 \) .............................................................................. 13  
       2.4.2. Combination of actions 2: \( t = \infty \) .......................................................................... 13  
   2.5. Preliminary design .................................................................................................................... 13  
       2.5.1. Determination of the boundary lines ........................................................................... 14  
       2.5.2. Determination of the Prestress force .......................................................................... 15  
       2.5.3. Determination of the number of tendons required .................................................. 16
1. Alternative 2

1.1. Cross section values

Area

\[ A1 = \frac{(0.3 + 0.4) \cdot 2.5}{2} \cdot 2 = 1.75 \, m^2 \]

\[ A2 = \frac{(5.2 + 5.4) \cdot 0.85}{2} = 4.505 \, m^2 \]

\[ A3 = 0.4 \cdot 5.4 = 2.16 \, m^2 \]

\[ Ac = A1 + A2 + A3 = 8.415 \, m^2 \]

Inertia

\[ Z1 = \frac{1}{3} \left( (0.3 + 0.4) - \frac{0.4 \cdot 0.3}{0.3 + 0.4} \right) = 0.176 \, m \]

\[ Z2 = \frac{1}{3} \left( \frac{0.85 \cdot (5.4 + 2 \cdot 5.2)}{5.4 + 5.2} \right) + 0.4 = 0.8223 \, m \]

\[ Z3 = \frac{0.4}{2} = 0.2 \, m \]

\[ Zs = \frac{1.75 \cdot 0.1762 + 4.505 \cdot 0.8223 + 2.16 \cdot 0.2}{8.415} = 0.5282 \, m \]

\[ Zs1 = 0.5282 - 0.1763 = 0.3520 \, m \]

\[ Zs2 = 0.8223 - 0.5282 = 0.2941 \, m \]

\[ Zs3 = 0.5282 - 0.2 = 0.3282 \, m \]
\[ I_c = \left[ 2,5 \cdot \left( \frac{0,3 + 0,4}{2} \right)^3 \cdot 2 + 1,75 \cdot 0,352^2 \right] + \left( \frac{5,4 \cdot 0,85^3}{12} - \frac{0,1 \cdot 0,85^3}{18} \right) + 4,505 \cdot 0,2941^2 + \left[ \frac{5,4 \cdot 0,4^3}{12} + 2,16 \cdot 0,3242^2 \right] = 1,159 \text{m}^4 \]

1.2 Load assessment:

1.2.1 Vertical loads

\[
\begin{array}{|c|c|c|}
\hline
\text{F1} & Q_{1k} & 240 \\
\text{F2} & Q_{2k} & 160 \\
\Sigma & & 400 \text{kN} \\
\hline
\end{array}
\]

\[
\begin{array}{|c|c|c|}
\hline
\text{F1} & q_{1k} & 9 \cdot 3 = 27 \\
\text{F2} & q_{2k} & 2,5 \cdot 3 = 7,5 \\
\Sigma & q_{fk} & 4,15 \cdot 2,05 = 8,5 \text{ kN} \\
\hline
\end{array}
\]

\[
q_{fk} = 2 + \frac{120}{25,7 + 30} = 4,15 \text{ kN/ m}
\]

\[
2,5 \leq q_{fk} \leq 5
\]

1.2.2 Horizontal loads

\[
Q_{lk} = 0,6 \cdot \alpha_{q_1} \cdot 2 \cdot Q_{1k} + 0,1 \cdot \alpha_{q_1} \cdot q_{1k} \cdot w \cdot L = 0,6 \cdot 0,8 \cdot 2 \cdot 300 + 0,1 \cdot 1 \cdot 9 \cdot 3 \cdot 25,7 = 311,13 \text{ kN}
\]
1.2.3 Centrifugal loads

\[ R = \infty \rightarrow Q_k = 0 \text{kN} \]

1.3 Moments:

\[ \sum G_k + P_{kd} + \psi_{11} \cdot Q_{kd} + \sum \psi_2 \cdot Q_{kd} \]

\[ \gamma_8 = 1,0 \]

\[ \gamma_q = 1,0 \]

\[ \psi_{11} = 0,75 \]

\[ \psi_2 = 0,4 \]

\[ G_k \]

\[ g_{\text{uben}} = A_c \cdot \rho_{\text{beton}} = 8,8415 \text{m}^2 \cdot 25 \frac{kN}{m^3} = 210,40 \frac{kN}{m} \]

\[ g_{\text{fahr}} = 0,008 \cdot 7 \cdot 24 = 13,44 \frac{kN}{m} \]

\[ g_{\text{kappen}} = A_{\text{kap}} \cdot \rho_{\text{beton}} \cdot 2 = 0,56145 \text{m}^2 \cdot 25 \frac{kN}{m^3} \cdot 2 = 28,07 \frac{kN}{m} \]

\[ g_{\text{schutz}} = 1 \cdot 2 = 2 \frac{kN}{m} \]

\[ g_{\text{geisenger}} = 0,5 \cdot 2 = 1 \frac{kN}{m} \]

\[ q_k \]

\[ q_{\text{fahr1}} = 27 \frac{kN}{m} \]

\[ q_{\text{fahr2}} = 7,5 \frac{kN}{m} \]

\[ q_{fk} = 8,5 \frac{kN}{m} \cdot 2 = 17kN \frac{kN}{m} \]

\[ q_{rk} = 2,5 \frac{kN}{m} \]

\[ q_{kd} = q_{\text{fahr2}} + q_{fk} + q_{rk} = 27 \frac{kN}{m} \]

\[ Q_k \]

\[ Q_{1k} = -240kN \]
\[ Q_{2k} = -160kN \]
\[ Q_{ku} = -400kN \]

### 1.3.1 Combination of actions 1: \( t = 0 \)

\[ Gkd = g\ddot{u}ber = 210,4kN/m \]
\[ M_{tot1} = \frac{Gkd \cdot l^2}{8} = 17,371 \text{ MN} \cdot \text{m} \]

### 1.3.2 Combination of actions 2: \( t = \infty \)

\[ Gkd = g\ddot{u}ber + gfahr + gkappen + ggeländer + gschutz = 254,90kN/m \]
\[ M_{tot2} = \frac{Gkd \cdot l^2}{8} + \frac{qkd \cdot l^2}{8} 0,75 + 0,4 \cdot \left( \frac{qkd \cdot l^2}{8} + \frac{Qkd \cdot l^2}{8} \right) = 24,70 \text{ MN} \cdot \text{m} \]

### 1.4 Preliminary design

\[ A_c = 8.415 \text{ m}^2 \quad \text{C35/45} \]
\[ W_{co} = \frac{I_c}{z_{so}} = -2.194 \text{ m}^3 \quad f_{ck} = 35 \text{ KN/m}^2 \]
\[ W_{cu} = \frac{I_c}{z_{su}} = 1.606 \text{ m}^3 \]

\( t = 0 \rightarrow M_{gkd} = 17.37 \text{ MN} \cdot \text{m} \)

\( t = \infty \rightarrow M_{gqd} = 24.96 \text{ MN} \cdot \text{m} \)

\[ d_{p1} = c_v + \frac{1}{2} \cdot d_{ha} + e_s = 110 + 50 + 15.83 = 0.1425 \text{ m} \]
\[ c_v = c_{nom} = c_{min} + \Delta_c = 100 + 10 = 110 \text{ mm} \]
\[ c_{min} = \max \left\{ \begin{array}{l} d_{ha} = 100 \text{ mm} \\ 50 \text{ mm} \end{array} \right\} \]
\[ \Delta_c = 10 \text{ mm} \]
\[ e_s = \frac{1}{6} \cdot d_{hi} = 1/6 \cdot 95 = 15.85 \text{ mm} \]
\[ z_{p_{\text{max}}} = h - |z_{sol}| - d_{p1} = 0.57097 \text{ m} \]

### 1.4.1 Determination of the boundary lines

- **\( t = 0 \)**
  - Compressive stress at the top edge of the component
  \[
  \sigma_{c,0,u} = \frac{-P_{0,u}}{A_c} - \frac{P_{0,u}z_p}{W_{y,u}} + \frac{M_g}{W_{y,u}} \rightarrow \frac{A_c \cdot M_g - A_c \cdot W_{y,u} \cdot \sigma_{c,0,u}}{W_{y,u} + A_c \cdot z_p}
  \]
  \[
  \sigma_{c,0,u} = -0.6 \cdot f_{ck}
  \]
  \[
  P_{0,u}(z_p) = \frac{A_c \cdot M_g - A_c \cdot W_{y,u} \cdot \sigma_{c,0,u}}{W_{y,u} + A_c \cdot z_p}
  \]

  - Tensile stress at the top edge of the component
  \[
  \sigma_{c,0,o} = \frac{-P_{0,o}}{A_c} + \frac{P_{0,o}z_p}{W_{y,o}} - \frac{M_g}{W_{y,o}} \rightarrow \frac{A_c \cdot M_g + A_c \cdot W_{y,o} \cdot \sigma_{c,0,o}}{W_{y,o} - A_c \cdot z_p}
  \]
  \[
  \sigma_{c,0,o} = 0.1 \cdot f_{ck}
  \]
  \[
  P_{0,o}(z_p) = \frac{A_c \cdot M_g + A_c \cdot W_{y,o} \cdot \sigma_{c,0,o}}{W_{y,o} - A_c \cdot z_p}
  \]

- **\( t = \infty \)**
  - Tensile stress at the lower edge of the component
  \[
  \sigma_{c,U,u} = \frac{-P_{U,u}^{0.8}}{A_c} - \frac{P_{U,u}^{0.8}z_p}{W_{y,u}} + \frac{M_{gq}}{W_{y,u}} \rightarrow \frac{5.0 \cdot A_c \cdot M_{gq} - 5.0 \cdot A_c \cdot W_{y,u} \cdot \sigma_{c,U,u}}{4.0 \cdot W_{y,u} + 4.0 \cdot A_c \cdot z_p}
  \]
  \[
  \sigma_{c,U,u} = 0.1 \cdot f_{ck}
  \]
  \[
  P_{U,u}(z_p) = \frac{5.0 \cdot A_c \cdot M_{gq} - 5.0 \cdot A_c \cdot W_{y,u} \cdot \sigma_{c,U,u}}{4.0 \cdot W_{y,u} + 4.0 \cdot A_c \cdot z_p}
  \]

  - Compressive stress at the lower edge of the component
\[
\alpha_{c,U,o} = \frac{-P_{U,o} \cdot 0.8}{A_c} + \frac{P_{U,o} \cdot 0.8 \cdot z_p}{W_{y,o}} - \frac{M_{gq}}{W_{y,o}} \to -\frac{1.0 \cdot 5.0 \cdot A_c \cdot M_{gq} + 5.0 \cdot A_c \cdot W_{y,o} \cdot \alpha_{c,U,o}}{4.0 \cdot W_{y,o} - 4.0 \cdot A_c \cdot z_p}
\]

\[
\alpha_{c,U,o} = -0.45 \cdot f_{ck}
\]

\[
P_{U,o}(z_p) = -\frac{5.0 \cdot A_c \cdot M_{gq} + 5.0 \cdot A_c \cdot W_{y,o} \cdot \alpha_{c,U,o}}{4.0 \cdot W_{y,o} - 4.0 \cdot A_c \cdot z_p}
\]

1.4.2 Determination of the Prestress force

- \( t = 0 \)

\( P_{D,u}(z_p = 1.0418 \text{ m}) = 67 \text{ MN-m} \)

\( P_{o,o}(z_p = 1.0418 \text{ m}) = 56 \text{ MN-m} \)

- \( t = \infty \)

\( P_{U,u}(z_p = 1.0418 \text{ m}) = 40.5 \text{ MN-m} \)

\( P_{U,o}(z_p = 1.0418 \text{ m}) = -38.67 \text{ MN-m} \)

Untere grenze: \( P_o = \max(P_{U,u}; P_{U,o}) = 40.5 \text{ MN-m} \)

Obere grenze: \( P_o = \max(P_{U,u}; P_{U,o}) = 56 \text{ MN-m} \)

\( P_o = 45 \text{ MN-m} \)

- \( t = 0 \)

\( z_{0,u}(x) = 0.6 \cdot f_{ck} \cdot \frac{W_{y,u}}{P_0} - \frac{W_{y,u}}{A_c} + \frac{M_g(x)}{P_0} \)

\( z_{0,o}(x) = \frac{W_{y,o}}{A_c} + \frac{M_g(x)}{P_0} \)

- \( t = \infty \)

\( z_{U,u}(x) = \frac{-W_{y,u}}{A_c} + 1.25 \frac{M_{gq}(x)}{P_0} \)
\[ z_{U,0}(x) = -9 \cdot f_{ck} \frac{W_{y,0}}{16 \cdot P_0} + \frac{W_{y,0}}{A_c} + 1.25 \cdot \frac{M_{gq}(x)}{P_0} \]

\[ z_{U,0}(x = 0) = -0.006 \text{ m} \]
\[ z_{o,0}(x = 0) = 0.6467 \text{ m} \]

### 1.4.3 Determination of the number of tendons required

\[ f_{pk,xul} = \min \{0.75 \cdot f_{pk} ; 0.85 \cdot f_{p,0.1k} \} \left( \frac{N}{mm^2} \right) = \]
\[ \min \{0.75 \cdot 1770 ; 0.85 \cdot 1500\} = 1257 \text{ N/mm}^2 \]
\[ A_0 = 33 \text{ cm}^2 \]
\[ n_{erf} = \frac{P_0}{A_p \cdot f_{pk,xul}} = 10.84 \sim 11 \]
2 Alternative 3

2.2 Cross section values

Area

\[ A_1 = A_2 = \frac{(0.6 + 0.75) \cdot 3}{2} = 2.025 \text{ m}^2 \]

\[ A_3 = \frac{(4.14 + 4.34) \cdot 1}{2} = 4.24 \text{ m}^2 \]

\[ A_4 = 0.75 \cdot 4.34 = 3.255 \text{ m}^2 \]

\[ A_c = A_1 + A_2 + A_3 + A_4 = 11.545 \text{ m}^2 \]

Inertia

\[ Z_1 = \frac{1}{3} \left( (0.6 + 0.75) - \frac{0.75 \cdot 0.6}{(0.6 + 0.75)} \right) = 0.3389 \text{ m} \]

\[ Z_2 = \frac{1}{3} \left( (0.6 + 0.75) - \frac{0.75 \cdot 0.6}{(0.6 + 0.75)} \right) = 0.3389 \text{ m} \]

\[ Z_3 = \frac{0.75}{2} = 0.375 \text{ m} \]

\[ Z_4 = \frac{1}{3} \left( \frac{1 \cdot (4.34 + 2 \cdot 4.14)}{4.34 + 4.14} \right) + 0.75 = 1.2461 \text{ m} \]

\[ Z_s = \frac{(2.025 \cdot 0.3389) \cdot 2 + 3.255 \cdot 0.375 + 4.24 \cdot 1.2461}{11.545} = 0.68225 \text{ m} \]

\[ Z_s = Z_2 = 0.68 - 0.339 = 0.341 \text{ m} \]

\[ Z_s = 0.68 - 0.375 = 0.305 \text{ m} \]

\[ Z_s = 1.2461 - 0.68 = 0.5661 \text{ m} \]
$$Ic = \left[ 3 \cdot \left( \frac{0,6 + 0,75}{2} \right)^3 + 2,025 \cdot 0,341 \right] + 2 \left[ \left( \frac{4,34}{12} - \frac{0,1}{18} \right) + 4,24 \cdot 0,562 \right] + \left[ \frac{4,34 \cdot 0,753^3}{12} + 3,2 \cdot 0,3^2 \right] = 2,793 m4$$

2.3 Load assessment:

2.3.1 Vertical loads

<table>
<thead>
<tr>
<th></th>
<th>α·Q₁ₖ (kN)</th>
<th>M (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Q₁ₖ</td>
<td>240</td>
</tr>
<tr>
<td>F2</td>
<td>Q₂ₖ</td>
<td>160</td>
</tr>
<tr>
<td>Σ</td>
<td></td>
<td>400 kN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>α·q₁ₖ (kN)</th>
<th>M (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>q₁ₖ</td>
<td>9 · 3 = 27</td>
</tr>
<tr>
<td>F2</td>
<td>q₂ₖ</td>
<td>2,5 · 3 = 7,5</td>
</tr>
<tr>
<td>*</td>
<td>q₆ₖ</td>
<td>3,84 · 2,05 = 7,89</td>
</tr>
<tr>
<td>R</td>
<td>q₉ₖ</td>
<td>2,5 · 0,5 · 2 = 2,5</td>
</tr>
<tr>
<td>Σ</td>
<td></td>
<td>44,89 kN</td>
</tr>
</tbody>
</table>

$$qf_k = 2 + \frac{120}{35 + 30} = 3,84 kN / m$$

$$2,5 \leq qf_k \leq 5$$

2.3.2 Horizontal loads
\[ Q_{lk} = 0,6 \cdot \alpha_{q_1} \cdot 2 \cdot Q_{1k} + 0,1 \cdot \alpha_{q_1} \cdot q_{1k} \cdot w \cdot L = 0,6 \cdot 0,8 \cdot 2 \cdot 300 + 0,1 \cdot 1 \cdot 9 \cdot 3 \cdot 35 = 382,5 \text{ kN} \]

### 2.3.3 Centrifugal loads

\[ R = \infty \Rightarrow Q_{\text{lk}} = 0 \text{ kN} \]

### 2.4 Moments

\[ \Sigma G_{kd} + P_{kd} + \psi_{11} \cdot Q_{kd} + \Sigma \psi_2 \cdot Q_{kd} \]

\[ \gamma_g = 1,0 \]

\[ \gamma_q = 1,0 \]

\[ \psi_{11} = 0,75 \]

\[ \psi_2 = 0,4 \]

\[ G_k \]

\[ g_{\text{uben}} = A_c \cdot \rho_{\text{beton}} = 11,595 \text{ m}^2 \cdot 25 \frac{\text{kN}}{\text{m}^3} = 289,88 \frac{\text{kN}}{\text{m}} \]

\[ g_{\text{fahr}} = 0,008 \cdot 7 \cdot 24 \frac{\text{kN}}{\text{m}^3} = 13,44 \frac{\text{kN}}{\text{m}} \]

\[ g_{\text{kappen}} = A_{\text{kap}} \cdot \rho_{\text{beton}} \cdot 2 = 0,6886 \text{ m}^2 \cdot 25 \frac{\text{kN}}{\text{m}^3} \cdot 2 = 34,43 \frac{\text{kN}}{\text{m}} \]

\[ g_{\text{schutz}} = 1 \cdot 2 = 2 \frac{\text{kN}}{\text{m}} \]

\[ g_{\text{geänger}} = 0,5 \cdot 2 = 1 \frac{\text{kN}}{\text{m}} \]

\[ q_k \]

\[ q_{\text{fahr1}} = 27 \frac{\text{kN}}{\text{m}} \]

\[ q_{\text{fahr2}} = 7,5 \frac{\text{kN}}{\text{m}} \]

\[ q_{f_k} = 8,5 \frac{\text{kN}}{\text{m}} \cdot 2 = 17 \frac{\text{kN}}{\text{m}} \]

\[ q_{\text{rk}} = 2,5 \frac{\text{kN}}{\text{m}} \]
\[ q_{kd} = q_{faehr} + q_{fk} + q_{rk} = 27 \frac{kN}{m} \]

\[ Q_k \]

\[ Q_{1k} = -240kN \]
\[ Q_{2k} = -160kN \]
\[ Q_{kd} = -400kN \]

### 2.4.1 Combination of actions 1: \( t = 0 \)

\[ G_{kd} = \text{g"uber} = 289,88kN/m \]

\[ M_{tot1} = \frac{G_{kd} \cdot l^2}{8} = 44,387 \text{ MN} \cdot \text{m} \]

### 2.4.2 Combination of actions 2: \( t = \infty \)

\[ G_{kd} = \text{g"uber} + \text{faehr} + \text{gkappen} + \text{gel"ander} + \text{gschutz} = 340,75 \text{ kN/m} \]

\[ M_{tot2} = \frac{G_{kd} \cdot l^2}{8} + \frac{q_{kd} \cdot l^2}{8} - 0,75 + 0,4 \left( \frac{q_{kd} \cdot l^2}{8} + \frac{Q_{kd} \cdot l^2}{8} \right) = 58,34 \text{ MN} \cdot \text{m} \]

### 2.5 Preliminary design

\[ A_c = 11,545 \text{ m}^2 \]
\[ W_{co} = \frac{l_c}{z_{co}} = -4,0938 \text{ m}^3 \]
\[ W_{cu} = \frac{l_c}{z_{cu}} = 2,6158 \text{ m}^3 \]

\[ d_{p1} = c_v + \frac{1}{2} \cdot d_{ha} + e_s = 128 + 59 + 18,3 = 0,2053 \text{ m} \]

\[ c_v = c_{nom} = c_{min} + \Delta_c = 118 + 10 = 128 \text{ mm} \]

\[ c_{min} = \max \left\{ \begin{array}{l} d_{ha} = 118 \text{ mm} \\ 50 \text{ mm} \end{array} \right. \]

\[ \Delta_c = 10 \text{ mm} \]

\[ e_s = \frac{1}{6} \cdot d_{hi} = 18,3 \text{ mm} \]

13
\[ z_{p,\max} = h - |z_{s0}| - d_{p1} = 0.86 \, m \]

### 2.5.1 Determination of the boundary lines

- \( t = 0 \)
  - Compressive stress at the top edge of the component
    \[
    \sigma_{c.0.u} = \frac{-P_{0,u}}{A_c} - \frac{P_{0,u} z_p}{W_{y,u}} + \frac{M_g}{W_{y,u}} \rightarrow \frac{A_c \cdot M_g - A_c \cdot W_{y,u} \sigma_{c.0.u}}{W_{y,u} + A_c \cdot z_p}
    \]
    \[\sigma_{c.0.u} = -0.6 \cdot f_{ck}\]
    \[P_{0,u}(z_p) = \frac{A_c \cdot M_g - A_c \cdot W_{y,u} \sigma_{c.0.u}}{W_{y,u} + A_c \cdot z_p}\]
  - Tensile stress at the top edge of the component
    \[
    \sigma_{c.0.o} = \frac{-P_{0,o}}{A_c} + \frac{P_{0,o} z_p}{W_{y,o}} - \frac{M_g}{W_{y,o}} \rightarrow \frac{A_c \cdot M_g + A_c \cdot W_{y,o} \sigma_{c.0.o}}{W_{y,o} - A_c \cdot z_p}
    \]
    \[\sigma_{c.0.o} = 0 \cdot f_{ck}\]
    \[P_{0,o}(z_p) = \frac{A_c \cdot M_g + A_c \cdot W_{y,o} \sigma_{c.0.o}}{W_{y,o} - A_c \cdot z_p}\]

- \( t = \infty \)
  - Tensile stress at the lower edge of the component
    \[
    \sigma_{c,U.u} = \frac{-P_{U,u} \cdot 0.8}{A_c} - \frac{P_{U,u} \cdot 0.8 z_p}{W_{y,u}} + \frac{M_{gq}}{W_{y,u}} \rightarrow \frac{5.0 \cdot A_c \cdot M_{gq} - 5.0 \cdot A_c \cdot W_{y,u} \sigma_{c,U.u}}{4.0 \cdot W_{y,u} + 4.0 \cdot A_c \cdot z_p}
    \]
    \[\sigma_{c,U.u} = 0 \cdot f_{ck}\]
    \[P_{U,u}(z_p) = \frac{5.0 \cdot A_c \cdot M_{gq} - 5.0 \cdot A_c \cdot W_{y,u} \sigma_{c,U.u}}{4.0 \cdot W_{y,u} + 4.0 \cdot A_c \cdot z_p}\]
- Compressive stress at the lower edge of the component

\[
\sigma_{c,U,o} = \frac{-P_{U,o} \cdot 0.8}{A_c} + \frac{P_{U,o} \cdot 0.8 \cdot z_p}{W_{y,o}} - \frac{M_{gq}}{W_{y,o}} \rightarrow \frac{1.0 \cdot (5.0 \cdot A_c \cdot M_{gq} + 5.0 \cdot A_c \cdot W_{y,o} \cdot \sigma_{c,U,o})}{4.0 \cdot W_{y,o} - 4.0 \cdot A_c \cdot z_p}
\]

\[
\sigma_{c,U,o} = -0.45 \cdot f_{ck}
\]

\[
P_{U,o}(z_p) = \frac{(5.0 \cdot A_c \cdot M_{gq} + 5.0 \cdot A_c \cdot W_{y,o} \cdot \sigma_{c,U,o})}{4.0 \cdot W_{y,o} - 4.0 \cdot A_c \cdot z_p}
\]

2.5.2 Determination of the Prestress force

- \( t = 0 \)

\[
P_{U,u}(z_p = 1.0418 \text{ m}) = 91.4 \text{ MN.m}
\]

\[
P_{U,o}(z_p = 1.0418 \text{ m}) = 87.8 \text{ MN.m}
\]

- \( t = \infty \)

\[
P_{U,u}(z_p = 1.0418 \text{ m}) = 67.1 \text{ MN.m}
\]

\[
P_{U,o}(z_p = 1.0418 \text{ m}) = -15.2 \text{ MN.m}
\]

Untere grenze: \( P_o = \max\{P_{U,u}; P_{U,o}\} = 67.1 \text{ MN.m} \)

Obere grenze: \( P_o = \max\{P_{U,u}; P_{U,o}\} = 87.8 \text{ MN.m} \)

\[
P_o = 70 \text{ MN.m}
\]

- \( t = 0 \)

\[
z_{0,u}(x) = 0.6 \cdot f_{ck} \cdot \frac{W_{y,u}}{P_0} - \frac{W_{y,u}}{A_c} + \frac{M_g(x)}{P_0}
\]

\[
z_{0,o}(x) = \frac{W_{y,o}}{A_c} + \frac{M_g(x)}{P_0}
\]

- \( t = \infty \)
\[ z_{U,u}(x) = \frac{-W_{y,u}}{A_c} + 1.25 \cdot \frac{M_{gq}(x)}{P_0} \]

\[ z_{U,O}(x) = -9 \cdot f_{ck} \cdot \frac{W_{y,O}}{16 \cdot P_0} + \frac{W_{y,O}}{A_c} + 1.25 \cdot \frac{M_{gq}(x)}{P_0} \]

\[ z_{u,u}(x = 0) = 0.815 \text{ m} \]
\[ z_{O,O}(x = 0) = 0.9887 \text{ m} \]

2.5.3 Determination of the number of tendons required

\[ f_{pk,xul} = \min\{0.75 \cdot f_{pk}; 0.85 \cdot f_{p,0.01}\} \left[ \frac{N}{mm^2} \right] = \]

\[ min\{0.75 \cdot 1770; 0.85 \cdot 1500\} = 1257 \text{ N/mm}^2 \]

\[ A_p = 33 \text{ cm}^2 \]

\[ n_{erf} = \frac{P_0}{A_p \cdot f_{pk,xul}} = 16.87 \sim 17 \]
Annex 2
Bridge – Structural Calculations
TABLE OF CONTENTS

1. Material Properties 6
   1.1 Concrete
   1.2 Reinforced concrete
   1.3 Prestressed concrete and Tendon
   1.4 Cladding Tube
   1.5 Anchor
   1.6 E-Modul
   1.7 Concrete cover

2. Section Properties 10
   2.1 Dimensions
   2.2 Net cross section
   2.3 Gross section Steg
   2.4 Ideal section Steg

3. Load Assessment 14
   3.1 Vertical loads
      3.1.1 Determination of dead loads
      3.1.2 Determination of traffic loads
         3.1.2.1 Uniformed distributed loads
         3.1.2.2 Cap
      3.1.3 Determination of actions and moments
         3.1.3.1 Actions
         3.1.3.2 Moments
   3.2 Horizontal loads
      3.2.1 Horizontal loads
      3.2.2 Centrifugal force
      3.2.3 Wind load
      3.2.4 Temperature effect
         3.2.4.1 Maximum variation of negative temperature component
         3.2.4.2 Bridge classification by cross section type
         3.2.4.3 Constant Temperature portion - characteristic values
         3.2.4.4 Constant fluctuation of the temperature component
         3.2.4.5 Linear temperature difference - characteristic values
         3.2.4.6 Simultaneous viewing of the constant temperature and the linear temperature difference

4. Predimensioning 24
   4.1 Determination of the basic distances
4.2 Determination of the boundary lines
   4.2.1 Determination of the prestressed force
4.3 E-Lines
4.4 Determination of the tendon and the clamping member
   4.4.1 Maximum admissible tendon load
4.5 Determination of the clamping member dial
   4.5.1 Maximum load for each member

5. Prestress
   5.1 Tendon profile
   5.2 Clamping force curve
      5.2.1 Group 1
      5.2.2 Group 2
   5.3 Creep, shrinkage and relaxation
      5.3.1 Creep
      5.3.2 Shrinkage
      5.3.3 Relaxation

6. Combination of Actions
   6.1 Ultimate Limit State
      6.1.1 Bending design
      6.1.2 Shear design
      6.1.3 Torsion
   6.2 Service Limit State
   6.3 Coefficient interaction

7. Internal Forces
   7.1 Load System
      7.1.1 Dead load
         7.1.1.1 Superstructure
         7.1.1.2 Roadway
         7.1.1.3 Kappen
         7.1.1.4 Handrails / Guardrails
      7.1.2 Traffic
         7.1.2.1 TS Mid – Maximum bending
         7.1.2.2 TS End – Maximum shear
   7.2 Graphs - Results
      7.2.1 Superstructure
         7.2.1.1 Roadway
         7.2.1.2 Kappen
         7.2.1.3 Handrails / Guardrails
      7.2.2 Traffic
         7.2.2.1 TS Mid
         7.2.2.2 TS End
   7.3 Ultimate Limit State
      7.3.1 t = 0 Superstructure dead load
7.3.2 \( t = \infty \) All loads
   7.3.2.1 TS Mid – max. Bending
   7.3.2.2 TS End – max. Shear force
7.4 Ultimate Service State
   7.4.1 \( t = \infty \) - alles Lasten
   7.4.1.1 TS Mid – max. Bending
   7.4.1.2 TS End – max. Shear force

8. Ultimate Limit State
8.1 Bending design
   8.1.1 Determination of the basic distances
   8.1.2 Bending design for \( t = 0 \)
   8.1.3 Bending design for \( t = \infty \)
8.2 Robustness reinforcement
8.3 Shear Design
8.4 Torsion Design
8.5 Shear and Torsion
8.6 Connection of compressed and tensioned straps
8.7 Surface reinforcement
8.8 Minimum shear reinforcement
8.9 Maximum reinforcement

9. Service Limit State
9.1 Required class
9.2 Prestress
9.3 Minimum reinforcement of crack with

10. End Cross Beam
10.1 Bending design
10.2 Robustness design
10.3 Shear design
10.4 Surface reinforcement
10.5 Crack with
10.6 Splitting tensile reinforcement
10.7 Torsion design

11. Bearing and Expansion Joints
11.1 Bearings
   11.1.1 Movement range
      11.1.1.1 Braking and Acceleration
      11.1.1.2 Temperature effect
      11.1.1.3 Prestress, creep and shrinkage
      11.1.1.4 Maximum values
   11.1.2 Design
      11.1.2.1 Deformation due to temperature, tension, creep, shrinkage and release
      11.1.2.2 Deformation due to loading
11.1.2.3 Deformation from torsion
11.1.2.4 Total deformation
11.1.2.5 Minimum bearing pressure

11.2 Expansive joints

Notes
1 Material Properties

1.1 Concrete

Concrete strength class C35/45
Exposure class XC4, XD3, XF4

Concrete compressive strength characteristic value
\[ f_{ck} := 35 \frac{N}{mm^2} \]

Minimum compressive strength
\[ f_{cm} := 43 \frac{N}{mm^2} \]

Average tensile strength
\[ f_{ctm} := 3.2 \frac{N}{mm^2} \]

Concrete tensile strength
\[ f_{cto} := 2.9 \frac{N}{mm^2} \]

Tensile strength 5% quantil
\[ f_{ctk.0.05} := 2.2 \frac{N}{mm^2} \]

Tensile strength 95% quantil
\[ f_{ctk.0.95} := 4.2 \frac{N}{mm^2} \]

Design value of the concrete compressive strength
\[ f_{cd} := \alpha_{cc} f_{ck} \gamma_c = 19.83 \frac{N}{mm^2} \]

Reduction factor (in-situ concrete)
\[ \alpha_{cc} := 0.85 \]

Minimum concrete strength
\[ f_{ck.cyl} := 35 \frac{N}{mm^2} \]
\[ f_{ck.cube} := 45 \frac{N}{mm^2} \]

Tensile concrete strength at when crack occurs
\[ f_{cteff} := \frac{f_{ctm}}{2} = 1.6 \frac{N}{mm^2} \]
1.2 Reinforced concrete

Reinforced concrete class BSt 500S

Characteristic value of steel yield point
\[ f_{yk} := \frac{500}{\text{mm}^2} \]

Design value of steel yield point
\[ f_{yd} := \frac{435}{\text{mm}^2} \]

Design value of steel yield point for shear reinforcement
\[ f_{ywd} := \frac{435}{\text{mm}^2} \]

Admissible tensile stress
\[ \sigma_{sd} := \frac{435}{\text{mm}^2} \]

1.3 Prestressed Steel and Tendon system

- SUSPA Strands 150 mm\(^2\) with subsequent bonding according to DIN 1045-1 and DIN Technical Report 102
- St 1570/1770, type of tendon 6-2

Characteristic tendon stress at 0.1%
\[ f_{p0.1k} := \frac{1500}{\text{mm}^2} \]

Characteristic tensile strength
\[ f_{pk} := 1770 \frac{N}{\text{mm}^2} \]

Admissible prestressing forces
\[ P_{o,max} := 4453 \text{kN} \]
\[ P_{mo,max} := 4208 \text{kN} \]

Area of prestressing member
\[ A_p := 33 \text{cm}^2 \]
1.4 Cladding Tube

Type I

- **External diameter**
  \[ d_{ha} := 107 \text{ mm} \]

- **Internal diameter**
  \[ d_{hi} := 100 \text{ mm} \]

- **Friction factor**
  \[ \mu := 0.20 \]

- **Unintended deflection**
  \[ \kappa := 0.0052 \frac{\text{rad}}{\text{m}} \]

- **Slip at the anchorage**
  \[ \Delta_{lse} := 6 \text{ mm} \]

  \[ E' := 0.6 \% \]

  \[ k := 1.5 \]

1.5 Anchor

Anchor type E with more armadure area MA, 6-22 Type Stranded wire Y1770S7 Y1860S7 15.7 and 15.7

Fixed anchor type HL 6-22 (150 mm2) stranded wire Y1770S7 Y1860S7 15.7 and 15.7

version III

1.6 E-Modul

Elastic Modulus (sectant modulus) \[ v \]

\[ E_{cm} := 34000 \frac{\text{N}}{\text{mm}^2} \]
Steel Elastic Modulus

Modulus of elasticity for steel span wires

\[ E_s := \frac{200000}{\text{N/mm}^2} \]

\[ E_p := \frac{195000}{\text{N/mm}^2} \]

1.7 Concrete Cover

\[ c_{\text{nom}} := c_{\text{min}} + \Delta c = 117 \text{mm} \]

\[ c_{\text{min}} := \max(d_{ha}, 50 \text{mm}) = 107 \cdot \text{mm} \]

\[ \Delta c := 10 \text{mm} \]

\[ c_v := 235 \text{mm} \]
2 Section properties

2.1 Dimensions

Effective length

Total height

Upper width

Lower width

Effective width

2.5.2.2 Geometrische Größen

2.5.2.2.1 Mitwirkende Plattenbreite, Lastausbreitung

DIN-Fachbericht 102:2009-03

Surface measure

Center of gravity

- up edge
- low edge
Geometrical moment of inertia “y” \[ I_c := 0.47 \, \text{m}^4 \]

Section modulus
\[ W_u := \frac{I_c}{z_{su}} = 0.58 \, \text{m}^3 \]
\[ W_o := \frac{I_c}{z_{so}} = 0.959 \, \text{m}^3 \]

Perimeter
\[ u := 1.75 \, \text{m} + 1.20 \, \text{m} + \frac{1.30 \, \text{m}}{2} + 0.35 \, \text{m} \cdot 2 + 2 \cdot 0.90 \, \text{m} + 1.50 \, \text{m} + 5.2 \, \text{m} = 12.8 \, \text{m} \]

2.2 Net cross section

\[ A_n := A_c - 5\pi \cdot \frac{d_{ha}^2}{4} = 3.68 \, \text{m}^2 \]

\[ z_n := \frac{G_c \cdot A_c - 5 \cdot A_p \left[ h_{tot} - c_v \right]}{A_c - 5 \cdot A_p} = 0.487 \, \text{m} \]

\[ z_{on} := z_n = 0.487 \, \text{m} \]

\[ z_{un} := h_{tot} - z_n = 0.813 \, \text{m} \]

\[ I_n := \frac{I_c}{5} \left[ I_o + A_o \left( G_c - c_v \right)^2 \right] = 0.467 \, \text{m}^4 \]

\[ A_o := \frac{\pi}{4} \cdot d_{ha}^2 = 89.92 \, \text{cm}^2 \]

\[ I_o := \frac{\pi}{4} \left( \frac{d_{ha}}{2} \right)^4 = 643.44 \, \text{cm}^4 \]

\[ W_{on} := \frac{I_n}{z_{on}} = -0.958 \, \text{m}^3 \]
2.3 Cross section Steg

\[ W_{un} := \frac{I_n}{z_{un}} = 0.575 \text{ m}^3 \]

\[ A_{st} := 1.75 \text{ m} \cdot 1.30 \text{ m} + 2 \cdot \frac{(0.1 \text{ m} \cdot 1.30 \text{ m})}{2} = 2.405 \text{ m}^2 \]

\[ G_{st} := \frac{(1.75 \text{ m} \cdot 1.30 \text{ m}) \cdot 0.65 \text{ m} + 2 \cdot \left( \frac{1.30 \text{ m} \cdot 0.1 \text{ m}}{2} \right) \cdot 0.86 \text{ m}}{1.75 \text{ m} \cdot 1.30 \text{ m} + \left( \frac{1.30 \text{ m} \cdot 0.1 \text{ m}}{2} \right) \cdot 2} = 0.661 \text{ m} \]

\[ I_{st} := \frac{1}{12} h_u h_{tot}^3 + A_1 \left( G_{st} - \text{cdg1} \right)^2 + 2 \cdot \left[ \frac{1}{36} h_{tot}^3 + A_2 \left( G_{st} - \text{cdg2} \right)^2 \right] = 0.338 \text{ m}^4 \]

\[ A_1 := 1.75 \text{ m} \cdot 1.30 \text{ m} = 2.275 \text{ m}^2 \]

\[ \text{cdg1} := \frac{h_{tot}}{2} = 0.65 \text{ m} \]

\[ A_2 := \frac{1.30 \text{ m} \cdot 0.1 \text{ m}}{2} = 0.065 \text{ m}^2 \]

\[ \text{cdg2} := \frac{2}{3} h_{tot} = 0.867 \text{ m} \]

2.4 Ideal cross section Steg

\[ A_i := A_{st} - \alpha_p \cdot 5 \pi \cdot \frac{d_{ha}^2}{4} = 2.14 \text{ m}^2 \]

\[ z_i := \frac{G_{st} \cdot A_i - 5 \cdot A_p \cdot (h_{tot} - c_y)}{A_i - 5 \cdot A_p} = 0.658 \text{ m} \]

\[ z_{oi} := z_i = 0.658 \text{ m} \]

\[ z_{ui} := h_{tot} - z_i = 0.642 \text{ m} \]
\[ I_t := I_{st} - 5 \left[ I_o + A_0 (G_{st} - c_v)^2 \right] = 0.33 \text{m}^4 \]

\[ W_{oi} := \frac{I_i}{-z_{oi}} = -0.502 \cdot \text{m}^3 \]

\[ W_{ui} := \frac{I_i}{z_{ui}} = 0.514 \cdot \text{m}^3 \]
3 Load Assessment

3.1 Vertical loads

3.1.1 Determination of dead loads

Superstructure
\[ g_{\text{\ddot{u}ben}} := A_t \cdot \rho_b = 186 \frac{\text{kN}}{\text{m}} \]

Roadway
\[ g_{\text{fahr}} := A_{\text{fahr}} \cdot \rho_f = 13.4 \frac{\text{kN}}{\text{m}} \]

Caps
\[ g_{\text{kap}} := A_{\text{kap}} \cdot 2 \cdot \rho_b = 28.6 \frac{\text{kN}}{\text{m}} \]

Handrail
\[ g_{\text{gale}} := 0.5 \cdot \frac{\text{kN}}{\text{m}} = 1 \cdot \frac{\text{kN}}{\text{m}} \]

Guardrail
\[ g_{\text{schu}} := 2 \cdot 1 \frac{\text{kN}}{\text{m}} = 2 \cdot \frac{\text{kN}}{\text{m}} \]

3.1.2 Determination of traffic loads

4.3.2 Lastmodell 1 (Doppelachsfahrzeug) DIN-Fachbericht 101:2009-03
Punctual loads

Tab. 4.2: Grundwerte und angepasste Grundwerte DIN-Fachbericht 101:2009-03

\[ Q_{k1} := 300\, \text{kN} \quad \alpha_{Q1} := 0.8 \quad Q_{1k} := Q_{k1} \cdot \alpha_{Q1} = 240\, \text{kN} \]

\[ Q_{k2} := 200\, \text{kN} \quad \alpha_{Q2} := 1.6 \quad Q_{2k} := Q_{k2} \cdot \alpha_{Q2} = 160\, \text{kN} \]

Distributed loads

Tab. 4.2: Grundwerte und angepasste Grundwerte DIN-Fachbericht 101:2009-03

Default value and adjustment factor for lane 1
\[ q_{k1} := 9\, \frac{\text{kN}}{\text{m}^2} \quad \alpha_{q1} := 1.6 \]

Default value and adjustment factor for lane 2
\[ q_{k2} := 2.5\, \frac{\text{kN}}{\text{m}^2} \quad \alpha_{q2} := 1.6 \]

Default value and adjustment factor for remaining surface
\[ q_{rk} := 2.5\, \frac{\text{kN}}{\text{m}^2} \quad \alpha_{qr} := 1.6 \]

Characteristic value for lane 1
\[ q_{1k} := q_{k1} \cdot \alpha_{q1} = 9\, \frac{\text{kN}}{\text{m}^2} \]

Characteristic value for lane 2
\[ q_{2k} := q_{k2} \cdot \alpha_{q2} = 2.5\, \frac{\text{kN}}{\text{m}^2} \]

Characteristic value for remaining surface
\[ q_{rk} := q_{rk} \cdot \alpha_{qr} = 2.5\, \frac{\text{kN}}{\text{m}^2} \]

3.1.2.1 Uniformly distributed load

5.3.2.1 Gleichmäßig verteilte Last DIN-Fachbericht 101:2009-03

\[ 2.5\, \frac{\text{kN}}{\text{m}^2} \leq q_{fk} \leq 5\, \frac{\text{kN}}{\text{m}^2} \]

\[ q_{fk} := 2 + \frac{120}{l_{\text{eff}} + 30} = 4.15 \]
3.1.2.2 Caps

$$q_{kap} := 2.5 \frac{kN}{m^2} \quad l_{ang} := 2.05 \text{ m}$$

3.1.3 Determination of actions and moments

3.1.3.1 Actions

Distances:

4.2.3 Unterteilung der Fahrbahn in rechnerische Fahrstreifen DIN-Fachbericht 101:2009-03

Land's 1 and 2 width \( w_1 := 3 \text{ m} \)

Remaining surface's width \( 1 \text{ m} \)

Kappen width \( 2.05 \text{ m} \)

Dead loads:

- \( t = 0 \) - Only superstructure

$$g_{to} := g_{\text{üben}} = 186 \frac{kN}{m}$$
- \( t = \) infinitely – All loads

\[ f_{tu} := f_{\text{uben}} + f_{\text{fahr}} + f_{\text{kap}} + f_{\text{gale}} + f_{\text{schu}} = 231\, \text{kN/m} \]

**Punctual loads:**

\[ Q_{TS,k} := Q_{1k} + Q_{2k} = 400\, \text{kN} \]

**Uniformly distributed loads:**

\[ q_{1k} := 9\, \frac{\text{kN}}{\text{m}} \cdot 3\, \text{m} = 27\, \text{kN} \]

\[ q_{2k} := 2.5\, \frac{\text{kN}}{\text{m}} \cdot 3\, \text{m} = 7.5\, \text{kN} \]

\[ q_{\text{kappe}} := q_{\text{kap}^{\text{lang}}} = 5.13\, \frac{\text{kN}}{\text{m}} \]

\[ q_{\text{fk}} := 2 \left( 4.15\, \frac{\text{kN}}{\text{m}} \cdot 2.05\, \text{m} \right) = 17\, \text{kN} \]

\[ q_{\text{rk}} := 2.5\, \frac{\text{kN}}{\text{m}} \cdot 1\, \text{m} = 2.5\, \text{kN} \]

\[ Q_{\text{UDL,k}} := q_{1k} + q_{2k} + q_{\text{fk}} + q_{\text{rk}} = 54\, \text{kN} \]

\[ q_{\text{kappe}} := q_{\text{kap}^{\text{lang}}} = 5.13\, \frac{\text{kN}}{\text{m}} \quad l_{\text{ang}} := 2.05\, \text{m} \]

**3.1.3.2 Moments**
Puntual loads

\[ M_{Q1_k} := Q_{1k} \cdot 3m + Q_{1k} \cdot 1m = 960 \text{kN} \cdot \text{m} \]

\[ M_{Q2_k} := Q_{2k} \cdot (-2m) = -320 \text{kN} \cdot \text{m} \]

\[ M_{\text{TS},k} := M_{Q1_k} + M_{Q2_k} = 640 \text{kN} \cdot \text{m} \]

Uniformly distributed loads

\[ M_{q1_k} := q_{1k} \cdot 2m = 54 \text{kN} \cdot \text{m} \]

\[ M_{qfk} := 0 \text{kN} \cdot \text{m} \]

\[ M_{q2_k} := q_{2k} \cdot (-1m) = -7.5 \text{kN} \cdot \text{m} \]

\[ M_{q_{rk}} := q_{rk} \cdot (-3m) = -7.5 \text{kN} \cdot \text{m} \]

\[ M_{\text{UDL},k} := M_{q1_k} + M_{q2_k} + M_{qfk} + M_{q_{rk}} = 39 \text{kN} \cdot \text{m} \]

Caps

\[ M_{\text{kap}} := 0 \text{kN} \cdot \text{m} \]

3.2 Determination of horizontal loads

4.4 Horizontallasten - charakteristische Werte DIN-Fachbericht 101:2009-03

3.2.1 Horizontal load

4.4.1 Lasten aus Bremsen und Anfahren DIN-Fachbericht 101:2009-03

\[ Q_{1k} := 0.6 \alpha_{Q1} \left( 2 \cdot Q_{1k} \right) + 0.1 \alpha_{q1} \cdot q_{1k} \cdot \text{l}_{\text{eff}} = 300 \text{kN} \]
Lane’s width \[ w_1 = 3 \text{ m} \]

\[ 288 = 360 \cdot \alpha Q_1 \leq Q_{1k} \leq 900 \]

### 3.2.2 Centrifugal force

4.4.2 Zentrifugallasten  
*DIN-Fachbericht* 101:2009-03

\[ Q_{1k} := 0 \text{kN} \quad \text{for} \, R = \text{infinitely} \]

<table>
<thead>
<tr>
<th>( Q_a = 0.2 \cdot Q_1 ) in kN</th>
<th>( Q_a - 40 \cdot Q_1 / r ) in kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Q_a = 0 )</td>
<td>( r &gt; 2000 \text{ m} )</td>
</tr>
<tr>
<td>( 200 \text{ m} \leq r \leq 1500 \text{ m} )</td>
<td></td>
</tr>
</tbody>
</table>

Tab. 4.3: Characteristic value of centrifugal force

### 3.2.3 Wind load

*Anhang N Windeinwirkungen auf Brücken*  
*DIN-Fachbericht* 101:2009-03

<table>
<thead>
<tr>
<th>( b / d )</th>
<th>( z_e \leq 20 \text{ m} )</th>
<th>( 20 \text{ m} &lt; z_e \leq 50 \text{ m} )</th>
<th>( 50 \text{ m} &lt; z_e \leq 100 \text{ m} )</th>
<th>( z_e \leq 20 \text{ m} )</th>
<th>( 20 \text{ m} &lt; z_e \leq 50 \text{ m} )</th>
<th>( 50 \text{ m} &lt; z_e \leq 100 \text{ m} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 30 \text{ m} \leq z_e \leq 40 \text{ m} )</td>
<td>1,75</td>
<td>2,45</td>
<td>2,90</td>
<td>1,45</td>
<td>2,05</td>
<td>2,40</td>
</tr>
<tr>
<td>( 40 \text{ m} &lt; z_e \leq 60 \text{ m} )</td>
<td>0,95</td>
<td>1,35</td>
<td>1,50</td>
<td>0,80</td>
<td>1,10</td>
<td>1,30</td>
</tr>
<tr>
<td>( 60 \text{ m} &lt; z_e \leq 100 \text{ m} )</td>
<td>0,95</td>
<td>1,35</td>
<td>1,50</td>
<td>0,80</td>
<td>0,85</td>
<td>1,00</td>
</tr>
</tbody>
</table>
• \( t = 0 \) – No traffic and noise protector wall influence

Girder height

\[ h_1 := 1.30 \text{m} \]

beam and formwork’s height

\[ h_o := 3.30 \text{m} \]

Cross section's width

\[ b := 11.1 \text{m} \]

\[ d := h_o = 3.3 \text{m} \]

\[ \frac{b}{d} = 3.364 \]

\[ w_o := 1.52 \frac{\text{kN}}{\text{m}^2} \]

\[ z_e := 8m + \frac{h_o}{2} = 9.65 \text{m} \]

\[ w_{ko} := w_o \cdot h_o = 5.016 \frac{\text{kN}}{\text{m}} \]

\[ z_{su} := 81 \text{cm} \]

\[ m_{wko} := w_{ko} \left( \frac{h_o}{2} - z_{su} \right) = 4.213 \frac{\text{kN} \cdot \text{m}}{\text{m}} \]

• \( t = \text{infiniets} \) – Traffic influence

Girder and traffic's height

\[ h_u := 5.30 \text{ m} \]

\[ d_u := h_u = 5.3 \text{ m} \]

\[ \frac{b}{d_u} = 2.094 \]

\[ w_u := 1.30 \frac{\text{kN}}{\text{m}^2} \]

\[ z_{eu} := 8m + \frac{h_u}{2} = 10.65 \text{m} \]

\[ w_{ku} := w_u \cdot h_u = 6.89 \frac{\text{kN}}{\text{m}} \]
3.2.4 Temperature

*Kapitel V Temperatureinwirkungen DIN-Fachbericht 101:2009-03*

3.2.4.1.1 Maximum variation of negative temperature component

\[
m_{wku} := w_{ku} \left( \frac{h_u}{2} - z_{su} \right) = 12.678 \text{kN} \cdot \frac{m}{m}
\]

3.2.4.2 Bridge classification by cross section type

Group 3 superstructures or deck slabs of concrete on concrete beams, concrete box girders.

3.2.4.3 Constant Temperature portion - characteristic values

Group 3 (Concrete bridge)

\[
T_{\text{emin}} := -17^\circ \text{K}
\]

\[
T_{\text{emax}} := 37^\circ \text{K}
\]

3.2.4.4 Constant fluctuation of the temperature component

Base temperature (10°C)

\[
T_0 := 10^\circ \text{K}
\]

\[
\Delta T_{N,\text{neg}} := T_{\text{emin}} - T_0 = -27^\circ \text{K}
\]
\[ \Delta T_{N, \text{pos}} := T_{\text{emax}} - T_0 = 27 \text{K} \]

\[ \Delta T_{N} := T_{\text{emax}} - T_{\text{emin}} = 54 \text{K} \]

3.2.4.5 Linear temperature difference - characteristic values

**Vertical component**

<table>
<thead>
<tr>
<th>Gruppen der Brückenüberbauten</th>
<th>Straßenbrücken</th>
<th>Eisenbahnbrücken</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positiver Temperaturunterschied</td>
<td>Negativer Temperaturunterschied</td>
</tr>
<tr>
<td></td>
<td>( \Delta T_{N, \text{pos}} ) in K</td>
<td>( \Delta T_{N, \text{neg}} ) in K</td>
</tr>
<tr>
<td>Gruppe 1</td>
<td>18</td>
<td>-13</td>
</tr>
<tr>
<td>Stahlüberbau aus Hohlkasten, Fachwerk oder Plattenbalken</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gruppe 2</td>
<td>15</td>
<td>-18</td>
</tr>
<tr>
<td>Verbundüberbau: Betonplatte auf einem Hohlkasten, Fachwerk oder Plattenbalken aus Stahl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gruppe 3</td>
<td>10</td>
<td>-5</td>
</tr>
<tr>
<td>Betonhohlkasten</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Betonplattenbalken</td>
<td>15</td>
<td>-8</td>
</tr>
<tr>
<td>Betonplatte</td>
<td>15</td>
<td>-8</td>
</tr>
</tbody>
</table>

\[ \Delta T_{M, \text{pos}} := 15 \text{K} \quad K_{\text{sur.o}} := 0.82 \]

\[ \Delta T_{M, \text{neg}} := -8 \text{K} \quad K_{\text{sur.u}} := 1.0 \]

\[ \Delta T_{M, \text{pos}} := \Delta T_{M, \text{pos}} \cdot K_{\text{sur.o}} = 12.3 \text{K} \]

\[ \Delta T_{M, \text{neg}} := \Delta T_{M, \text{neg}} \cdot K_{\text{sur.u}} = -8 \text{K} \]

\[ \Delta T_{M} := \Delta T_{M, \text{pos}} - \Delta T_{M, \text{neg}} = 20.3 \text{K} \]
### Tab. 6.2: Faktoren $K_{\text{sur}}$ zur Berücksichtigung der verschiedenen Belagsdicken

<table>
<thead>
<tr>
<th>Belagsdicken in mm</th>
<th>Beton Oberseite wärmer $K_{\text{sur}}$</th>
<th>Beton Unterseite wärmer $K_{\text{sur}}$</th>
<th>Stahl Oberseite wärmer $K_{\text{sur}}$</th>
<th>Stahl Unterseite wärmer $K_{\text{sur}}$</th>
<th>Verbundkonstruktion Oberseite wärmer $K_{\text{sur}}$</th>
<th>Verbundkonstruktion Unterseite wärmer $K_{\text{sur}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.5 $^1)$</td>
<td>1.0</td>
<td>1.6 $^1)$</td>
<td>0.6</td>
<td>1.1</td>
<td>0.9</td>
</tr>
<tr>
<td>60</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>80</td>
<td>0.82</td>
<td>1.0</td>
<td>0.82</td>
<td>1.1</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>100</td>
<td>0.7</td>
<td>1.0</td>
<td>0.7</td>
<td>1.2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>150</td>
<td>0.5</td>
<td>1.0</td>
<td>0.7</td>
<td>1.2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>300</td>
<td>0.3</td>
<td>1.0</td>
<td>0.7</td>
<td>1.2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Schotterbett (50 cm)</td>
<td>0.6</td>
<td>1.0</td>
<td>0.6</td>
<td>1.4</td>
<td>0.8</td>
<td>1.2</td>
</tr>
</tbody>
</table>

$^1)$ Die Grenzwerte sind obere Grenzen.

3.2.4.6 Simultaneous viewing of the constant temperature and the linear temperature difference

\[
\Delta T_M + \Delta T_N \cdot \omega_N
\]

\[
\Delta T_M \cdot \omega_M + \Delta T_N
\]

\[
\omega_M := 0.75
\]

\[
\omega_N := 0.35
\]
4 Predimensioning

In order to carry out the preliminary design of the clamping load, 2 stages are considered for the prove of the SLS (Service Limit State). For \( t = 0 \) and \( t = \infty \). According to ARS 11/2003, the requirement is to choose class B and thus the frequent combination of actions relevant for the detection of decompression.

For the predimensioning of the structure thus, the Frequent Combination of Actions has been followed, according to:

9.5 Grenzzustände der Gebrauchstaugliche  DIN-Fachbericht 101:2009-03

9.5.1 Nachweis der Gebrauchstauglichkeit

<table>
<thead>
<tr>
<th>Bauweisen des Längstrageystems</th>
<th>Anforderungsklasse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>längs</td>
</tr>
<tr>
<td>Stahlbetonüberbau</td>
<td>D</td>
</tr>
<tr>
<td>Spannbetonüberbau mit Spanngliedern im Verbund oder Mischbauweise</td>
<td>C ³</td>
</tr>
<tr>
<td>Überbau mit Kastenuferschnitt mit ausschließlich externen Spanngliedern</td>
<td>C</td>
</tr>
</tbody>
</table>

¹) Es gilt ZTV-ING, Teil 3, Abschn. 2, 2.3.2 (5).
²) Es ist zusätzlich DIN-Fachbericht 102, Regel II-4.4.0.3 (4) P nachzuweisen.
³) Für Spannbetonüberbauten mit Spanngliedern im Verbund oder Mischbauweise mit statisch bestimmtem Längstrageystem ist die Anforderungsklasse B zu wählen.

Frequent combination of actions

\[
\sum G_{kj} + P_k + \psi_{k1} Q_{k1} + \sum \psi_{2i} Q_{ki}
\]

- \( t = 0 \) - SLS

\[
M_{0d} := \frac{g_{to} \cdot l_{ef}}{8} = 15356 \, \text{kN} \cdot \text{m}
\]

\[
g_{to} := g_{üben} = 186 \, \text{kN} / \text{m}
\]
t = infinity - SLS

\[ M_{ud} := M_{gd} + \psi_{1.1.TS} M_{TS} + \psi_{1.1.UDL} M_{UDL} = 21002 \text{kN} \cdot \text{m} \]

\[ M_{TS} := \frac{Q_{TS,k^1\text{eff}}}{4} \]

\[ M_{UDL} := \frac{Q_{UDL,k^1\text{eff}}^2}{8} \]

\[ M_{gd} := \frac{g_{tu^1\text{eff}}^2}{8} \]

\[ g_{tu} := g_{\text{üben}} + g_{\text{fahr}} + g_{\text{kap}} + g_{\text{gale}} + g_{\text{schu}} = 231 \text{kN/m} \]
4.1 Determination of the basic distances

\[ d_{p1} := c_v + \frac{1}{2} \cdot d_{hi} + \Delta s = 302 \text{ mm} \]

\[ \Delta s := \frac{1}{6} \cdot d_{hi} = 17 \text{ mm} \]

\[ z_{cpmax} := h_{tot} - G_c - d_{p1} = 508 \cdot \text{mm} \]

4.2 E-Linien

- \( t = 0 \)

Compressive stresses at the lower edge of the component

\[ \sigma_{c.0.u} = \frac{-P_{0.u}}{A_c} - \frac{P_{0.u} \cdot z_p}{W_{y,u}} + \frac{M_g}{W_{y,u}} \rightarrow \frac{A_c \cdot M_g - A_c \cdot W_{y,u} \cdot \sigma_{c.0.u}}{W_{y,u} + A_c \cdot z_p} \]

\[ \sigma_{c.0.u} = -0.6 \cdot f_{ck} \]

\[ P_{0.u(z_p)} = \frac{A_c \cdot M_g - A_c \cdot W_{y,u} \cdot \sigma_{c.0.u}}{W_{y,u} + A_c \cdot z_p} \]
Tensile stresses at the top edge of the component

\[
\alpha_{c.0.o} = \frac{-P_{0.o} - P_{0.o}z_p}{A_c} + \frac{M_q}{W_{y.o}} - \frac{A_c \cdot M_q + A_c \cdot W_{y.o} \cdot \alpha_{c.0.o}}{W_{y.o} - A_c \cdot z_p}
\]

\[
\alpha_{c.0.o} = 0.8f_{ck}
\]

\[
P_{0.o}(z_p) = \frac{A_c \cdot M_q + A_c \cdot W_{y.o} \cdot \alpha_{c.0.o}}{W_{y.o} - A_c \cdot z_p}
\]

- \( t = \infty \)

Tensile stresses at the lower edge of the component

\[
\alpha_{c.U.u} = \frac{-P_{U.u} \cdot 0.8}{A_c} - \frac{P_{U.u} \cdot 0.8 \cdot z_p}{W_{y.u}} + \frac{M_q}{W_{y.u}} - \frac{5.0 \cdot A_c \cdot M_q - 5.0 \cdot A_c \cdot W_{y.u} \cdot \alpha_{c.U.u}}{4.0 \cdot W_{y.u} + 4.0 \cdot A_c \cdot z_p}
\]

\[
\alpha_{c.U.u} = 0.8f_{ck}
\]

\[
P_{U.u}(z_p) = \frac{5.0 \cdot A_c \cdot M_q - 5.0 \cdot A_c \cdot W_{y.u} \cdot \alpha_{c.U.u}}{4.0 \cdot W_{y.u} + 4.0 \cdot A_c \cdot z_p}
\]

Compressive stresses at the lower edge of the component

\[
\alpha_{c.U.o} = \frac{-P_{U.o} \cdot 0.8}{A_c} + \frac{P_{U.o} \cdot 0.8 \cdot z_p}{W_{y.o}} - \frac{M_q}{W_{y.o}} + \frac{1.0 \left(5.0 \cdot A_c \cdot M_q + 5.0 \cdot A_c \cdot W_{y.o} \cdot \alpha_{c.U.o}\right)}{4.0 \cdot W_{y.o} - 4.0 \cdot A_c \cdot z_p}
\]

\[
\alpha_{c.U.o} = -0.45f_{ck}
\]

\[
P_{U.o}(z_p) = \frac{5.0 \cdot A_c \cdot M_q + 5.0 \cdot A_c \cdot W_{y.o} \cdot \alpha_{c.U.o}}{4.0 \cdot W_{y.o} - 4.0 \cdot A_c \cdot z_p}
\]
4.3 Determination of the tendon and the clamping member

\[ P_{0,u}(z_{p_{\text{max}}}) := 20.3 \text{MN} \]
\[ P_{U,u}(z_{p_{\text{max}}}) := 37.6 \text{MN} \]

\[ P_{U,o}(z_{p_{\text{max}}}) := -26.3 \text{MN} \]
\[ P_{0,o}(z_{p_{\text{max}}}) := 45.2 \text{MN} \]

Lower limit of clamping force

\[ P_{\text{min}} := \max(P_{U,u}, P_{U,o}) = 37.6 \text{MN} \]

Upper limit of clamping force

\[ P_{\text{max}} := \min(P_{0,u}, P_{0,o}) = 20.3 \text{MN} \]

Determination of the clamping force

\[ P_0 = 30 \text{MN} \]
4.3.1 Tendon boundaries

- \( t = 0 \)

**lower**

\[
 z_{0,u}(x) = 0.6 \cdot f_{ck} \left( \frac{W_{y,u}}{P_0} - \frac{W_{y,u}}{A_c} + \frac{M_g(x)}{P_0} \right)
\]

**upper**

\[
 z_{0,o}(x) = \frac{W_{y,o}}{A_c} + \frac{M_g(x)}{P_0}
\]

- \( t = \infty \)

**lower**

\[
 z_{U,u}(x) = \frac{-W_{y,u}}{A_c} + 1.25 \cdot \frac{M_{qg}(x)}{P_0}
\]

**upper**

\[
 z_{U,o}(x) = -9 \cdot f_{ck} \cdot \frac{W_{y,o}}{16 \cdot P_0} + \frac{W_{y,o}}{A_c} + 1.25 \cdot \frac{M_{qg}(x)}{P_0}
\]

\[\begin{align*}
 z_{U,u}(0m) &= -0.156m \\
 z_{0,o}(0m) &= 0.258m
\end{align*}\]
4.4 Determination of the clamping member dial

Tendon type 6-22 with tensile steel St 1570/1770 according to:

*SUSPA-Litzenspannverfahren 150 mm² mit nachträglichem Verbund nach DIN 1045-1*
*DIN-Fachbericht 102: 4.2.3.5.4 Anfängliche Vorspannkraft*

\[ Ap = 33 \, \text{cm}^2 \]

\[ f_{pk,zul} = \min \{0.75 \cdot f_{pk}; 0.85 \cdot f_{p,0.1k}\} \left[\frac{N}{\text{mm}^2}\right] = \]

\[
\min \{0.75 \cdot 1770; 0.85 \cdot 1500\} = 1257 \, N/\text{mm}^2
\]

\[ n_{erf} = \frac{P_0}{Ap \cdot f_{pk,zul}} = \frac{37 \cdot 10^6}{3300 \cdot 1257} = 8.9 \sim 10 \]

4.4.1 Maximum load for a each member

\[ P_{\text{omax}} = \frac{P_0}{n} = 3 \times 10^3 \, \text{kN} \]
5 Prestressing

*SUSPA-Litzenspannverfahren 150 mm² mit nachträglichem Verbund nach DIN 1045-1 und DIN-Fachbericht 102*

5.1 Tendon profiles

\[ z \quad \text{Tendon course function} \]

**Group 1**

\[ z_1(x) := 0.00307 \cdot x^2 - 0.079 \cdot x \]

**Group 2**

\[ z_2(x) := 0.000109 \cdot x^2 - 0.0028015 \cdot x - 0.49 \]

\[ z'_1 := 0.00614 \cdot x_1 - 0.079 \]

\[ z'_2 := 0.000218 \cdot x_2 - 0.0028015 \]

5.2 Clamping force curve

\[ z' \quad \text{Derivation tendon function} \]

\[ \theta_\omega \quad \text{Unselected deflection} \]

\[ \theta_\omega := k \cdot l_\text{eff} = 0.134 \]
\( \theta \) Scheduled deflection
\( \theta_t \) Total deflection

The maximum achievable force on clamping anchor

\[
P_{\text{omax}} := 3000 \text{ kN}
\]
\[
E' := 0.6\%
\]

\[
P_{\text{omax}} := P_{\text{omax}} \cdot (100\% - E') = 2982 \text{ kN}
\]

5.2.1 Group 1

\[
z'_{1o} := -0.00308 \cdot x_1 + 0.03953
\]

**Prestressing force at END**

\[
x_1 := 0 \quad z'_{1o} := -0.079 \\
x_1 := 25.7 \quad z'_{1f} := 0.078798
\]
\[
\theta_f := z'_{1o} - z'_{1f} = -0.1578 \\
\theta_{tf} := \theta_{o} - \theta_f = 0.291
\]

\[
P_f := P_{\text{omax}} \cdot \exp[-\mu \cdot \left(\theta_{tf} + \kappa \cdot 25.7 \text{ m}\right)] = 2755\cdot \text{kN}
\]

**Prestressing force at BLOCKING POINT**

\[
l_B := \frac{\Delta_{\text{lsc}} \cdot \kappa \cdot \theta_{B} \cdot E_p}{\sqrt{P_{\text{omax}} - P_f}} = 20.15 \text{ m}
\]
\[
x_1 := 20.15 \quad \theta_{B} := z'_{1o} - z'_{B1} = -0.1237
\]
\[
z'_{B1} := 0.044721 \quad \theta_{tB} := \theta_{o} - \theta_B = 0.2574
\]

\[
P_B := P_{\text{omax}} \cdot \exp[-\mu \cdot \left(\theta_{tB} + \kappa \cdot 25.7 \text{ m}\right)] = 2774\cdot \text{kN}
\]

\[
\theta_s := z'_{1o} - z'_{s1} = -0.1237
\]
Prestressing force at CENTER

\[ z'_{s1} := z'B_1 = 0.044721 \]
\[ P_{s1} := P_B \exp[-\mu \left( \theta_{td} + \kappa \cdot 20.15 \text{m} \right)] = 2643 \text{kN} \]

\[ x_1 := 12.85 \]
\[ \theta_m := z'_{1o} - z'_m = -0.0789 \]
\[ z'_m := -0.000101 \]
\[ \theta_{tm} := \theta_\omega - \theta_m = 0.213 \]

\[ P_{m01} := P_{omax} \exp[-\mu \left( \theta_{tm} + \kappa \cdot 25.7 \text{m} \right)] = 2799 \text{kN} \]

\[ P_{f1}(x) := P_{omax} \exp[-\mu \left( \theta_{tf} + \kappa \cdot x \text{m} \right)] \]

5.2.2 Group 2

\[ z'_{2} := 0.000218 \cdot x_2 - 0.0028015 \]

Prestressing force at the END

\[ x_2 := 0 \]
\[ z'_{2o} := -0.0028015 \]
\[ \theta_{f2} := z'_{2o} - z'_{2f} = -0.006 \]
\[ x_2 := 25.7 \]
\[ z'_{2f} := 0.0028011 \]
\[ \theta_{tf2} := \theta_\omega - \theta_f = 0.1392 \]
Prestressing force at BLOCKING POINT

\[ \alpha_{B_2} := \frac{\Delta_\text{lse} \cdot \varepsilon_{\text{eff}} \cdot A_p \cdot E_p}{P_{\text{omax}} - P_{f2}} = 24.95 \text{ m} \]

\[ z_{B_2} := 0.0026376 \quad \theta_{B_2} := z_{2o} - z_{B_2} = -0.005 \]

\[ x_2 := 24.95 \quad \theta_{tB_2} := \theta_{\omega} - \theta_{B_2} = 0.139 \]

\[ P_{B_2} := P_{\text{omax}} \cdot \exp[-\mu \cdot (\theta_{tB_2} + \kappa \cdot 25.7 \text{ m})] = 2841 \cdot \text{kN} \]

\[ z_{s2} := z_{B_2} = 2.6376 \times 10^{-3} \quad \theta_{s2} := z_{2o} - z_{s2} = -0.005 \]

\[ P_{s2} := P_{B_2} \cdot \exp[-\mu \cdot (\theta_{t} + \kappa \cdot 24.95 \text{ m})] = 2630 \cdot \text{kN} \]

Prestressing force at CENTER

\[ x_2 := 12.8 \quad \theta_{m2} := z_{2o} - z_{m2} = -0.003 \]

\[ z_{m2} := -0.0000002 \quad \theta_{tm2} := \theta_{\omega} - \theta_{m2} = 0.1364 \]

\[ P_{\text{mo2}} := P_{\text{omax}} \cdot \exp[-\mu \cdot (\theta_{tm2} + \kappa \cdot 25.7 \text{ m})] = 2842 \cdot \text{kN} \]
5.3 Creep, Shrinkage and Relaxation

\[ P_{f2}(x) := P_{\text{omax}} \exp \left[ -\mu \left( \theta_{f2} + \kappa \cdot x \right) \right] \]

\[ \begin{array}{c}
\text{RH} \quad \text{relative environmental humidity } \% \\
\text{RH}_0 \quad = 100\% \text{ (Reference)} \\
t_0 \quad \text{concrete's age in days at the beginning of loading process} \\
h_0 \quad \text{effective thickness in mm} \\
\psi(t,t_0) \quad \text{creep speed in } \% \\
\varepsilon_{ca} \quad \text{autogeneous shrinkage strain component} \\
\varepsilon_{cd} \quad \text{drying shrinkage strain component} \\
\varepsilon_{cs} \quad \text{total shrinkage strain} \\
\Delta \sigma_{pr} \quad \text{tension changes due to relaxation in the prestressing steel as a function of the output tensions} \\
\sigma_{c,QP} \quad \text{concrete stresses in the amount of prestressing steel axis due to dead load and output tensions} \\
z_{c,\text{omax}} \quad \text{distance between center of gravity of the concrete section and tendon axis} \\
\alpha_p \quad \text{Ratio of the modul of elasticity of prestressing steel and concrete} \\
\Delta_{\text{pcsr}} \quad \text{clamping force changes due to creep, shrinkage and relaxation}
\end{array} \]

DIN-Fachbericht 102:2009-03 3.1.5.5 Kriechen und Schwinden and 4.2.3.5.5 Spannkraftverluste
5.3.1 Creep
\[ t_0 := 10 \]
\[ h_0 := 2 \cdot \frac{A_c}{u} = 58.1 \cdot \text{cm} \]
\[ \varphi(t, t_0) := 2\% \]

5.3.2 Shrinkage
\[ f_{ck} = 35 \cdot \frac{N}{\text{mm}^2} \]
\[ \varepsilon_{ca} := 0.06:\]
\[ \varepsilon_{cd} := \frac{0.17}{1000} = 0.00017 \]
\[ \varepsilon_{cs} := \varepsilon_{ca} + \varepsilon_{cd} = 0.06317 \]

5.3.3 Relaxation
\[ M_{perm} := \frac{15349}{2} \text{kN-m} = 7674.5 \text{kN-m} \]
\[ P_{mo} := 3P_{m01} + 2P_{m02} = 14110 \text{kN} \]

Stress losses
\[ \sigma_{cp} := \frac{M_{perm}}{I_c} \cdot z_{cpmax} = 8.3 \cdot \frac{N}{\text{mm}^2} \]
\[ \sigma_{cpo} := \frac{-P_{mo}}{A_c} \left( 1 + \frac{A_c}{I_c} \cdot z_{cpmax} \right)^2 = -11.55 \cdot \frac{N}{\text{mm}^2} \]
\[ \sigma_{cQP} := \sigma_{cp} + \sigma_{cpo} = -3.25 \cdot \frac{N}{\text{mm}^2} \]
Relaxation losses

\[ \alpha_{pmo} := \frac{P_{mo}}{5 \cdot A_p} = 855.17 \frac{N}{mm^2} \]

\[ \frac{\alpha_{pmo}}{f_{pk}} = 0.5 \quad \Delta R_{zt} := 0.9 \% \]

\[ \Delta \sigma_{pr} := \Delta R_{zt} \alpha_{pmo} = 7.7 \frac{N}{mm^2} \]

\[ t = \infty \]

\[ \Delta \text{pcsr} := \frac{\varepsilon_{cs} \cdot E_p + 0.8 \Delta \sigma_{pr} + \alpha_p \cdot q(t,t_0) \left( \sigma_{cp} + \sigma_{cpo} \right)}{1 + \alpha_p \cdot 5 \cdot \left( 1 + \frac{A_c}{A_p} \cdot \frac{2}{\sigma_{cpmax}} \right) \left( 1 + 0.8 q(t,t_0) \right)} = 11408 \frac{N}{mm^2} \]

\[ \Delta \text{csr} := \frac{\Delta \text{pcsr}}{\sigma_{pmo}} = 13.34 \% \]
6 Combination of Actions

Kapitel II Grundlagen der Tragwerksplanung DIN-Fachbericht 101:2009-03

6.1 Ultimate Limit State

Permanent and temporary situations:

$$\Sigma \gamma G_j + \gamma P_b P_k + \gamma Q_1 Q_{k1} + \Sigma \gamma Q_{i1} \psi_{0i} Q_k$$

Combinations for accidental design situations

$$\Sigma \gamma G_j C_{kj} + \gamma P_b P_k + A_d + \psi_1 Q_{k1} + \Sigma \psi_2 Q_{ki}$$

Combinations for the design situations caused by earthquake:

$$\Sigma G_{kj} + P_k + A_{Ed} + \Sigma \psi_2 Q_{ki}$$

For the dimensioning in Ultimate Limit State (ULS) the „Permanent and Temporary situation“ combination of actions must be used according to the norvtime DIN-Fb 102:

$$\Sigma \gamma G_j + \gamma P_b P_k + \gamma Q_1 Q_{k1} + \Sigma \gamma Q_{i1} \psi_{0i} Q_k$$

6.1.1 Bending Design

$t = 0$

$$M_{gk} := \frac{g_{to} \cdot l_{eff}^2}{8}$$

$$\gamma G_j := 1.35$$

$$M_{Edo} := \gamma_g M_{gk}$$

$t = \text{infinite}$

$$g_{tu} := g_{\text{üben}} + g_{\text{fahr}} + g_{\text{kap}} + g_{\text{gale}} + g_{\text{schu}}$$
\[ M_{gk} := \frac{g_{tu}^1\text{eff}}{2} \]

\[ Q_{TS.} := Q_{1k} + Q_{2k} \]

\[ Q_{UDL.k} := q_{1k} + q_{2k} + q_{fk} + q_{rk} \]

\[ M_{UDL.k.long} := \frac{Q_{UDL.k}^1\text{eff}}{2} \]

\[ M_{TS.k.long} := \frac{Q_{TS.k}^1\text{eff}}{2} \]

\[ \gamma_G := 1.35 \]

\[ \gamma_{Q1} := 1.5 \]

\[ M_{Edu} := \gamma G M_{gk} + \gamma Q1 M_{TS.k.long} + \gamma Q1 M_{UDL.k.long} \]

### 6.1.2 Shear design

\[ Q_{TS.} := Q_{1k} + Q_{2k} \]

\[ Q_{UDL.k} := q_{1k} + q_{2k} + q_{fk} + q_{rk} \]

\[ \gamma_G = 1.35 \]

\[ \gamma_{Q1} := 1.5 \]

\[ V_{Edmax} := \gamma G g_{tu} + \gamma Q1 Q_{UDL.k} + \gamma Q1 Q_{TS.k} \]
6.1.3 Torsion

\[ M_{TS,k} := M_{Q1k} + M_{Q2k} \]

\[ M_{UDL,k} := M_{q1k} + M_{q2k} + M_{qfk} + M_{qrk} \]

\[ \gamma_{Q1} := 1.5 \]

\[ T_{Ed} := \gamma_{Q1} M_{TS,k} + \gamma_{Q1} M_{UDL,k} \]

6.2 Service Limit State

Characteristic (rare) combination:

\[ \Sigma G_{kj} + P_k + Q_{k1} + \Sigma \psi_{0i} Q_{ki} \]

Frequent combination:

\[ \Sigma G_{kj} + P_k + \psi_{1i} Q_{k1} + \Sigma \psi_{2i} Q_{ki} \]

Quasi-permanent combination:

\[ \Sigma G_{kj} + P_k + \Sigma \psi_{2i} Q_{ki} \]

For the proof of requirements in SLS the „Frequent combination“ of actions must be followed according to the normative DIN-Fb102:

\[ \psi^{'}_{1TS} := 0.8 \]

\[ \psi^{'}_{1UDL} := 0.8 \]

\[ M_{\text{perm}} := M_{gk} + \psi^{'}_{1TS} M_{TS,k} + \psi^{'}_{1UDL} M_{UDL,k} \]
### 6.3 Coefficient interaction

<table>
<thead>
<tr>
<th>Einwirkung</th>
<th>Bezeichnung</th>
<th>$\psi_0$</th>
<th>$\psi_1$</th>
<th>$\psi_2$</th>
<th>$\psi_1^{1)}$</th>
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<td>Verkehrslasten (siehe 4.4.1)</td>
<td>gr 1 (LM1) 4) TS</td>
<td>0,75</td>
<td>0,75</td>
<td>0,2</td>
<td>0,80</td>
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<td></td>
<td>gr 1 (LM1) 4) UDL</td>
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<td></td>
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<td>gr 2 (Horiz. Lacton)</td>
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<td>gr 3 (Fußg. Lasten)</td>
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<tr>
<td>Windlasten</td>
<td>$F_{w_2}$</td>
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<td>0,50</td>
<td>0</td>
<td>0,60</td>
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<tr>
<td>Temperatur (siehe 1.5.1)</td>
<td>$T_2$</td>
<td>0 3)</td>
<td>0,50</td>
<td>0,50</td>
<td>0,80</td>
</tr>
</tbody>
</table>

### Tab. D.2: $\psi$-Beiwerte für Geh- und Radwegbrücken

<table>
<thead>
<tr>
<th>Einwirkung</th>
<th>Bezeichnung</th>
<th>$\psi_0$</th>
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<tr>
<td>Windlasten</td>
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<td>Temperatur</td>
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<td>S/V</td>
<td>Λ</td>
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<td><strong>Ständige Einwirkungen</strong></td>
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<tr>
<td>Eigenlasten der tragenden und nichttragenden</td>
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<tr>
<td>Bauteile, ständige Einwirkungen des Baugrundes,</td>
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<td>Grundwasser und Wasser</td>
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<tr>
<td>ungünstig</td>
<td>(\gamma_{\text{r-e}})</td>
<td>1,35 (^{2), 3), 4))</td>
<td>1,00 (^{5))</td>
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<tr>
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<td><strong>Horizontaler Erddruck aus Auflast</strong> (^7)</td>
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<td>1,00 (^{5))</td>
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<td>Verkehr (^9)</td>
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<td><strong>Andere variable Einwirkungen</strong></td>
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</tr>
<tr>
<td><strong>Außergewöhnliche Einwirkungen</strong></td>
<td>(\gamma_{s})</td>
<td>--</td>
<td>1,00 (^{5))</td>
<td></td>
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</tbody>
</table>

S - Ständige Bemessungssituation
V - Völlig wiederholbare Bemessungssituation
A - Außergewöhnliche Bemessungssituation
7 Internal Forces

7.1 Load System

7.1.1 Dead load

7.1.1.1 Superstructure
7.1.1.3 Caps
7.1.1.4 Handrails / Guardrails
7.1.2 Traffic

7.1.2.1 TS Mid – Maximum Bending
7.2.1.1 Roadway
7.2.1.2 Caps
7.2.1.3  Handrail / Guardrail
7.3 Ultimate Limit State

7.3.1 $t = 0$ (Superstructure dead load)
7.3.2  \( t = \infty \) (All loads)

7.3.2.1  TS Mid – max. Bending
7.4  Service Limit State

7.4.1  $t = \infty$  (All loads)

7.4.1.1  TS Mid – max. Bending
7.4.1.2  TS End – max. Shear
8 Ultimate Limit State

8.1 Bending Design

8.1.1 Determination of the basic distances

\[ d_p := h_{tot} - d_{p1} = 1 \text{ m} \]

\[ d_s := h_{tot} - c_{nom} - \frac{\phi_1}{2} = 1.17 \text{ m} \]

\[ d := \frac{d_p + d_s}{2} = 1.09 \text{ m} \]

8.1.2 Bending design for \( t = 0 \)

\[ N_{Ed} := 3P_{mol} + 2P_{mo2} = 14110 \text{kN} \]

\[ M_{Edo} := \frac{10938}{2} \text{kN \cdot m} \]

Moment in ULS – Only selfweight of superstructure

\[ M_{Edso} := M_{Edo} - N_{Ed} \left( d_p - c_{nom} - \frac{\phi_1}{2} \right) = -6826 \text{kN \cdot m} \]
\[ \mu_{Edso} = \frac{M_{Edso}}{b_{eff}d^2f_{cd}} = -0.06 \quad \omega_0 := 0.0515 \]

\[ \zeta_\sigma := 0.076 \]

\[ \zeta_\omega := 0.971 \]

\[ A_{so} := \frac{1}{\sigma_{sd}} \left( \omega_0 b_{eff}d_p f_{cd} - N_{Ed} \right) = -213.24 \text{cm}^2 \]

No reinforcement required

8.1.3 Bending Design for \( t = \infty \)

\[ M_{Edu} := 21478.30 \text{kN} \cdot \text{m} \]

Moment in ULS for all loads

\[ \mu_{Edsu} = \frac{M_{Edu}}{b_{eff}d^2f_{cd}} = 0.19 \quad \xi_u := 0.232 \]

\[ \omega_u := 0.1882 \]

\[ \zeta_u := 0.903 \]

\[ z_I := \xi_u \cdot d = 98 \cdot \text{cm} \]

\[ x := \xi_u \cdot d = 25.2 \cdot \text{cm} \]

\[ z_u := h_{tot} - x = 1.048 \text{m} \]

\[ a := d - z_I = 10.53 \text{cm} \]
Strains:

\[ \varepsilon_p := \frac{N_{Ed}}{5 \cdot A_p \cdot E_p} = 0.0044 \]

\[ \varepsilon_{pmo} := \frac{\sigma_{pmo} \left(1 + \frac{\Lambda_{csr}}{100}\right)}{E_p} = 0.005 \]

\[ \Delta \varepsilon_p := \varepsilon_p \left[ \frac{z_u - d_p1}{z_u - \left(c_{nom} + \frac{\phi_1}{2}\right)} \right] = 0.0036 \]

\[ \varepsilon_{pges} := \varepsilon_{pmo} + \Delta \varepsilon_p = 0.00852 \]

Calculation of the reinforcement:

\[ \sigma_{pmax} := \frac{f_{p0.1k}}{\gamma_s} = 1304 \frac{N}{mm^2} \]

\[ \sigma_p := \varepsilon_{pges} \cdot E_p = 1662 \frac{N}{mm^2} \]

\[ \sigma_p > \sigma_{pmax} \]

\[ A_{perf} := \frac{1}{\sigma_{pmax}} \cdot \omega_u \cdot b_{eff} \cdot d_p \cdot f_{cd} = 135.45 cm^2 \]

\[ A_{pvohr} := 5 \cdot A_p = 165 cm^2 \]

\[ A_{su} := \left( A_{perf} - A_{pvohr} \right) \frac{\sigma_{pmax}}{\sigma_{sd}} \left( \frac{d_p - a}{d_s - a} \right) = -74.12 cm^2 \]

No reinforcement required
8.2  Robustness Reinforcement

\[ M_v = f_{ctm} \frac{I_c}{z_I} = 1534 \text{kN}\cdot\text{m} \]

\[ A_{\text{minR}} := \frac{M_v}{z_I\sigma_y} = 31 \cdot \text{cm}^2 \]

8.3  Shear Design

\[ \alpha_{cw} = 1.0 \text{ EC2-1-1/NA, 6.2.3} \]

\[ z_\| \] lever arm of internal forces

\[ \theta \] angle of inclination of the compression strut

\[ \alpha \] angle between shear reinforcement and component axis

\[ V_{Ed} \] maximum value of share

\[ P_d \] tension values at distance "d"

\[ V_{Rd,max} \] carrying capacity of the compression strut

\[ V_{Rd,s} \] carrying capacity of shear reinforcement

\[ V_{Ed} := 2989.89 \text{kN} \]

\textbf{Prestressing force at distance „d“}

\[ x_1 := 1.09 \]

\[ \theta_d := z_1^0 - z_d = -0.007 \]

\[ z_d := -0.0723074 \]

\[ \theta_{td} := \theta_0 - \theta_d = 0.1403 \]
\[ P_{d1} := P_{\text{omax}} \cdot \exp \left[ -\mu \cdot \left( \theta_{td} + \kappa \cdot 25.7 \text{m} \right) \right] = 2840 \cdot \text{kN} \]

\[ x_1 := 1.09 \quad \theta_{d2} := z_{2o} - z_{d2} = -0.0002 \]

\[ z_{d2} := -0.00256388 \quad \theta_{td2} := \theta_{o} - \theta_{d2} = 0.1339 \]

\[ P_{d2} := P_{\text{omax}} \cdot \exp \left[ -\mu \cdot \left( \theta_{td2} + \kappa \cdot 25.7 \text{m} \right) \right] = 2844 \cdot \text{kN} \]

\[ P_{d} := 3 \cdot P_{d1} + 2 \cdot P_{d2} = 14208 \cdot \text{kN} \]

\[ V_{Rd,cc} := c \cdot 0.48 \cdot f_{ck} \cdot \left( 1 - 1.2 \cdot \frac{\sigma_{cd}}{f_{cd}} \right) \cdot b_{w} \cdot z_{\Pi} = 543 \text{ kN} \]

\[ c \cdot := 0.5 \]

\[ \sigma_{cd} := 5 \cdot \frac{P_{d}}{A_{c}} = 19.1 \cdot \frac{\text{N}}{\text{mm}^2} \]

\[ f_{cd} = 19.83 \cdot \frac{\text{N}}{\text{mm}^2} \]

\[ f_{ck} := 35 \cdot \frac{\text{N}}{\text{mm}^2} \]

\[ z_{\Pi} := 0.9 \cdot d = 97.71 \text{ cm} \]

\[ V_{Rd,\text{max}} := \alpha_{cw} \cdot v_{1} \cdot f_{cd} \cdot b_{w} \cdot z_{\Pi} \cdot c o t \theta + c o t (\alpha) \left( 1 + c o t \theta \right) = 19506 \cdot \text{kN} \]

\[ \alpha_{cw} := 1.0 \quad \alpha := 90^\circ \]

\[ \cot \theta := \frac{1.2 + 1.4 \cdot \frac{\sigma_{cd}}{f_{cd}}}{1 - \frac{V_{Rd,\text{cc}}}{V_{Ed}}} = 3.113 \quad 1 < \cot \theta < 3 \quad \cot \theta := 3 \]
\[ v_1 := 0.75 \left( 1.1 - \frac{f_{ck}}{500 \text{ N/mm}^2} \right) = 0.77 \quad v_1 < 0.75 \]
\[ v_1 := 0.75 \]

\[ V_{pd} := \left( 3 \cdot P_{d1} \tan \alpha_1 + 2 \cdot P_{d2} \tan \alpha_2 \right) \left( 1 - \frac{\Delta_{csr}}{100} \right) = 546 \cdot \text{kN} \]

\[ \tan \alpha_1 := 0.0723074 \]
\[ \tan \alpha_2 := 0.00256388 \]

\[ V_{Rds} := V_{Ed} - V_{pd} = 2444 \cdot \text{kN} \]

\[ a_{sw} := \frac{V_{Rds}}{\Pi \cdot f_{yw}d \cdot \left( \cot \theta + \cot (\alpha) \right) \cdot \sin (\alpha)} = 19.16 \cdot \text{cm}^2 / \text{m} \]

8.4 Torsion design

*DIN-Fachbericht 102:2009-03* - 4.3.3 Torsion

\[ T_{Ed} \quad \text{design value of the applied torsional moment} \]

\[ T_{Rdmax} \quad \text{rated value of the absorbable by the concrete compression strut torsional} \]

\[ \rho_l \quad \text{longitudinal reinforcement ratio} \]

\[ k \quad \text{Coefficient for the influence of the effective height "d"} \]

\[ \nu \quad \text{EC2-1-1/NA, 6.2.2} \]

\[ A_k \quad \text{Area enclosed by the center line} \ u_k \]

\[ t_{eff} \quad \text{wall thickness of the hollow cross-section} \]

\[ \theta \quad \text{Strut angle, for torsion alone} = 45 \degree \]

\[ u_k \quad \text{peripheral of surface} \ A_k \]

\[ T_{Ed} := 193.59 \text{kNm} \]
Torsional Reinforcement not required for d \geq 80 \text{ cm}.

\[ T_{Ed} \leq \frac{V_{Ed} b_w}{4.5} \quad \text{and} \quad \frac{V_{Ed} b_w}{4.5} = 2970 \text{kN m} \]

\[ V_{Ed} \left(1 + \frac{4.5 T_{Ed}}{V_{Ed} b_w}\right) \leq V_{Rdc} \]

\[ V_{Ed} \left(1 + \frac{4.5 T_{Ed}}{V_{Ed} b_w}\right) = 3185 \text{kN} \]

\[ V_{Rd.c} := \left(\frac{C_{Rdc} k^3}{1000 \rho_1 f_{ck}} + 0.12 \sigma_{cp}\right) b_w d = 449 \text{kN} \]

\[ k := 1 + \frac{200 \text{mm}}{d} = 1.428 \quad \text{and} \quad k < 2 \]

\[ \rho_1 := \frac{A_s}{b_w d} = 0.001 \quad \text{and} \quad \rho_1 \leq 0.02 \]

\[ \sigma_{cp} := \frac{N_{Ed}}{A_c} = 3.79 \frac{N}{\text{mm}^2} \]

\[ C_{Rdc} := \frac{0.15}{\gamma_c} = 0.1 \]

\[ V_{Rd.c} \geq V_{Rdc.min} \]

\[ V_{Rdc.min} := \left(v_{min.} + 0.12 \sigma_{cp}\right) b_w d = 3075 \text{kN} \]

\[ \frac{v_{min.}}{\gamma_c} \left(k^3 f_{ck}\right)^{0.5} = 0.176 \]

\[ \kappa_1 := 0.0375 \quad \text{for} \quad d \geq 80 \text{ cm} \]

\[ V_{Rd.c} \geq V_{Rdc.min} \]
Torsion reinforcement required

\[ T_{Ed} \leq T_{Rd,max} \]

\[ T_{Rd,max} := \frac{v \cdot f_{cd} \cdot 2 \cdot A_k \cdot t_{eff}}{\cot(\theta) + \tan(\theta)} = 17498 \text{kN} \cdot \text{m} \]

Chosen diameter of reinforcement

\( \phi_1 := 20 \text{mm} \)

\( d_{bü} := 16 \text{mm} \)

Geometry

\[ t_{eff} := 2 \left( c_v + d_{bü} + \phi_1 \right) = 542 \text{mm} \]

\[ u := b + 2.05m + 1.3m^2 = 6.4m \]

\[ u_k := 2 \left( 1.30m - t_{eff} + b - t_{eff} \right) = 3.932m \]

\[ A_k := u \cdot t_{eff} = 3.469 \text{m}^2 \]
\[
\nu := 0.525 \left( 1.1 - \frac{f_{ck}}{500 \frac{N}{mm^2}} \right) = 0.541 \\
\nu \leq 0.525 \\
\nu := 0.525
\]

\[\theta := 45^\circ\]

Determination of the torsion reinforcement

\[
a_{swT} := \frac{T_{Ed}}{2 A_k \cdot f_{yd} \cdot \cot(\theta)} = 1.04 \text{cm}^2 / \text{m}
\]

Determination of longitudinal torsion reinforcement

\[
A_sT := \frac{T_{Ed} u_k}{f_{yd} \cdot 2 A_k \cdot \tan(\theta)} = 1.56 \text{cm}^2
\]

\[
a_sT := \frac{A_sT}{u_k} = 0.4 \text{cm}^2 / \text{m}
\]

8.5 Shear and Torsion

*DIN-Fachbericht 102:2009-03 - Torsion mit Querkraft*

Strut bearing capacity

\[
\left( \frac{T_{Ed}}{T_{Rd,\text{max}}} \right)^2 + \left( \frac{V_{Ed}}{V_{Rd,\text{max}}} \right)^2 \leq 1
\]

\[
\left( \frac{T_{Ed}}{T_{Rd,\text{max}}} \right)^2 + \left( \frac{V_{Ed}}{V_{Rd,\text{max}}} \right)^2 = 0.023
\]

\[
a_{swQT} := a_{swT} \cdot 2 + a_{swQ} = 47.708 \text{cm}^2 / \text{m}
\]
Separation

\[ s_{\text{max}T} : = \frac{u_k}{8} = 49 \text{cm} \]

Choose:

\[ s_{\text{QTI}} : = 20 \text{cm} \]
\[ s_{\text{QT}} : = 20 \text{cm} \]

Diameter

External \quad \phi 20 = 2 \ell
Internal \quad \phi 16 = 2 \ell

\[ a_{\text{svohrQT}} := \phi \cdot \frac{1}{2} \cdot \frac{1}{s_{\text{QT}}} + 2 \cdot \phi \cdot \frac{1}{16} \cdot \frac{1}{s_{\text{QT}}} = 51.52 \frac{\text{cm}^2}{\text{m}} \]

Longitudinal reinforcement

\[ a_{\text{svohrQTI}} := \phi \cdot \frac{1}{20} \cdot \frac{1}{s_{\text{QTI}}} = 15.71 \frac{\text{cm}^2}{\text{m}} \]

10.6 Connection of compressed and tensioned straps

*DIN-Fachbericht 102:2009-03 - 4.3.2.5 Schub zwischen Balkensteg und Gurten*

\( \Delta x \) considered length (at most half the distance between zero and maximum moment)

\( \Delta F_d \) Longitudinal force difference in a one continuous strip
Compressed strap

\[ V_{RdmaxD} := 0.492 \cdot f_{cd} \cdot h_f \cdot \Delta x = 21666 \cdot kN \]

\[ a_{sfD} := \frac{V_{Ed}}{f_{yd} \cdot 1.2} = \frac{57.28}{m \cdot cm^2} \]

Tensioned strap

\[ V_{RdmaxZ} := 0.500 \cdot f_{cd} \cdot h_f \cdot \Delta x = 220184 \cdot kN \]
8.6 Surface Reinforcement

\[ f_{ck} = 35 \frac{N}{mm^2} \quad \rho := \frac{1.02}{1000} = 0.00102 \quad h_f := 45cm \]

\[ a_{sfZ} := \frac{V_{Ed}}{f_{yd} \cdot 1.0} = 68.73 \frac{m \cdot cm^2}{m} \]

\[ a_{sOD} := 1.0 \rho \cdot h_{tot} = 13.26 \frac{cm^2}{m} \]

\[ a_{sOZ} := 1.0 \rho \cdot h_f = 4.59 \frac{cm^2}{m} \]

8.7 Minimum Shear Reinforcement

**\( \rho_w \)** Minimum reinforcement ratio

**\( \alpha \)** Inclination angle of the shear reinforcement

**\( b_w \)** Authoritative web width

**\( \Phi_q \)** Shear reinforcement diameter \( \Phi_q := 16mm \)

**\( s_{\text{max}} \)** Strap distances in longitudinal direction

**\( s_{q\text{max}} \)** Strap distances in the transverse direction

\[ f_{ck} = 35 \frac{N}{mm^2} \quad \rho_w := \frac{1.02}{1000} = 0.00102 \]

\[ a_{sw\text{min}} := \rho_w \cdot (b_w \cdot \sin(\alpha)) = 45.63 \frac{cm^2}{m} \]

**High-spacing of shear reinforcement for C35/45 < C50/60**

\[ \frac{V_{Ed}}{V_{Rd\text{max}}} = 0.153 \quad 0 < \frac{V_{Ed}}{V_{Rd\text{max}}} < 0.3 \]

\[ s_{\text{max}} := 30cm \quad 0.7 h_{tot} = 91cm \quad 30cm < 0.7 h_{tot} \]

81
\[ s_{q_{\text{max}}} := 80 \text{cm} \quad 1.0 \ h_{\text{tot}} = 130 \text{cm} \quad s_{q_{\text{max}}} < 1.0 \ h_{\text{tot}} \]

\[ a_{\text{svohr}} := 2 \left( \pi \cdot \frac{\phi}{4} \right) \cdot \frac{1}{s_{Q}} = 15.39 \frac{\text{cm}^2}{\text{m}} \]

8.8 Maximum Reinforcement

\[ \Phi \] Longitudinal reinforcement diameter \[ \phi_1 = 20 \text{mm} \]

\[ s_l \] Longitudinal spacing distance

\[ s_q \] Transverse spacing distance

\[ A_{\text{smax}} := 0.8\% \cdot A_c = 297.6 \cdot \text{cm}^2 \]

Distance for \( C35/45 < C50/60 \)

\[ \frac{x}{d} = 0.232 \quad \frac{x}{d} < 0.45 \]

\[ 0.25 \ h_{\text{tot}} = 32.5 \text{cm} > s_l \quad s_l := 20 \text{cm} \]

\[ h_{\text{tot}} = 1.3 \text{m} > s_q \quad s_q := 60 \text{cm} \]
9 Serve Limit State

4.4 Nachweise in den Grenzzuständen der Gebrauchstauglichkeit - DIN-Fachbericht 102:2009-03

9.1 Required Class

According to ARS 11/2003, for statically determined prestressed concrete bridges that are performed with tendons with bond the required class is class B.

From this requirement the following requirements have to be verified:

Decompression - frequent combination of actions
Crack width limitation - not frequent combination of actions
Value of crack width - \( w_k = 0.2 \text{mm} \)

9.2 Prestress

To account for possible variations in the prestressing force the proof required in the SLS, two characteristic values of the prestressing force can be set to a upper and lower limit value applies to the others, for preload with subsequent bond:

Upper Value: \( P_{k,\text{sup}} = r_{\text{sup}} \cdot P_{m.t} \) \quad \text{mit} \quad r_{\text{sup}} = 1.1

Lower Value: \( P_{k,\text{inf}} = r_{\text{inf}} \cdot P_{m.t} \) \quad \text{mit} \quad r_{\text{inf}} = 0.9

9.3 Minimum reinforcement of crack width

\( A_{ct} \quad \text{Concrete cross-section or cross-section part in the tensile zone immediately prior to crack formation} \)

\( \sigma_s \quad \text{admissible stress in the reinforcement for crack width limitation depending on the limiting diameter} \)

\( k_c \quad \text{Factor for the stress distribution in the tensile zone} \quad A_{ct} \)

\( k \quad \text{Factor for a non-linear stress distribution} = k_{\text{riss}} \)

\( \varphi \quad \text{Limiting diameter} \)

\( h_t \quad \text{Height of the tension section in cross-section} \)
Top plate for $t = 0$

\[ P_{mo} = 14082 \text{kN} \]

\[ \sigma_{c,\text{ges.QS}} := \frac{P_{mo}}{A_n} = -3.84 \frac{N}{\text{mm}^2} \]

\[ z_{s,\text{o.ges.QS}} := 0.487 \frac{N}{\text{mm}^2} \text{m} \]

\[ h_t := \frac{-z_{s,\text{o.ges.QS}} f_{cteff}}{\sigma_{c,\text{ges.QS}} f_{cteff}} = 12.68 \text{cm} \]

\[ A_{ct} := h_t \cdot b_{eff} = 0.601 \text{m}^2 \]

\[ F_{crGurt} := \frac{f_{cteff}}{2} A_{ct} = 481.076 \text{kN} \]

**Tension straps of T-beams**

\[ k_c := \frac{0.9 F_{crGurt}}{A_{ct} f_{cteff}} = 0.45 \quad k_c > 0.5 \quad k_{c, \text{c.}} := 0.5 \]

\[ \phi_{10} := 10 \text{mm} \]

84
\[ \phi := \phi \cdot 10 \cdot \frac{f_{\text{cto}}}{f_{\text{cteff}}} = 18 \text{ mm} \]
\[ 4 \left( \frac{h_{\text{tot}} - d_s}{h_t} \right) f_{\text{cto}} \]
\[ \frac{k_c \cdot k_{\text{riss}} \cdot h_t \cdot f_{\text{cteff}}}{4k_c \cdot k_{\text{riss}} \cdot h_t \cdot f_{\text{cteff}}} = 20 \]
\[ 18 \leq 20 \]

\[ \sigma_s := 196 \frac{N}{\text{mm}^2} \] für \( w_k = 0.2 \) und \( \varphi = 18 \text{ mm} \)

\[ A_{s, \text{riss.pl}} := \frac{k_c \cdot k_{\text{riss}} \cdot f_{\text{cteff}} \cdot A_{ct}}{\sigma_s} = 18.26 \text{ cm}^2 \]

**Top Steg for** \( t = 0 \)

\[ h_t < 40 \text{ cm} \]

No minimum reinforcement required

**Steg bottom for** \( t = \infty \)

\[ f_{\text{cteffu}} := f_{\text{ctm}} = 3.2 \frac{N}{\text{mm}^2} \]

\[ P_{\mu} := P_{\mu 0} \left( 1 - \frac{A_{\text{csr}}}{100} \right) = 12228 \text{kN} \]

\[ \sigma_{c, \text{ges.QSu}} := \frac{-P_{\mu}}{A_i} = -5.709 \frac{N}{\text{mm}^2} \]

\[ z_{u, \text{steg}} := z_{ui} = 0.642 \text{m} \]

\[ z_{u, \text{ges.QS}} := 0.813 \text{m} \]

\[ \sigma_{c,u} := \frac{\left( \sigma_{c, \text{ges.QSu}} + f_{\text{cteff}} \right) z_{u, \text{steg}}}{z_{u, \text{ges.QS}}} = -3.243 \frac{N}{\text{mm}^2} \]
\[ h_{t, st} := \frac{-z_{u, ges, QS} f_{cteffu}}{\sigma_{c, ges, QS} f_{cteffu}} = 14.24 \text{ cm} \]

\[ A_{ct, st} := h_{t, st} b_{eff} - 5 \cdot A_p = 0.659 \text{ m}^2 \]

Rectangular sections and steeg of T-Beam

\[ k_{c, st} := 0.4 \left( 1 + \frac{-\sigma_{c, u}}{h_{tot} \cdot k_1 \cdot h'_{tot} f_{cteffu}} \right) = 0.608 \quad k_{c, st} \leq 1 \]

\[ k_1 := 1.5 \quad \text{if } N_{Ed} \text{ is a longitudinal force} \]

\[ h'_{tot} := 1.0 \text{ m bei } h_{tot} > 1 \text{ m} \]

\[ k_{riss, st} := 0.5 \quad \text{by tensile stresses due to internal forced, } h_{tot} > 80 \text{ cm} \]

\[ \phi'_{st} := \Phi 10 \frac{f_{cto}}{f_{cteffu}} = 9 \text{ mm} \quad \frac{4 \left( h_{tot} - d_s \right) f_{cto}}{k_{c, st} k_{riss, st} h_{t, st} f_{cteffu}} = 10 \quad 9 \leq 10 \]

\[ \sigma_{s, st} := 280 \frac{N}{\text{mm}^2} \quad \text{for } w_k = 0.2 \text{ and } \phi' = 9 \text{ mm} \]

\[ A_{s, riss, st} := \frac{k_{c, st} k_{riss, st} f_{cteffu} A_{ct, st}}{\alpha_{s, st}} = 23.8 \text{ cm}^2 \]
10 End Cross Beam

10.1 Bending design

\[
\begin{align*}
M_{Eds2} := M_{Ed2} &= -893.91 \text{kN}\cdot\text{m} \\
M_{Eds1} := M_{Ed1} &= 437.45 \text{kN}\cdot\text{m} \\
\mu_{Eds2} := \frac{M_{Ed2}}{b \cdot f_{cd} \cdot d^2} &= -0.01 \\
\mu_{Eds1} := \frac{M_{Ed1}}{b \cdot f_{cd} \cdot d^2} &= 0.01 \\
\omega_1 := 0.0101 &\quad \omega_2 := 0.0101 \\
\zeta := 0.95 &\quad \xi := 0.03 \\
f_{cd} &= \text{Design value of the concrete compressive strength} \\
\gamma_c := 1.5 &\quad \alpha_{cc} := 0.85 \\
b &= \text{Width} \\
d &= \text{Distance from the reinforcement} \\
A_{s1B} := \frac{1}{\sigma_{sd}} \left( \omega_1 \cdot b \cdot d \cdot f_{cd} \right) &= 10.98 \text{cm}^2 \\
A_{s2B} := \frac{1}{\sigma_{sd}} \left( \omega_2 \cdot b \cdot d \cdot f_{cd} \right) &= 10.98 \text{cm}^2
\end{align*}
\]

10.2 Robustness Reinforcement

\[
M_V := f_{ctm} \frac{I_c}{z_I} = 1185 \text{kN}\cdot\text{m}
\]

\[
f_{ctm} = \text{average flexural strength of concrete C35/45} \\
l_c = \text{Inertia of the cross section} \\
z_I = \text{Hard axis distance to tensile edge in state I} \\
z_{II} = \text{Lever arm of internal forces after cracking (state II)}
\]

\[
f_{ctm} := 3.2 \frac{\text{N}}{\text{mm}^2} \\
l_c := \frac{(1.6m)^4}{12} = 0.546m^4 \\
z_I := \zeta d = 1.475m \\
z_{II} := 0.9d = 1.341m
\]
\[ f_{yk} = \text{Strength characteristic of steel} \]

\[ f_{yk} := 500 \frac{N}{mm^2} \]

\[ A_{\text{minR}} := \frac{M_v}{\frac{d}{2} f_{yk}} = 18 \text{cm}^2 \]

### 10.3 Shear design

Design of normal concrete with and without shear reinforcement perpendicular to longitudinal force:

- **Design resistance**

  \[ V_{Rdmax} := \frac{V_1 \cdot f_{cd} \cdot b \cdot z \cdot II}{\tan \theta + \cot \theta} = 13472 \text{kN} \]

  \[ \cot \theta := 1.21 \]

  \[ V_1 := 0.64 \]

  \[ 1.2 < \cot \theta < 3 \]

  \[ \theta := 39.6^\circ \]

  \[ \tan \theta := 0.827 \]

- **Shear reinforcement**

  \[ a_{sw} := \frac{V_{Ed}}{f_{ywd} \cdot b \cdot z \cdot II \cdot \cot \theta} = 3.4 \text{cm}^2 / \text{m} \]

  \[ V_{Ed} = \text{Shear value at a distance "d"} \]

  \[ V_{Ed} := 240 \text{kN} \]

  \[ f_{ywk} = \text{Strength characteristics of steel shear} \]

- **Minimum shear reinforcement**

  \[ a_{swminQ} := \rho \cdot b \cdot \sin(90) = 14.59 \text{cm}^2 / \text{m} \]

  \[ \rho_w = \text{Minimum shear reinforcement ratio for} \]

  \[ f_{ck} := 35 \frac{N}{mm^2} \]

  \[ \rho_w := 0.001 \]

- **Reinforcement selection**

  \[ \frac{V_{Ed}}{V_{Rdmax}} = 0.02 \]

  \[ V_{Ed} < 0.3 V_{Rdmax} \]

  \[ \phi := 14 \text{mm} \]

  \[ F_{14} := 1.54 \text{cm}^2 \]
10.4 Surface Reinforcement

For beams with \( b = h \) and \( h > 1.0 \) and components in ambient conditions other exposure classes (XC4, XD3, XF4)

\[
a_{\text{sminO}} := \rho \cdot b = 16.32 \text{ cm}^2 \text{ m}
\]

\( \rho \) = Fundamental values of the surface reinforcement for

\[
f_{ck} := 35 \frac{N}{\text{mm}^2} \quad \rho := 0.0010;
\]

10.5 Crack width

For reinforced concrete members with exposure class XD3 the calculated values \( w_{\text{max}} \) is:

\[
w_{\text{max}} := 0.3
\]

\[
A_{\text{sminRi}} := \frac{k_c \cdot k \cdot f_{\text{c eff}} \cdot A_{\text{ct}}}{\alpha_s} = 21.73 \text{ cm}^2 \text{ m}
\]

\( k_c \) = Factor taking into account the stress distribution of the tension zone \( A_{\text{ct}} \) before cracking and the changes to the inner lever arm during the transition to the state II in pure bending is:

\( k = \) Factor for a non-linear stress distribution.

For \( h > 80 \) cm ist:

\( k_c := 0.4 \)

\( k := 0.52 \)

\( f_{\text{c eff}} \) = Tensile strength of the concrete when the crack occur

\[
f_{\text{c eff}} := \frac{f_{\text{ctm}}}{2} = 1.6 \frac{N}{\text{mm}^2}
\]

\( A_{\text{ct}} \) = Teilquerschnitt in der Zugzone

\[
A_{\text{ct}} := h_t \cdot b = 1.28 \text{ m}^2
\]
\( \delta_s \) = admissible stress in the reinforcement for crack width limitation depending on the limiting diameter.

\[
\phi_2 := 10 \text{mm}
\]

\[
\phi := \phi_2 \frac{f_{ct0}}{f_{cteff}} = 18 \text{mm} \quad \phi_2 \frac{4(h_{tot} - d) f_{ct0}}{0.208 h_t f_{cteff}} = 48 \text{mm} \quad 18 \times 48
\]

Für \( \phi = 18 \text{mm} \) und \( w_k = 0.3 \) \( \sigma_s := \frac{240}{2} \text{N/mm}^2 \)

10.6 Splitting tensile reinforcement

\[ P_d := \gamma_p P_{omax} = 4050 \text{kN} \quad \gamma_p := 1.35 \]

- X-Direction

\[ P_{d1} := 2 \cdot P_d = 8100 \text{kN} \quad e_1 := 18 \text{cm} \]
\[ P_{d2} := 3 \cdot P_d = 12150 \text{kN} \quad e_2 := -3 \text{cm} \]

\[ M_d := P_{d1} e_1 + P_{d2} e_2 = -2309 \text{kN} \cdot \text{m} \]

\[ W_{co} := W_y = 0.683 \text{m}^3 \]
\[ W_{cu} := W_y = 0.683 \text{m}^3 \]

\[ A_{cv} := \frac{b}{2} h_{tot} = 1.28 \text{m}^2 \]

\[
\sigma_{co} := \frac{5P_d}{A_{cv}} - \frac{M_d}{W_{co}} = -12.44 \frac{\text{N}}{\text{mm}^2}
\]

\[
\sigma_{cu} := \frac{5P_d}{A_{cv}} + \frac{M_d}{W_{cu}} = -19.2 \frac{\text{N}}{\text{mm}^2}
\]

\[ F_{do} := 11.304 \frac{\text{MN}}{\text{m}} \]
\[ F_{du} := 22.688 \frac{\text{MN}}{\text{m}} \]
\[ \beta_1 := 5^\circ \quad z_{x1} := P_d \cdot \tan(\beta_1) = 354 \text{kN} \]
\[ \beta_2 := 16.7^\circ \quad z_{x2} := P_d \cdot \tan(\beta_2) = 1215 \text{kN} \]
\[ A_{sx} := \frac{z_{x2}}{f_{yd}} = 27.93 \text{cm}^2 \]

- Y-Direction

  - Bottom
  \[
  \sigma_{co,u} := \frac{10P_d}{A_{ch}} = 2.28 \frac{N}{\text{mm}^2} \\
  A_{ch} := b_{tot} \cdot h_{tot} = 17.76 \text{m}^2 \\
  b_{tot} := 11.1 \text{m} \\
  \beta_3 := 33^\circ \\
  z_{yu} := P_d \cdot \tan(\beta_3) = 2630 \text{kN} \\
  A_{sy,u} := \frac{z_{yu}}{f_{yd}} = 60.46 \text{cm}^2 \\
  \]

\[ b/2 = 80 \text{ cm} \]
Top

\[ z_{yo} := P_d \cdot \tan(\beta_3) = 2630 \text{kN} \]

\[ A_{syo} := \frac{z_{yo}}{f_yd} = 60.46 \text{cm}^2 \]

10.7 Torsion design

Shear force and Torsion:

\[ T_{Ed} := 290.4 \text{kN} \cdot \text{m} \]

\[ \frac{V_{Ed} \cdot b}{4.5} = 85.3 \text{kN} \cdot \text{m} \quad T_{Ed} > 85.3 \text{kN} \cdot \text{m} \]

\[ T_{Rdmax} := \frac{V_T \cdot f_{cd} \cdot \frac{1}{2} \cdot A_k \cdot t_{eff}}{\cot \theta + \tan \theta} = 2349 \text{kN} \cdot \text{m} \]

\( V_T \) coefficient defined in the EC2-1-1/NA 6.2.2
\[ \nu_T := 0.525 \left( 1.1 - \frac{f_{ck}}{500 \text{ N/mm}^2} \right) = 0.541 \quad \nu_T < 0.525 \quad \nu_{T_c} := 0.525 \]

\[ A_k := u_k u = 0.858m^2 \]

\[ u_k := c_{nom} + \theta 14 + \frac{12}{2} = 0.134m \]

\[ u := 4b = 6.4m \]

\[ t_{eff} := 2u_k \]

\[ a_{sw} := \frac{T_{Ed}}{2A_k \cot \theta f_{yd}} = 3.217 \text{ cm}^2/m \]

\[ A_T := \frac{T_{Ed} u_k}{\tan \theta f_{yd}} = 0.631 \text{ cm}^2 \quad A_T < A_{sl} \]
11 Bearings and Expansive Joints

11.1 Bearings

MAURER SÖHNE GmbH & Co. KG - Elastomer Typ I 350x450 Type B

Dimensions:

\[ a := 350 \text{mm} \]
\[ b := 450 \text{mm} \]
\[ d_e := 99 \text{mm} \]
\[ n := 6 \]
\[ A := a \cdot b = 0.158 \text{m}^2 \]
\[ a_r := a - 8 \text{mm} = 0.342 \text{m} \]
\[ b_r := b - 8 \text{mm} = 0.442 \text{m} \]
\[ A_r := a_r \cdot b_r = 0.151 \text{m}^2 \]

Shear modulus

\[ G_d := \frac{800 \text{kN}}{\text{m}^2} \]
\[ G_o := \frac{600 \text{kN}}{\text{m}^2} \] Sommer
\[ G_u := \frac{3000 \text{kN}}{\text{m}^2} \] Winter

11.1.1 Movement range

11.1.1.1 Braking and Acceleration

\[ \Delta x_{x.Ql.min} := -\frac{Q_{lk} \cdot d_e}{4 \cdot a \cdot b \cdot G_o} = -16 \text{mm} \]
\[ \Delta x_{x.Ql.max} := \frac{Q_{lk} \cdot d_e}{4 \cdot a \cdot b \cdot G_o} = 79 \text{mm} \]
11.1.1.2 Temperature effect

Constant fluctuation of the temperature component

For Bearings 20K increased needed

\[ \Delta T := 20K \]
\[ \Delta T_{N,\text{neg.min}} := \Delta T_{N,\text{neg}} - \Delta T = -47K \]
\[ \Delta T_{N,\text{pos.max}} := \Delta T_{N,\text{pos}} + \Delta T = 47K \]

\[ \varepsilon_{\Delta T,\text{max}} := \varepsilon_{\Delta T_{N,\text{pos.max}}}' = \frac{0.47}{m} \]

\[ \varepsilon_{\Delta T,\text{min}} := \varepsilon_{\Delta T_{N,\text{neg.min}}}' = \frac{-0.47}{m} \]

\[ \Delta x_{\Delta T,\text{max}} := \varepsilon_{\Delta T,\text{max}}'_{\text{eff}} = 12\text{mm} \]

\[ \Delta x_{\Delta T,\text{min}} := \varepsilon_{\Delta T,\text{min}}'_{\text{eff}} = -12\text{mm} \]

11.1.1.3 Prestress, creep and shrinkage

Prestress

\[ P_{\text{mo}} := -14082\text{kN} \]

\[ \varepsilon_{\text{cp}} := \frac{P_{\text{mo}}}{A_c'E_{\text{cm}}} = -0.111 \frac{\text{mm}}{m} \]

Creep

\[ \psi := 2.0\psi \]

\[ \varepsilon_{\text{cc}} := \psi \varepsilon_{\text{cp}} = -0.222 \frac{\text{mm}}{m} \]

Shrinkage

95
Total elongation due to prestressing, creep and shrinkage:

\[ \varepsilon_{cpcs} := \varepsilon_{cp} + 1.35 (\varepsilon_{cc} + \varepsilon_{cs}) = -0.496 \frac{\text{mm}}{\text{m}} \]

\[ \Delta_{x,vks,\text{min}} := \varepsilon_{cpcs,\text{eff}} = -13 \text{mm} \]

11.1.4 Maximum values

\[ \Delta_{x,\text{max}} = \Delta x_{\Delta T,\text{max}} + \Delta x_{x,QL,\text{max}} = 91 \text{mm} \]

\[ \Delta_{x,\text{min}} = \Delta x_{\Delta T,\text{min}} + \Delta x_{x,QL,\text{min}} + \Delta x_{x,vks,\text{min}} = -41 \text{mm} \]

11.1.2 Dimensioning

Coefficient \( s \)

\[ t := 12 \text{mm} \]

\[ s := \frac{a_r b_r}{2 (a_r + b_r) t} = 8.03 \]

11.1.2.1 Deformation due to temperature, tension, creep, shrinkage and release

\[ \Delta_x := \frac{\max(\Delta_{x,\text{max}}, \Delta_{x,\text{min}})}{2} = 45 \text{mm} \]

\[ \Delta_x \leq 49.5 \text{mm} \]  
Max. deformation

\[ \varepsilon_{\Delta x} := \frac{\Delta_x}{n \cdot t} = 0.63 \]

\[ \varepsilon_{\Delta x} < 1 \% \]
11.1.2.2 Deformation due to loading

\[ V_{\text{Edmax}} := 1950 \text{kN} \]
\[ \varepsilon_{\text{Nd}} := \frac{1.5 V_{\text{Edmax}}}{G_d A_r s} = 3.011 \]

11.1.2.3 Deformation due to torsion

\[ \theta_d := 0.01 \quad \text{Unfavorable rotation angle} \]

\[ \varepsilon_{yd} := \frac{\theta_d}{2n} \left( \frac{a}{t} \right)^2 = 0.709 \]

11.1.2.4 Total deformation

\[ \varepsilon_{\text{tot}} := \varepsilon_{\Delta x} + \varepsilon_{\text{Nd}} + \varepsilon_{yd} = 4.349 \]

\[ \varepsilon_{\text{tot}} < 7 \]

11.1.2.5 Minimum bearing pressure

\( V_{\text{Edmin}} \) Minimum value due to the weight of the structure

\[ V_{\text{Edmin}} := 1227.60 \text{kN} \]

\[ \frac{V_{\text{Edmin}}}{a \cdot b} > \frac{5}{\text{mm}^2} \]

\[ \frac{V_{\text{Edmin}}}{a \cdot b} = \frac{7.79}{\text{N/mm}^2} \]
11.2 Expansive Joints

Finger expansion joint Typ F130 – HEBAG AG – Fingerübergänge - SH-FINGER-DEHNFUGE TYP TRANSGRIP®

\[
\Delta x = \frac{-\Delta x_{\text{min}} + \Delta x_{\text{max}}}{2} = 65.595\text{mm}
\]

\[
\Delta x < 70\text{mm}
\]
**Notes**

1. DIN-Fachbericht 100:2010-03 - Tabelle 1 Exsitionsklassen  
2. DIN-Fachbericht 102:2009-03 Tabelle 3.1: Betonfestigkeitsklassen, charakteristische Druckfestigkeiten fck (Zylinder) und zentrische Zugfestigkeiten des Betons fctm und fctk (in MN/m²)  
3. DIN-Fachbericht 102:2009-03  4.2.1.3.3 Spannungs-Dehnungs-Linien p.91  
4. DIN-Fachbericht 102:2009-03 - Tabelle 7 – Druckfestigkeitsklassen für Normal- und Schwerbeton  
5. DIN-Fachbericht 102:2009-03 Tabelle R2: Einordnung der gängigen schweißgeeigneten Betonstähle in Deutschland in die Duktilitätsklassen  
6. DIN-Fachbericht 102:2009-03 - Tabelle 3.2: Werte für die mittleren Elastizitätsmoduln Ec0m als Tangentenmoduln und Ecm als Sekantenmoduln (in MN/m²)  
Annex 3
Soil Calculations
\( V_{t1} := \frac{1}{2} (280.183 \text{ m} - 11.55 \text{ m}) \cdot (130.205 \text{ m} - 120.013 \text{ m}) \cdot 11.10 \text{ m} = 15195.39 \text{ m}^3 \)

\( V_{t2} := 2[11.55 \text{ m} \cdot (130.205 \text{ m} - 120.013 \text{ m}) \cdot 11.10 \text{ m}] = 2613.331 \text{ m}^3 \)

\( V_{t3} := \frac{1}{3} \cdot \pi \cdot (11.55 \text{ m})^2 \cdot 8 \text{ m} = 1117.59 \text{ m}^3 \)

\( l_1 := 14.05 \text{ m} \)

\( l_2 := 268.633 \text{ m} \)

\( h_{12} := 7.025 \text{ m} \)

\( V_{t4} := 2 \left( \frac{1}{6} \cdot l_1 \cdot l_2 \cdot h_{12} \right) = 8838.138 \text{ m}^3 \)

\( V_{t5a} := (350 \text{ m} - 317.443 \text{ m}) \cdot (131.233 \text{ m} - 120.013 \text{ m}) \cdot 11.10 \text{ m} = 4054.714 \text{ m}^3 \)

\( V_{t5b} := \frac{1}{2} (132.832 \text{ m} - 131.233 \text{ m}) \cdot (350 \text{ m} - 317.443 \text{ m}) \cdot 11.10 \text{ m} = 288.925 \text{ m}^3 \)

\( V_{t5} := V_{t5a} + V_{t5b} = 4343.639 \text{ m}^3 \)

\( l_3 := 900 \text{ m} - 350 \text{ m} = 550 \text{ m} \)

\( l_4 := 7.025 \text{ m} \)

\( V_{t6} := 2 \left( \frac{1}{6} \cdot l_3 \cdot l_4 \cdot h_{12} \right) = 9047.615 \text{ m}^3 \)
$V_{t7} := \frac{1}{2} (900\text{m} - 350\text{m}) \cdot (132.832\text{m} - 120.013\text{m}) \cdot 11.10\text{m} = 39129.997\text{ m}^3$

$V_{\text{tot.terr}} := V_{t1} + V_{t2} + V_{t3} + V_{t4} + V_{t5} + V_{t6} + V_{t7} = 80285.697\text{ m}^3$
Annex 4
Road Layout
Table of Contents

Directional Traffic .............................................................................................................................................. 3
Determinant hour quarter ................................................................................................................................. 4
Traffic Category .................................................................................................................................................. 4
Levelled Area ................................................................................................................................................... 5
Road Layout ..................................................................................................................................................... 5
Bituminous Mixture ....................................................................................................................................... 5
Traffic hours as a percentage of the average daily traffic (ADT or I.M.D)

The Basic traffic or Determinant traffic is that which is used for dimensioning the road infrastructure (cross sections, number of tracks, etc..) and other facilities to help the circulation (intersections, signs, etc..).

To calculate the determinant traffic dimensioning projects, the IH-100, which evaluated in percentage terms relative to the IMD, is used, corresponding to the time intensity recorded in the time ranks 100th ordered from highest to lower the traffic intensities.

The Determinant traffic of a road is function of either its situation or function, and, as a result, of the circulation type.

The case of study corresponds to:

- Class A: Urban traffic roads

In approximated terms, the IH-100, expressed as a percentage of the ADT, corresponding to the type of road considered, are the following:

<table>
<thead>
<tr>
<th>CLASS</th>
<th>TYPE OF ROAD AS A FUNCTION OF THE % ADT</th>
<th>VALUE OF THE IH-100 AS A % OF THE ADT</th>
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<td>A</td>
<td>Urban traffic roads</td>
<td>8,0%</td>
</tr>
</tbody>
</table>

Is considered an ADT of lightweight vehicles of:

\[ \text{IMD}_{\text{lig}} = 10.000\text{veh/day} \]

Is considered that 7.4% of the ADT correspond to heavyweight vehicles:

\[ \text{IMD}_{\text{p}} = 7.4\% \times \text{IMD}_{\text{lig}} = 740 \text{ veh/dia} \]

\[ \text{IH-100} = 8\% \times \text{IMD}_{\text{p}} = 60 \text{ veh/h} \]

**Directional Traffic**

When the road is set for both direction of traffic, the calculations must be done for one direction of traffic. When no data about the intensities of traffic in both directions is available,
The determinant traffic typically refers to hourly intensities, although the intensity of traffic can not be uniform along the 60 minutes in an hour, especially on urban roads. For this reason to calculate this type of road is usually done using the so-called "rush hour factor", which is determined by the ratio of the traffic passing through an hour and 4 times the traffic passing through the 15 minutes of more intensity.

Under intermittent traffic conditions is normal a peak hour factor of about 0.85, and the 15 minutes are called determinant hour quarter whose value corresponds to approximately 30% of traffic hours given in the table 1.2.1.

\[ I_{Det} = 0.85 \times IH-100d = 30 \text{ veh/h} \]

\[ I_{15D} = 30\% \times IH-100d = 10 \text{ veh/15min} \]

For the dimensioning it will be used a calculation value of:

\[ I_{Det} = 30 \text{ veh/h} \]

**Traffic Category**

<table>
<thead>
<tr>
<th>CATEGORÍA DE TRÁFICO PESADO</th>
<th>T00</th>
<th>T01</th>
<th>T02</th>
<th>T03</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMDp</td>
<td>≥ 4 000</td>
<td>&lt; 4 000</td>
<td>&lt; 2 000</td>
<td>&lt; 800</td>
</tr>
<tr>
<td>(vehículos pesados/día)</td>
<td>≥ 2 000</td>
<td>≥ 800</td>
<td>≥ 200</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CATEGORÍA DE TRÁFICO PESADO</th>
<th>T31</th>
<th>T32</th>
<th>T33</th>
<th>T34</th>
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</thead>
<tbody>
<tr>
<td>IMDp</td>
<td>&lt; 200</td>
<td>&lt; 100</td>
<td>&lt; 50</td>
<td>&lt; 25</td>
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<tr>
<td>(vehículos pesados/día)</td>
<td>&lt; 100</td>
<td>&lt; 50</td>
<td>&lt; 25</td>
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\[ < 50 \rightarrow T41 \]
Levelled Area

Concrete pavement -> E3

Road Layout

Section type 4134

Bituminous Mixture

<table>
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<tr>
<th>TIPO DE CAPA</th>
<th>TIPO DE MEZCLA (*)</th>
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<tr>
<td></td>
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<td>T00 a T1</td>
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<tr>
<td>Rodadura</td>
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<td>A</td>
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<td>D y S</td>
<td></td>
<td>6-5</td>
</tr>
<tr>
<td>Intermédia</td>
<td>D y G</td>
<td>5-10***</td>
</tr>
<tr>
<td>Base</td>
<td>S y G</td>
<td>7-15</td>
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<tr>
<td></td>
<td>MAM</td>
<td>7-13</td>
</tr>
</tbody>
</table>

(*) Ver definiciones en tabla 5 o artículos 542 y 543 del PO-3.
(***) Salvo en asfalto, para los que se seguirá lo indicado en el apartado 7.
For the category of heavy traffic T41 in sections with a total thickness of bituminous mixture of 8 cm, when opting for a road lay type D or S can be projected as a single layer, when can be ensured an adequate roughness during the realization of the work.

- Road surface (Bed lay + Interlayer) 8 cm
- Base HF-4.0 20 cm

Information obtained from www.carreteros.org and IC 6.1
Annex 5
Signs, buoying and fenders
Table of Contents

1. INTRODUCTION .................................................................................................................. 3
2. ACTIONS TO CARRY OUT .................................................................................................. 3
3. CURRENT REGULATIONS ................................................................................................. 3
4. HORIZONTAL SIGNALING. ROAD MARKS ....................................................................... 3
   4.1 INTRODUCTION ............................................................................................................. 3
   4.2 PROHIBITION OF ADVANCEMENT ............................................................................. 4
   4.3 TYPES OF MARKS ROAD .......................................................................................... 4
       4.3.1 LONGITUDINAL MARKINGS .................................................................................. 4
       4.3.1.2 CONTINUOUS LINES .................................................................................... 4
       4.3.2 CROSS MARKINGS ............................................................................................. 5
5. VERTICAL SIGNALING ........................................................................................................ 5
   5.1 VERTICAL SIGNAL CONSIDERED .............................................................................. 5
6. VERTICAL MARKS ............................................................................................................... 5
7. SAFETY BARRIERS ............................................................................................................ 5
   7.1 CRITERIA APPROVED ............................................................................................... 5
1. INTRODUCTION

All supplementary items necessary for the proper entry into service of the work of this project are included in this Annex.

The work defined in this Annex aim to define, for the construction of the Prestressed Bridge in Berlin, the directives to follow for the painting of road markings and implementation of vertical signage and road marking.

This Annex refers to the "Road Markings", "Vertical Signaling" and "Safety barriers". It is not included though the definition of the provisional signaling during execution of works.

The signaling that will be available corresponds to that of a conventional one lane road in each direction of movement with characteristics corresponding to a road with a design speed of 30 Km / h.

2. ACTIONS TO CARRY OUT

The actions to be developed in this area of signage, markings and defenses of the work described in this Annex are:

- Provision of horizontal markings (road markings)
- Provision of vertical signs.
- Provision of flexible barrier (with reflector) according to plans

3. CURRENT REGULATIONS

The rules used are:

- Signals vertical circulation (MOPTMA, June 1992), based on the catalog of signals (MOPTMA, November 1986)
- Instruction 8.2-IC. Pavement Markings (July 1987).
- Recommendations on vehicle restraint systems, 1996, after the Order Circular 321/95 T and P
- Order Circular 18/2004 on employment criteria of protection systems for motorcyclists.
- Order on criteria Circular 18bis/2008 utilization of protection systems for motorcyclists.

4. HORIZONTAL SIGNALING. ROAD MARKS.

4.1 INTRODUCTION

Pavement markings are lines or figures, applied on the pavement of the road, whose mission is to satisfy one or more of the following functions:

- Mark traffic lanes.
- Separate traffic systems
- Show the limits of the road
- Mark the areas excluded for regular vehicular traffic
- Regulate the movement
- Complete or clarify the meaning of the vertical signals
- Repeat or remember a vertical signal
- Allow the movements indicated
- Advertise, guide and direct users.

Road marking are generally white corresponding to the reference B-118 of the UNE 48103.

This document contains the details of it, as well as the dimensions of each of the road markings used. The characteristics of all the materials used and the implementation of the various types of road markings are subject to definition in the relevant sections of the Particular Technical Specification requirements of this project.

A general description of them is performed.

All road marks are reflective and colors, thicknesses and shapes are listed below.

### 4.2 PROHIBITION OF ADVANCEMENT

In order to provide the boundaries, starting points and characteristics of the continuous line, the instructions for regulatory horizontal signaling 8.2-IC has been followed. The continuous longitudinal marks as a consequence of the lack of visibility for advancements, it started when the sight distance available, between observer and obstacle is 1.2 meters above the floor and 1 meter from the inner margin of the wing is less than 165 meters.

The continuous line is maintained when the distance between two continuous longitudinal road markings is less than 340 meters, as it is a new road layout. In these cases the two prohibitions will join because it is considered that there is not enough to complete the advancement or to desist from the attempt.

### 4.3 TYPES OF MARKS ROAD

#### 4.3.1 LONGITUDINAL MARKINGS

- Continuous Longitudinal

#### 4.3.1.2 CONTINUOUS LINES

- Line for organization of overtaking on two-lane and two-way traffic. M-2.2. Sets the prohibition of overtaking due to lack of visibility needed to complete once started, or to withdraw it. It is a line of 10 cm thick.
- Line for edge of roadway. M-2.6. Its function is to define the boundaries of the road. It is a line of 10 cm thick for roads with VM < 100 Km / h and roadside <1.5 meters.
4.3.2 CROSS MARKINGS

Cross markings are not planned.

5. VERTICAL SIGNALING

5.1 VERTICAL SIGNAL CONSIDERED

The vertical signaling refers to road signs and posters for orientation, located at the boundaries or on the road.

The action here is to place specified signals within the trunk and links projected, the necessary vertical signaling. Their measures correspond to the kind of standardized way. By gathering via conventional road characteristics, measures of the signals corresponding to it are:

- Circulars: 60 cm of Diameter

6. VERTICAL MARKS

In addition to horizontal and vertical signaling the definition of an element beacon is included:

- Reflector for safety barriers.

7. SAFETY BARRIERS

7.1 CRITERIA APPROVED

It is planned the placement of guardrails in the total length of the bridge as a protection of some element implanted in the side of the road. It will be provided a security barrier, double wave in the road side. Also will be provided provisions of protective elements for motorcycles.

The defense elements arranged in this project are:

- Flexible Safety Barrier with galvanized metal band and double wave type section BMSNA4/120b (According OC 321/95 "Recommendations on vehicle restraint systems, MOPTA" and changes to the Order Circular 6/01..)
- Flexible Safety Barrier with galvanized metal band section BMSNA4/120c double wave type (According 18bis/2008 OC "on criteria systems for protective motorcycle").
Annex 6
Planification of Works
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTIVITIES AND DURATIONS</td>
<td>3</td>
</tr>
<tr>
<td>GENERAL STRUCTURE OF THE WORKS – BUDGET ASSIGNED</td>
<td>6</td>
</tr>
<tr>
<td>RELATION ACTIVITIES – BUDGET</td>
<td>7</td>
</tr>
<tr>
<td>STRUCTURE OF THE PLANNIFICATION OF THE WORKS – BUDGET ASSIGNED</td>
<td>11</td>
</tr>
<tr>
<td>ANALYSIS RESULTS</td>
<td>15</td>
</tr>
<tr>
<td>ANALYSIS RESULTS AND LINKS</td>
<td>20</td>
</tr>
<tr>
<td>DIAGRAMS</td>
<td>37</td>
</tr>
<tr>
<td>MONTHLY PLANNIFICATION</td>
<td>37</td>
</tr>
<tr>
<td>DAILY PLANNIFICATION</td>
<td>41</td>
</tr>
<tr>
<td>DETAILED PLANNIFICATION</td>
<td>54</td>
</tr>
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</tr>
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<td>-----</td>
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<tr>
<td>1</td>
<td>Esbossada del terreny</td>
</tr>
<tr>
<td>2</td>
<td>Tancament exterior</td>
</tr>
<tr>
<td>3</td>
<td>Delimitació zones de pas maquinaria</td>
</tr>
<tr>
<td>4</td>
<td>Senyalització interior i exterior</td>
</tr>
<tr>
<td>5</td>
<td>Preparació zona d'aplec</td>
</tr>
<tr>
<td>6</td>
<td>Instal·lació casetes</td>
</tr>
<tr>
<td>7</td>
<td>Anivellament i repàs</td>
</tr>
<tr>
<td>8</td>
<td>Excavació del terreny</td>
</tr>
<tr>
<td>9</td>
<td>Compactació i anivellació del terreny</td>
</tr>
<tr>
<td>10</td>
<td>Formigoniat de neteja</td>
</tr>
<tr>
<td>11</td>
<td>Zapatas</td>
</tr>
<tr>
<td>12</td>
<td>Colocació d'escates</td>
</tr>
<tr>
<td>13</td>
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</tr>
<tr>
<td>14</td>
<td>Vertit i compactació de terres</td>
</tr>
<tr>
<td>15</td>
<td>Excavació del terreny</td>
</tr>
<tr>
<td>16</td>
<td>Compactació i anivellació del terreny</td>
</tr>
<tr>
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<td>Formigoniat de neteja</td>
</tr>
<tr>
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<tr>
<td>20</td>
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</tr>
<tr>
<td>21</td>
<td>Vertit i compactació de terres</td>
</tr>
<tr>
<td>22</td>
<td>Formigoniat de neteja</td>
</tr>
<tr>
<td>23</td>
<td>Xarxa de drenatge</td>
</tr>
<tr>
<td>24</td>
<td>Armat</td>
</tr>
<tr>
<td>25</td>
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</tr>
<tr>
<td>26</td>
<td>Formigoniat</td>
</tr>
<tr>
<td>27</td>
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</tr>
<tr>
<td>28</td>
<td>Col·locació de neoprenes</td>
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<td>Xarxa de drenatge</td>
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<td>Col·locació de neoprenes</td>
</tr>
<tr>
<td>36</td>
<td>Montatge de cimbrat</td>
</tr>
<tr>
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<td>Encofrat</td>
</tr>
<tr>
<td>38</td>
<td>Armat</td>
</tr>
<tr>
<td>39</td>
<td>Pretensats</td>
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<td>Desencofrat</td>
</tr>
<tr>
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<tr>
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<tr>
<td>43</td>
<td>Formigonat de base</td>
</tr>
<tr>
<td>44</td>
<td>Tubs de serveis</td>
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</tr>
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<td>51</td>
<td>Reg d'imprimació</td>
</tr>
<tr>
<td>52</td>
<td>Mescla Bituminosa</td>
</tr>
<tr>
<td>53</td>
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<tr>
<td>54</td>
<td>Senyalització horitzontal</td>
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</tr>
<tr>
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</tr>
<tr>
<td>58</td>
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<tr>
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</tr>
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## ESTRUCTURA DEL PLA DE TREBALL

**Data:** 06/01/14

**Estat:** Planejament

**Data inici:** 03/03/2014

**Data fi:** 03/12/2014

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### RELACIÓ TASQUES/PRESSUPOST

**Data:** 06/01/14

**Estat:** Planejament  **Data inici:** 03/03/2014  **Data fi:** 03/12/2014

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Imports referents a PEM EUR
## Estructura del Pla de Treball

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- 1016 - Compactació i anivellament: 50.480,73 EUR
- 1023 - Xarxa drenant: 4.988,34 EUR
- 1024 - Armat: 8.084,86 EUR
- 1025 - Encofrat: 3.484,29 EUR
- 1026 - Formigonacci: 19.388,59 EUR
- 1027 - Desencofrat: 3.875,30 EUR
- 1028 - Col·locació de neoprens: 8.883,00 EUR
- 1029 - Xarxa drenant: 0,00 EUR
- 1030 - Formigó de neteja: 0,00 EUR
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- 1035 - Col·locació de neoprens: 0,00 EUR
- 1.1.6 - Deck: 106.019,79 EUR

Imports referents a PEM

EUR
# ESTRUCTURA DEL PLA DE TREBALL

**Estat:** Planejament  
**Data inici:** 03/03/2014  
**Data fi:** 03/12/2014

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**Imports referents a PEM EUR**
# ESTRUCTURA DEL PLA DE TREBALL

**Data:** 06/01/14  
**Estat:** Planejament  
**Data inici:** 03/03/2014  
**Data fi:** 03/12/2014

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Pàg.: 1

Estat: Planejament  
Data inici: 03/03/2014  
Data fi: 03/12/2014

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**Data:** 06/01/14  
**Estat:** Planejament  
**Data inici:** 03/03/2014  
**Data fi:** 03/12/2014

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**Data inici:** 03/03/2014  
**Data fi:** 03/12/2014

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DATA INICI: 03/03/2014

DATA FI: 03/12/2014

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Data: 06/01/14

Estat: Planejament
Data inici: 03/03/2014
Data fi: 03/12/2014

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Data inici: 03/03/2014  
Data fi: 03/12/2014

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**Pàg.:** 12
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**Data inicis:** 03/03/2014  
**Data fins:** 03/12/2014

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Estat: Planejament

Data inici: 03/03/2014
Data fi: 03/12/2014

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Estat: Planejament

Data inici: 03/03/2014

Data fi: 03/12/2014

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- Desinstal·lació de casetes
- Tancament exterior

**Restrics. d'inici:**

- Rom. de desinstal·lació de casetes: 4
- Rom. de tancament exterior: 3

**Inici:**

- 24/11/14
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- 28/11/14
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- 01/12/14

**Total:**

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### RESULTATS DE L’ANÀLISI I LLISTA DE LLIGAMS

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**Data inici:** 03/03/2014  
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Fi contr: 03/12/2014

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Fi actual: 03/12/2014

Última analisi: 03/03/2014

Data: 06/01/2014

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ACTIVITATS CRÍTICAS

Activitat crítica: Xarxa drenant

Comentari: El diagrama representa el planejament de les tasques associades amb la construcció d'una estructura. Les tasques estan ordenades en funció de les seves dates primeres i últimes planificades, permetent una millora de la visibilitat del progrés de cada una d'elles. Els percentatges d'avanç són visualitzats per mitjà de barreres. Les tasques critèries d'inici i de fi són indicades amb col·locació de neoprens. Les dates realitzades es mostren en el quadrant inferior de la taula. A més, s'hi indiquen les tasques que han estat tramificades, corregudes o cancel·lades.
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- **Fecha de última actualización**
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- **Fecha de ultima contratación**
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- **Crítica de finalización**
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**Durada**

**Fecha primera planificada**

**Fecha última planificada**

**Fecha real**

**Fecha contratación**

**Inici real**

**Fecha actual**

**Última análise**

**Data**

**Pag:**
### Diagrama de Barras: Planejament 5 - PFG

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**Activitat crítica**

- Folguença inicial
- Folguença final

**Folguença**

- Ordre: Orden del trabajo
- Durada: Duración del trabajo
- Cost: Costo del trabajo
- Dates primeres planif: Fecha de primer planteamiento
- Dates últimes planif: Fecha de último planteamiento
- Lligam: Llave del trabajo
- Tramificada: Tramificado
- Crítica d'inici: Crítica de inicio
- Crítica de fi: Crítica de final

**Inici contr: 03/03/2014**

**Fi contr: 03/12/2014**

**Inici real: 03/03/2014**

**Fi actual: 03/12/2014**

**Fi contr: 03/12/2014**
## DIAGRAMA DE BARES. PLANEJAMENT

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**Nota:** La vista previa de este documento contiene una tabla que muestra información detallada sobre las actividades, incluyendo fechas y costos. La tabla muestra actividades como la adquisición de licencias, contratación, inicio de obra, preparación de zonas de acopio, nivelación y compactación de tierras, excavación del terreno, compactación y nivelación, formigón de neteja, colocación de escamas, colocación de armaduras, relleno y compactación de tierras, etc. Cada actividad tiene asociada una fecha de inicio y, en algunos casos, una fecha de finalización. La tabla también incluye una columna con la duración de cada actividad, así como la tasa de resumen y el ligar de la actividad.
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  - 11: INCI/OSRA
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  - 11: 214 dies
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**Activitat crítica**

- Inici contr: 03/03/2014
- Fi contr: 03/12/2014
- Inici real: 03/03/2014
- Fi actual: 03/12/2014
- Última analisi: 03/03/2014
- Data: 06/01/2014
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### 1.1.5 End Beam 2
- **Descripció**: End Beam 2
- **Durada**: 23/09/14 - 30/09/14
- **Dates últimes planificades**: 23/09/14
- **Dates últimes efectuada**: 30/09/14
- **Última analisi**: 03/03/2014

### 1.3. Deix
- **Descripció**: Deix
- **Durada**: 30/08/14 - 03/09/14
- **Dates últimes planificades**: 15/08/14
- **Dates últimes efectuada**: 03/09/14

### 1.4. Desencofrat
- **Descripció**: Desencofrat
- **Durada**: 26/08/14 - 30/09/14
- **Dates últimes planificades**: 26/08/14
- **Dates últimes efectuada**: 30/09/14

### 1.6. Baixar
- **Descripció**: Baixar
- **Durada**: 30/08/14 - 03/09/14
- **Dates últimes planificades**: 15/08/14
- **Dates últimes efectuada**: 03/09/14

### 1.7. Acabades
- **Descripció**: Acabades
- **Durada**: 23/09/14 - 23/11/14
- **Dates últimes planificades**: 23/09/14
- **Dates últimes efectuada**: 23/11/14

- **Activitat crítica**: Yes

### 1.7.1 Paving
- **Descripció**: Paving
- **Durada**: 27/09/14 - 23/11/14
- **Dates últimes planificades**: 27/09/14
- **Dates últimes efectuada**: 23/11/14

### 1.7.3 Frenades horitzontals
- **Descripció**: Frenades horitzontals
- **Durada**: 1.249,65
- **Dates últimes planificades**: 1.249,65
- **Dates últimes efectuada**: 1.249,65

### 1.7.4 Frenades verticals
- **Descripció**: Frenades verticals
- **Durada**: 362,98
- **Dates últimes planificades**: 362,98
- **Dates últimes efectuada**: 362,98

### 1.7.2 Barres
- **Descripció**: Barres
- **Durada**: 3.592,80
- **Dates últimes planificades**: 3.592,80
- **Dates últimes efectuada**: 3.592,80

### 1.1.7.3 Paviment
- **Descripció**: Paviment
- **Durada**: 30/08/14 - 15/09/14
- **Dates últimes planificades**: 15/09/14
- **Dates últimes efectuada**: 15/09/14

### 1.1.7.2 Boreres
- **Descripció**: Boreres
- **Durada**: 1.488,12
- **Dates últimes planificades**: 21/01/2014
- **Dates últimes efectuada**: 1.488,12

### 1.1.7.1 Mocàs bituminosa
- **Descripció**: Mocàs bituminosa
- **Durada**: 1.488,12
- **Dates últimes planificades**: 21/01/2014
- **Dates últimes efectuada**: 1.488,12

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- **Descripció**: Reg d'imprimació
- **Durada**: 4.681,12
- **Dates últimes planificades**: 21/01/2014
- **Dates últimes efectuada**: 4.681,12

### 1.1.7.1 Senyalització horitzontal
- **Descripció**: Senyalització horitzontal
- **Durada**: 1.526,85
- **Dates últimes planificades**: 09/11/14
- **Dates últimes efectuada**: 1.526,85

### 1.1.7.1 Senyalització vertical
- **Descripció**: Senyalització vertical
- **Durada**: 362,98
- **Dates últimes planificades**: 09/11/14
- **Dates últimes efectuada**: 362,98

### 1.1.7.1 Senyalització vertical i horizontal
- **Descripció**: Senyalització vertical i horizontal
- **Durada**: 4.681,12
- **Dates últimes planificades**: 21/01/2014
- **Dates últimes efectuada**: 4.681,12

### 1.1.7.1 Senyalització vertical
- **Descripció**: Senyalització vertical
- **Durada**: 362,98
- **Dates últimes planificades**: 09/11/14
- **Dates últimes efectuada**: 362,98
### DIAGRAMA DE BARRES. PLANEJAMENT

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- Folgança inicial
- Folgança final
- Tasca resum
- Ligam
- Percentatge d'avanç
- Dates primers planificats
- Dates últimes planificats
- Tramificada
- Crítica d'inici
- Crítica de fi
### DIAGRAMA DE BARRRES. PLANEJAMENT

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**Duraça**

**Tasca resum**

**Folgança inicial**

**Folgança final**

**Tramificada**

**Crítica d'inici**

**Crítica de fi**

**Dates primeres planif**

**Dates últimes planif**

**Percentatge d'avenç**

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Inici contr: 03/03/2014  
Fi contr: 03/12/2014  
Inici real: 03/03/2014  
Fi actual: 03/12/2014  
Última anàlisi: 03/03/2014  
Data: 06/01/2014  
Pag: 16
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- Folgança inicial
- Folgança final
- Tasca resum
- Lligam
- Percentatge d'avanç
- Tramificada
- Crítica d'inici
- Crítica de fi

**Dates primeres planíf:都没有**

**Dates últimes planíf:**

- Inici real: 03/03/2014
- Fi actual: 03/12/2014
- Data: 06/01/2014

**Última anàlisi:** 03/03/2014
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Annex 7
Expropriations
\[ A_1 := 11.10 \text{ m} \cdot 900 \text{ m} - 25.7 \text{ m} \cdot (11.10 \text{ m} + 2 \cdot 11.55 \text{ m}) = 9111.06 \text{ m}^2 \]

\[ A_2 := 4 \left[ \frac{1}{2} \cdot 11.55 \text{ m} \cdot \frac{(900 \text{ m} - 25.7 \text{ m})}{2} \right] = 10098.165 \text{ m}^2 \]

\[ A_3 := 4 \cdot (3 \text{ m} \cdot 437.30 \text{ m}) = 5247.6 \text{ m}^2 \]

\[ A_{\text{exp}} := A_1 + A_2 + A_3 = 24456.825 \text{ m}^2 \]
Annex 8
Environmental Impact Assessment
# Table of Contents

1. **INTRODUCTION** .................................................................................................................................................. 3

2. **DESCRIPTION OF THE STUDY AREA** ................................................................................................................. 3
   2.1 **PHYSIC ENVIRONMENT** .................................................................................................................................. 3
      2.1.1 **HIDROLOGY AND GEOTECHNICS** ........................................................................................................ 3
   2.2 **NATURAL ENVIRONMENT** .............................................................................................................................. 3
      2.2.1 **FLORA, FAUNA AND VEGETATION** ...................................................................................................... 3
      2.2.3 **LANDSCAPE** ........................................................................................................................................... 4
      2.2.4 **ESPACIOS NATURALES** ...................................................................................................................... 4
      2.2.5 **WATER QUALITY** ..................................................................................................................................... 4

3. **IMPACTS IDENTIFICATION AND ASSESSMENT** .................................................................................................. 4
   3.1 **IMBALANCE OF THE SOIL MOVEMENT** ....................................................................................................... 4
   3.2. **LAND OCCUPATION** ..................................................................................................................................... 5
   3.3. **FLOOD RISK** ................................................................................................................................................. 5
   3.4. **DECREASE OF WATER QUALITY** .................................................................................................................. 5
      3.4.1 **SURFACE WATER** .................................................................................................................................... 5
      3.4.2 **UNDERGROUND WATER** .................................................................................................................... 5
   3.5. **DESTRUCTION OF VEGETATION** ................................................................................................................... 6
   3.6. **DIRECT IMPACT OVER THE FAUNA** ............................................................................................................. 6
   3.7. **DECREASE OF THE LANDSCAPE QUALITY** .................................................................................................. 6
   3.8. **RISK OF HERITAGE AFFECTION** .................................................................................................................. 6
   3.9. **HUMAN HABIT AFFECTION** ........................................................................................................................ 6
      3.9.1. **NOISE LEVEL RISING** ........................................................................................................................ 6
      3.9.2. **LEVEL RISE OF PARTICLE EMISSION** ............................................................................................... 6

4. **PROPOSED CORRECTIVE MEASURES** .................................................................................................................. 7
   4.1. **CUIDADO DURANTE EL DESARROLLO DE LAS OBRAS** ............................................................................. 7
   4.2. **ROAD PLATFORM IRRIGATION AND CLEAN UP** ....................................................................................... 7
   4.3. **CLEANING AT THE END OF THE WORK** ..................................................................................................... 7
   4.4. **LIMITATION OF OCCUPATION** ..................................................................................................................... 7
   4.5. **TEMPORARY FACILITIES AND TEMPORARY STOCKPILES** ............................................................... 7
   4.6. **LOANS** ......................................................................................................................................................... 7
   4.7. **HERITAGE** ..................................................................................................................................................... 8
   4.8. **REVEGETATION** .......................................................................................................................................... 8
   4.9. **CONTROL OF NOISE LEVELS** ...................................................................................................................... 8
1. INTRODUCTION

This Environmental Impact Assessment aims to analyze environmentally the Prestressed Bridge Construction Project.

It has been drafted in compliance with the current regulations involving two administrations:


This study aims to define the environmental impacts and their valuation.

2. DESCRIPTION OF THE STUDY AREA

2.1 PHYSIC ENVIRONMENT

2.1.1 HIDROLOGY AND GEOTECHNICS

In Berlin, there are two large potentiometric surfaces (groundwater layers). The deeper level carries salt water and is separated from the upper potentiometric surface by an approx. 80 meter thick layer of clay, except at occasional fault points in the clay. The upper level carries fresh water and has an average thickness of 150 meters. It is the source of Berlin's drinking (potable) and process (non-potable) water supplies. It consists of a variable combination of permeable and cohesive loose sediments. Sand and gravel (permeable layers) combine to form the groundwater aquifer, while the clay, silt and organic silt (cohesive layers) constitute the aquitard.

2.2 NATURAL ENVIRONMENT

2.2.1 FLORA, FAUNA AND VEGETATION

The conditions of life for wild plant and animal species have clearly worsened since the middle of the last century, especially in urban areas. About half of the wild plants and animal species previously attested in Berlin are today extinct, threatened by extinction, or endangered.

The most important causes for species decline are the destruction of the natural habitats and the changes in the conditions of life. As a consequence of the utilization of areas for development, soil impermeability, etc. habitats have been and are being destroyed or fragmented so greatly that they no longer offer undisturbed refuge for sensitive species. Furthermore, the entry of harmful materials from industry, trade, transportation systems and households leads to considerable impairment of the natural foundations of life. In Berlin, this has become apparent through major impoverishment of moss and lichen flora and damage to forest areas.
2.2.3 LANDSCAPE

Landscape Protection Areas (LSGs; §20) are legally established areas which are especially protected for the conservation or restoration of the productive power of the ecosystem, or the utilization ability of natural products, because of the diversity, uniqueness or beauty of the landscape appearance, or because of their particular significance for recreation.

The area of study is located outside of any protected area.

2.2.4 ESPACIOS NATURALES

Nature Protection Areas (NSGs; §19) are legally established areas in which nature is strictly protected in whole or in individual parts. The protection extends particularly to areas which are of considerable significance for the conservation of biocenoses or habitats of wild plant or animal species, for scientific, cultural, natural-historic or regional reasons, because of their rarity, diversity, particular uniqueness or outstanding beauty.

This project is located outside of any protected area.

2.2.5 WATER QUALITY

The results of the area of study developed by the Senate Department for Health, the Environment and Consumer Protection of Berlin show very clearly the extensive area from which material was introduced into Berlin's groundwater close to the surface over many years: whereas pollution by chloride and boron is limited to specific areas, large parts of the Berlin urban area are affected by markedly increased concentrations of sulphate, which are clearly exceeding the threshold value stipulated in the Drinking Water Ordinance (TrinkWV) - the primary cause is the large-scale disposal of building rubble and debris. In the case of ammonium and potassium, besides geogenic causes such as mucky sediments, other anthropogenic sources such as wastewater disposal in the past or current leakage from the sewer system, must be considered.

3. IMPACTS IDENTIFICATION AND ASSESSMENT

3.1 IMBALANCE OF THE SOIL MOVEMENT

The study project is located in a completely flat area, which means that the 8 meters high to be achieved for the construction of the bridge are achieved by filling. The project has not clearance surfaces; therefore, the entire volume is land fill which shall be delivered from the quarry by road transport. Thus, this impact is negative, also permanent, irreversible, continuous and unrecoverable.

However, as the volumes are not high, the overall magnitude of the impact is moderate.
3.2. LAND OCCUPATION

The occupation of land is an adverse, permanent, irreversible and irretrievable impact. In this case, but, since the infrastructure is right next to a railway infrastructure and buildings are not relatively close, is considered to be a compatible impact.

3.3. FLOOD RISK

Groundwater levels in a metropolitan area like Berlin are subject not only to such natural factors as precipitation, evaporation and subterranean outflows, but are also strongly influenced by such human factors as water withdrawal, construction, surface permeability, drainage facilities, and recharge.

In case of flood risk, within the inner ring of the city (S-Bahn) there are exceptions for situations of extended, intensive rainfall events. Once water reaches a certain height in the drains, or if the pumping stations can no longer cope with volume of water received, the combined sewage which, in case of such downpours, consists mainly of rainwater (at a ratio of about 1:9) flows untreated into the water bodies via rainwater overflow canals. The occurrences of such overflow situations and the quantities discharged from the combined system into the receiving waters fluctuate, depending on the frequency of strong rainfall.

Thus, considering that the sewage system of the city is efficient enough, the flood risk is considered low-moderated.

3.4. DECREASE OF WATER QUALITY

3.4.1 SUFFACE WATER

As this project is not located near any water source or asset which communicate with the general network of runoff is not considered for this project that may have an impairment in this aspect.

3.4.2 UNDERGROUND WATER

Due to the permeability of the materials present in the area, the aquifer vulnerability is average overall.

The danger of contamination of the aquifer is relatively high in construction phase, as the water table is shallow and there is no impermeable layer that protects it. In operational phase may be an episode of contamination from accidental spills of oil and fuel residues.

Thus, the impact on groundwater is an adverse impact, mainly in construction phase, reversible and recoverable, irregular and discontinuous. The magnitude of the condition is compatible, since no areas of high vulnerability are rare in the area.
3.5. DESTRUCTION OF VEGETATION

It is not envisaged that the project will have an adverse effect with respect to vegetation as the area has not currently vegetation; since corresponds to a fully developed area.

However, it should be noted the presence of certain trees to be felled in the construction phase. The removal of vegetation is an adverse, permanent, recoverable and continuing impact of moderate magnitude to not be an area of special natural interest.

3.6. DIRECT IMPACT OVER THE FAUNA

During the work, they can be removed specimens of certain species of low movement capability (due to earthmoving) as amphibians and reptiles, while species that have a greater range of motion may be moved to adjacent areas, such as may be the most birds.

Occasional collision of an animal may also occur, although this is unlikely given the low presence of animals in the area.

The occupation of land by the proposed infrastructure can remove some of the local wildlife habitat, and it is an impact that will remain in the operational phase, but being a very settled area of human activity, it is an impact of a compatible magnitude.

3.7. DECREASE OF THE LANDSCAPE QUALITY

The impact on the landscape is derived from the negative impact of the different elements used in the construction phase (machinery dirt stockpiles ...) plus the impact of the work itself in operational phase. The work planned cause an adverse impact on the area of moderate magnitude. It is temporary and reversible phase of work, and permanent and irreversible phase of exploitation, recoverable and continuous.

3.8. RISK OF HERITAGE AFFECTION

The area to which the project is limited does not affect any declared local heritage item.

3.9. HUMAN HABIT AFFECTION

3.9.1. NOISE LEVEL RISING

Increased noise caused by different causes will come depending on the phase in which the project is found: under construction will be produced because of the machinery and earthworks. In contrast, in exploitation phase will generated traffic in the area.

The impact of noise on phase work is adverse, temporary, recoverable, irregular and discontinuous, while that of the operational phase is irreversible, recoverable and continuous. Both impacts are considered to be of moderate magnitude.

3.9.2. LEVEL RISE OF PARTICLE EMISSION

The ability of the area to disperse air pollutants is low, although the number of rainy days allows cleaning of the atmosphere, partly offsetting the above effect.
It is expected that air quality in the operation phase is similar to that existing at the present in addition to allowing the reduction of pollutant emissions due to the new path, which by redirecting the traffic to the perimeter of the neighborhood is expected to decrease the values on the walking areas of the district. It is therefore not considered a significant magnitude impact.

4. PROPOSED CORRECTIVE MEASURES

4.1. CUIDADO DURANTE EL DESARROLLO DE LAS OBRAS

While the work is taking place, it will be necessary to take special care with the elements as heritage and vegetation zones to protect, by signaling those areas, which shall remain unchanged. Furthermore, all remaining at the end of the work around the area which has been affected during the work items are removed.

4.2. ROAD PLATFORM IRRIGATION AND CLEAN UP

In periods when rainfall is low, the different existing platforms and vehicle paths must be watered to prevent the emission of particles. It shall also be ensured that the trucks are in conditions of minimal cleaning before leaving the working area.

4.3. CLEANING AT THE END OF THE WORK

All construction residues shall be removed at the end of the work, and all temporary facilities authorized sending all waste that may be in the dumps.

4.4. LIMITATION OF OCCUPATION

At the beginning of the work should be clearly marked areas that may be occupied either by work or by machinery, stockpiles, temporary facilities and vehicle corridors.

4.5. TEMPORARY FACILITIES AND TEMPORARY STOCKPILES

The areas where it will be deposited stockpiles and parks equipment and temporary facilities will be selected based on both technical, economic and ecological criteria.

4.6. LOANS

When borrow material is necessary for the implementation of the embankments, it will be necessary to establish a land loan, which may both quarry as any other work that runs nearby the same time. The latter should be preferred against the contributions of quarries.
4.7. HERITAGE

If during any works archaeological items are found, it must be reported to management.

4.8. REVEGETATION

Since the slopes resulting from the action in the area may have been altered its stability, and to improve aspects of vegetation and landscape, the area must be replanted to complete the works. It must be removed the first layer in this soil, earthmoving and profiling of ground, a scarifying and subsequent decompaction and the contribution of topsoil. To finish is hydro sowing the area with grass species and shrubs in appropriate areas.

4.9. CONTROL OF NOISE LEVELS

As there is an increase in the noise level in the implementation phase, reasonable hours of work that is compatible with the pace of the work and planning should be established. In this way, not work nor holidays or between 20:00 and 8:00 on week-days, ensuring at all times that the established sound levels are not exceeded.

Some of the necessary machinery in the work may exceed that limit, so means should be taken to attenuate these noises.
Annex 9
Study of Safety and Health
# Table of Contents

1.1 PURPOSE OF THE STUDY OF HEALTH AND SAFETY ........................................... 4
  1.1.1 Identification of the work ........................................................................... 4
  1.1.2 Object ........................................................................................................ 4
1.2 DEVELOPER – OWNER ......................................................................................... 4
1.3 AUTHOR OF THE HEALTH AND SAFETY STUDY ............................................. 5
1.4 PROJECT DATA .................................................................................................. 5
  1.4.1 Project Author ............................................................................................. 5
  1.4.2 Typology of the work .................................................................................. 5
  1.4.3 Situation ....................................................................................................... 5
  1.4.4 Connections .................................................................................................. 5
  1.4.5 Supplies and Services ................................................................................... 5
  1.4.6 Location of care services, rescue and safety .................................................. 6
  1.4.7 Budget and physical implementation of the project ....................................... 6
  1.4.8 Lead time ..................................................................................................... 6
  1.4.9 Staff planned ................................................................................................ 6
  1.4.10 Trades involved in the development of the work ......................................... 6
  1.4.11 Typology of materials to be used in the work ............................................. 7
  1.4.12 Equipment required to develop the works .................................................. 7
1.5 PROVISIONAL FACILITIES ............................................................................... 9
  1.5.1 Provisional Electric Installation .................................................................... 9
  1.5.2 Provisional water installation ........................................................................ 10
  1.5.3 Installation of sanitation ............................................................................... 10
  1.5.4 Other facilities. Fire prevention and protection ............................................. 11
1.6 HEALTH SERVICES AND FACILITIES STAFF .............................................. 12
  1.6.1 Toilets .......................................................................................................... 12
  1.6.2 Dressing ....................................................................................................... 12
  1.6.3 Dining room .................................................................................................. 12
  1.6.4 Rest area ...................................................................................................... 13
  1.6.5 Area for the assistance of the injured ............................................................ 13
1.7 AUXILIAR AREAS .............................................................................................. 14
  1.7.1 Central and plants ......................................................................................... 14
  1.7.2 Workshops ..................................................................................................... 14
  1.7.2 Storage rooms .............................................................................................. 15
1.8 WASTE .............................................................................................................. 15
1.9 TREATMENT OF MATERIALS AND / OR HAZARDOUS SUBSTANCES .......... 16
1.1 PURPOSE OF THE STUDY OF HEALTH AND SAFETY

1.1.1 Identification of the work

The study of health and safety concern the constructive project of a Prestressed Bridge in Berlin, Germany.

1.1.2 Object

This S.H.S. aims to establish the technical basis for setting the parameters of the prevention of occupational risks in the performance of the work of implementing the project works object of this study, as well as fulfill the obligations arising from the Law 31 /1995 and RD 1627 /1997, in order to facilitate the control and monitoring of the commitments made in this regard by the Contractor.

In the present study Safety and Health has conducted a comprehensive study of the risks inherent in the execution of the work and consequent preventive and precautionary measures to ensure the safety of people in the implementation of risk pursuant works what determines the Law 3 /2007 of 4 July public works in his article 18.3.h).

Thus, integrated into the staff / construction project the basic premises for the Contractor an anticipate and plan the technical and human resources necessary for the performance of preventive obligations in this center work according to your plan itself Preventive Action company , its functional organization and the means to be used which should be all gathered in the Plan for Safety and Health , to be submitted to the Coordinator of Safety and Health Implement phase prior to the start of construction for approval and initiation of procedures Opening Statement before the Labour Authority .

Where necessary to implement safety measures not provided for in this study, at the express request of the health and safety coordinator in the execution phase of the work, the contractor shall prepare the corresponding schedule Plan Safety and Health of the work develop and determine the security measures to be carried out with the memory specifications, measurements, prices and budget that may be applicable if any.

1.2 DEVELOPER – OWNER

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1.3 AUTHOR OF THE HEALTH AND SAFETY STUDY

Editor S.H.S. 
Carla Comadran Casas 
Degree / nes: 
Civil Engineer 
No. referee. : 
Professional Office: 
Campus Nord 
Location: 
Barcelona

1.4 PROJECT DATA

1.4.1 Project Author

Project Author: Carla Comadran Casas 
Degree / nes: Civil Engineer 
No. referee. : 
Professional Office: Campus Nord 
Location: Barcelona

1.4.2 Typology of the work

The case of study concerns the construction of a Prestressed Bridge with subsequent bond under German normative in Berlin, Germany.

1.4.3 Situation

Site: Germany 
Street, square: Kynaststrasse 
Number: 
ZIP Code: 
Population: Berlin

1.4.4 Connections

Road: Stralauer Allee and Marktstrasse 
Railway: S-Bahn Ring 
Metro Line: 
Bus Line: 

1.4.5 Supplies and Services

Water: NO 
Gas: NO 
Electricity: YES 
Sewer: NO 
Other: NO
1.4.6 Location of care services, rescue and safety

Evangel. Krankenhaus Herzberge – Tagesklinik Boxhagener Strasse
Boxhagener Straße 76
10245 Berlin
030 29668485

1.4.7 Budget and physical implementation of the project

The Execution Material Budget (PEM) estimated for this project, excluding additional Health and Safety, Industrial Overhead and Profit, is € 741,640,74 € (SEVEN HUNDRED AND FOURTYONE THOUSAND SIX HUNDRED AND FORTY EURO AND SEVENTYFOUR CENT).

1.4.8 Lead time

The estimated duration of the work of execution of the work term is 9 months.

1.4.9 Staff planned

The estimated staff for the implementation of the project is 4 persons.

The estimation has been made as follows:

\[
\begin{align*}
\text{PEM (no health and safety)} & = 741,640,74 \text{ €} \\
\text{Total amount of labor (15% PEM)} & = 111,246.11 \text{ €} \\
\text{Lead time} & = 9 \text{ months} \times 4 \text{ weeks} / \text{ month} \times 40 \text{ hours} / \text{ week} = 1440 \text{ hours} \\
\text{Average price labor / hour} & = 22 \text{ €/h} \\
\text{Total hours} & = \text{Lead time} \times \text{Average price labor / hour} = 31680 \\
\text{Number of employees} & = \text{Total amount of labor} / \text{price total hours} = 4
\end{align*}
\]

1.4.10 Trades involved in the development of the work

Team leader
Official 1st
Official 1st gardener
Laborer specialist
    - Reinforcement
    - Concrete
    - Prestress
Assistant
Laborer
Pawn
1.4.11 Typology of materials to be used in the work

BEACONING FOR WORK SAFETY
STEEL FOR CORRUGATED BARS
MINERAL FERTILIZERS SLOW RELEASE
MINERAL FERTILIZERS FUND
HIGH VOLTAGE
STEEL HANDRAILS
BARRIERS
CEMENT
NAILS
WIRES
CONCRETE WITHOUT ADDITIVES
GEOTÈXTILS
AGGREGATES FOR PAVEMENTS
AGGREGATES FOR PAVEMENTS WITH HYDROCARBON BINDERS
CRUSHED STONE (GRAVELS)
DRAINING POLYETHYLENE LAYS
HYDROCARBON BINDERS
AUXILIAR DRAINING MATERIALS
AUXILIAR MATERIALS FOR THE FORMWORK AND SHORING
AUXILIAR MATERIALS FOR PROTECTION
EXPANSIVE JOINT MATERIALS
HOT BITUMEN MIXURES
MORTARS AND ADDITIVES
HANDRAILS
CONCRETE PIECES FOR SIDEWALKS
PAINTS FOR SIGNALING
PINUS SP
STRUT
SANDSTONE
SIGNS
SIGNS AND POSTERS OF EXTRUDED ALUMINIUM
BOARDS
SOIL
VEGETAL SOILS
TOWERS
ALL-IN-ONE (SOIL)
CONCRETE CIRBULAR TUBES
REINFORCED CONCRETE CIRCULAR TUBS
POLYETHYLENE TUBES FOR CABLES AND OPTICAL FIBER
PVC TUBES
PVC TUBES FOR DRAINAGE

1.4.12 Equipment required to develop the works

Backhoe de 50 hp, with hammer between 200 kg - 400 kg
Backhoe de 74 hp, with hammer between 200 kg - 400 kg
Backhoe 95 hp, with hammer between 800 kg - 1500 kg
Portable compressor, with two pneumatic hammers between 20 kg - 30 kg
Machinery equipment saw diamond blade to cut
Shovel chargers of 110 hp, type CAT-926 or similar
Shovel charger of 170 hp, type CAT-950 or similar
Mini wheel loader with backhoe attachment 60 cm in width
Digger-loader 110 HP, ENG-212 or equivalent type
Digger-loader 385 HP, ENG-245 or equivalent type
Backhoe 50 HP, type CAT-416 or equivalent
Backhoe 74 HP, type CAT-428 or equivalent
Backhoe 95 HP, type CAT-446 or equivalent
Crawler excavator with scarifier (D-7)
Crawler excavator with scarifier (D-9)
125 hp motor grader
150 hp motor grader
Propelled vibratory roller 6 to 8 t
Propelled vibratory roller of 8 to 10 t
Propelled vibratory roller of 12 to 14 t
Propelled vibratory roller of 14 to 18 t
Vibrating tamper duplex 1300 kg
Vibrating plate tamper with 60cm width
Truck 150 hp, 12 t (5.8 m3)
Truck 200 hp, 15 t (7.3 m3)
Truck 250 hp, 20 t (9.6 m3)
Truck 400 hp, 32 t (15.4 m3)
Truck tractor 450 hp, 36 t (17.5 m3)
Tanker 6000 the
Tanker 10000 l
Truck crane 5 t
Truck crane 10 t
Self-propelled crane 12 t
Self-propelled crane 24 t
Self-propelled crane 40 t
Dumper 1500 Kg
Van 3500 kg
Internal Concrete Vibrator
Concrete pump truck
Bituminadora auto irrigation asphalt
Paver for paving bituminous mixture
Paver of granulated
Propelled sweeper
Propelled roller of 14 to 16 t
Propelled vibratory roller tire
Sweeper with material collector
Batching plant to 60 m3 / h
Machine for paint markings, self-propelled
Machine for paint markings, thermoplastic paint
Nailing machine for metal studs
Portable compressor with accessories paint markings
Team truck 13 t with boilers for thermoplastic paint
Ruler vibratory of concrete for paving
Components and auxiliary welding
Equipment and auxiliary elements for cutting oxiacetilenic
Chainsaw for cutting down trees
Machine for tensioned process
Machine for detensioned process
Tensioning head
Machine to bend round steel
Electric shears
Drill machine
Pumps for test tubes
Tractor equipment for subsurface treatment
Hydro seeder mounted on truck
Generator of 45/60 kVA, with consumption including
Generator of 80/100 kVA, with consumption including Portable Compressor 7/10 m³/min flow

1.5 PROVISIONAL FACILITIES

1.5.1 Provisional Electric Installation

- Service connection
  - Will be conducted according to the supply company.
  - The section will be determined by the installed power.
  - There will be a protective device (fuses and power limiters)
  - Will always located outside the supply of lifting equipment and areas without passing vehicles.

- Risk Overview
  - Shall be ensured a protection to indirect contacts by differential minimum sensitivity of 300 mA. For lighting and double insulated power tools, sensitivity shall be 30 mA.
  - Shall be ensured a protection towards direct contacts which have no live parts exposed (scuppers, connecting nuts, automatic terminals, etc.).
  - Shall be provided switches circuit breakers for each independent circuit court. The lifting appliances should be of universal cut (they cut all drivers, including the neutral)
  - Must be protection against weather.
  - It is recommended to use special key to open.
  - Shall be signaled with standard electrical hazard warning (RD 485/97) signal.

- Drivers
  - Provide for a 1000 v insulation rated voltage
  - Drivers will be buried, or stapled to vertical walls or ceilings away from areas of passing vehicles and / or people.
  - The joints shall be made using plugs, never connecting strips, twisted or taped.

- Side Tables
  - Any point of consumption can be more than 25 m from one of the boxes.
  - Although its composition will vary according to need, the more conventional switchgear for secondary plant equipment is as follows:
    - 1 general breaker 4P: 30 A.
    - 1 Differential 30 A: 30 mA.
    - 1 3P breaker 20 mA.
    - 4 Breaker 2P 16A
    - 1 Connection to electricity 3P + T: 25 A.
    - 1 Connection to electricity 2P + T: 16 A
    - 2P 2 Port Power: 16 A
    - 1 Safety transformer (220 v / 24 v)
- 1 Connection 2P to electricity 16 A

- Power Connections
  - Include ground scuppers, except for the connection of double insulated equipment where protected by a circuit to facilitate disconnection.
  - The following colors are used:
    - 24 v connection: Violet.
    - 220 v connection: Blue.
    - 380 v connection : Red
  - No "thief" type connections are used.

- Electrical machinery
  - Shall be placed on the ground.
  - Lifting appliances shall be provided with universal cut off switch.
  - Is connected to ground guides elevators and crane rails or other fixed lifting appliances.
  - Establishing connection to the current database, it will always be by standard plug.

- Lighting Progress
  - The circuit will have high sensitivity differential protection of 30 mA.
  - The lamp shall be insulated type.
  - Stage to the center point of the socket and the neutral to next to the shell side is connected.
  - The points of light on the walkways will be installed on roofs to ensure inaccessibility to people.

- Portable Lighting
  - The supply voltage shall not exceed 24 V or alternatively have double insulation Class II of protection intrinsic in anticipation of indirect contact.
  - It will have insulated handle, protective housing of the bulb with Shock capacity and supporting element.

1.5.2 Provisional water installation

The internal distribution of work may be performed with flexible PVC pipe with tethers distribution and galvanized or copper rod, sized according to the Basic Construction Standards relating to plumbing in the consumption points, all ensuring complete sealing and insulating dielectric in the necessary areas.

1.5.3 Installation of sanitation

Since the beginning of the work temporary facilities will be connected to the public sewerage system construction which will produce waste water discharges.
1.5.4 Other facilities. Fire prevention and protection

Below are the precautions to be taken regarding fuels (solids, liquids, gases, vapors, dust), after cleaning the area and additional extinguishing media, monitoring and ventilation are indicated.

Universal precautions for prevention and fire protection shall be:

- The electrical installation shall be in accordance with that established in Section MIBT 026 existing Low Voltage Electrotechnical Regulations for local risk of fire or explosion.
- The presence of flammable products in the workplace shall be the quantities strictly necessary for the production process the scheduled stops. The rest is stored in the facilities of work, and if this is not possible will be done in isolated and conditioned enclosures. In any case, local and isolated enclosures shall meet the specified in the “MIE- APQ- 001 Storage of flammable and combustible liquids “Technical Standard Regulations on Handling of Chemicals.
- Airtight containers and non-combustible containers in which they will have to deposit flammable waste, scraps, etc. will be installed.
- Anti-backfire on the blower hoses or gas welding equipment valves are placed.
- The storage and use of liquefied gases shall comply with what is set at MIE current instruction pressure regulation devices in rule 9, paragraphs 3 and 4 in that relating to storage, use, and service startup particular conditions of flammable gases.
- The evacuation roads will be free of obstacles. There will be a signage indicating smoking places banned and extinguishers location, evacuation roads, etc.
- Inflammable items must be clearly separated from combustible materials, and they must avoid any contact with electrical circuits and equipment.
- The equipment, fixed and mobile, powered by electricity, must have good electrical connections and fixed sites, which shall be provide insulation on earth. All drips, and waste generated during the work must be regularly removed, leaving the space clean daily around the machines.
- The fuel transfer operations must be carried out with good ventilation, outside the influence of sparks and ignition sources. It must be anticipated the consequences of potential spills during any operation, avoiding dirt and sand.
- The prohibition of smoking or lighting any flame has to be part of the action to take on these jobs.
- Where combustible liquids or deposits are being moved the motors must be stopped.
- When racing or holes to allow the passage of pipes are made, they must be sealed quickly to prevent the passage of smoke or flame in an area of a building to another, avoiding the spread of fire. If these holes are formed in fire walls or ceilings, said sealing will be done immediately and with products that ensure sealing against smoke, heat and flames.
- In the situations described above (warehouses, machinery, fixed or mobile, decanting fuel assembly power facilities) and on those in which an ignition source is handled, it is necessary to place extinguishers whose load capacity is in line with nature fuel volume and material as well as sand and soil where flammable liquids are used, with the tool itself to extend it. In case large amounts of stockpiles, storage or packaging concentration, must be provided protection irrigation hoses that provide plenty of water.
Location and distribution of fire extinguishers in the work

The basic principles for the location of fire extinguishers are:

- The hand extinguishers are placed indicated on vertical supports fixed to walls or pillars, so that the top of the extinguisher remains at most 1.70 m from the floor.
- In areas with potential for fires “A”, the distance traveled horizontally, from any point until the nearest extinguisher shall not exceed 25 m.
- In areas with potential for fires “B”, the distance traveled horizontally, from any point until the nearest extinguisher shall not exceed 15 m.
- The portable extinguishers will be placed at the points where it is deemed that there is a greater likelihood of cause a fire, if possible, near exits and always in easy visibility and access. In large venues or when there are obstacles that impede its location is conveniently signaling its location.

1.6 HEALTH SERVICES AND FACILITIES STAFF

Preliminary project facilities are tailored to the characteristics specified in Annex IV of RD 1627-1697 and R. D. 486/97 of 24 October, on the MINIMUM SAFETY AND HEALTH IN THE CONSTRUCTION SITE.

1.6.1 Toilets

- Toilets: 1 toilet / 10 people

- Cabins evacuation: You have to install a walk-in 1.5 m² x 2.3 m high, equipped with squatters, at least for every 25 people.

- Local Showers: It will have a shower for every 10 workers, minimum dimensions of 1.5 m² x 2.3 m high, equipped with hot-cold water with non-slip floor.

1.6.2 Dressing

2 m² / hired worker.

1.6.3 Dining room

For calculation purposes shall be considered an area between 1.5 - 2 m² per worker who eats at work.

Equipped with long bench or chairs near a supply of water (1 sink for every 10 people), means for heating meals (1 micro wave for every 10 people), and bins (60 l capacity with lid) to deposit garbage.
1.6.4 Rest area

In those works that simultaneously work more than 50 workers for more than 3 months, it is recommended that a room used exclusively for the rest of the staff would be established, located as close as possible to the dining and services.

1.6.5 Area for the assistance of the injured

In those workplaces where there are simultaneously more than 50 workers for more than a month, an area for the injured will be provided. Local first aid provide at least:

- A first aid kit.
- A stretcher.
- A source of drinking water.

The material and first-aid rooms must be clearly marked and located near the works.

The floor and walls of the room to assist injured should be waterproof, preferably painted in bright colors. Shall be available the box address and phone of the nearest health centers, ambulances and firefighters.

In the works in which the simultaneous occupancy level is between 25 and 50 workers, local assistance to injured may be replaced by a medicine cabinet located in the site office. The cabinet kit, guarded by the lifeguard of the work, shall be provided with at least: alcohol, hydrogen peroxide, antiseptic ointment, gauze, bandages of different health dimensions, compressive elastic bandages self adhesive, tape, bandages, antiseptic mercurochrome or equivalent analgesics, bicarbonate, ointment for insect bites, burn ointment, scissors, tweezers, portable eye shower, clinical thermometer, box of sterile gloves and tourniquet.

For smaller contracts, may be sufficient to have a pocket kit, guarded by the manager.

The Contractor shall establish additional material and human resources to carry out the Health Surveillance according to the provisions of Law 31 /95.

In addition, there will be a portable kit containing the following:

- Approved disinfectants and antiseptics.
- Sterile gauze.
- Cotton wool.
- Bandages.
- Tape.
- Adhesive dressings.
- Scissors.
- Tweezers.
- Single-use gloves.

The first aid equipment shall be reviewed periodically and replenished immediately if the material is used or expired.
1.7 AUXILIAR AREAS

1.7.1 Central and plants

They will be strategically placed according to the needs of the work. In transit vehicles to access much care should be taken in relation to the order, markings and signage, with a minimum zone width of 6 m rolling gantry gauge height limitation, minimum of 4 m.

Access to the facility remains restricted exclusively to personnel required for its operation and shall be expressly marked out, signposted and prohibited the presence of any person in the turning radius of the perimeter. All entrances or walkways located above 2 m above the ground or lower level platform heights will provide regulatory handrail of 1 m high.

Mobile elements and transmissions will be screened in the areas of work which may enable step entrapments or otherwise will be found clearly marked. The horizontal gaps are shall be avoid and, if not possible as in the case of the skip pit, will be available regulatory side rails 1 m high and stop for rolling vehicles.

The cement silos will not be airtight, to avoid the effect of pressure. The silo receipt is doomed with solid or slatted metal reattached. The cover shall have regulatory perimeter railing 1 m in height. Access via stairs shall be protected by metal rings (Ø 0.80 m) from 2 m to the start.

The electrical installation shall comply with the specifications of the Low Voltage Electro technical Regulations.

The preventive maintenance is performed in accordance with the instructions of the manufacturer or importer.

1.7.2 Workshops

They will be strategically placed according to the needs of the work.

Generally the premises for workshops will have the following minimum dimensions (not counting the space occupied by machinery, apparatus, equipment and / or materials): 3 m in height, 2 m² and 10 m³ volume per worker.

The movement of personnel and materials will be sorted very carefully marked out and signposted, with a minimum zone width independent of passage of personnel (no charge) to 1.20 m² main corridors (1 m in side) of pathways for mechanical handling of materials.

In traffic areas, the gap between machinery and / or equipment will never be less than 0.80 m (counted from the foremost point of the route from the nearest mobile element).

Around the radiant heat generator equipment, a clearance of not less than 1.50 m shall be maintained, shall be shielded and provide portable extinguishing devices. Provisional fixtures suspended over walkways will be channeled to a minimum height of 1.90 m above the pavement.
The minimum illumination intensity, at places of operation of machinery and equipment shall be 200 lux. Emergency lighting will be able to maintain at least an hour, an intensity of 5 lux and its power source shall be independent of the normal lighting system.

Access to the different workshops must remain restricted only to personnel assigned to each of them and shall be expressly marked out, signposted and prohibited the presence of everyone in a radius of action of suspended loads, as well as the travel and easements of machinery and/or equipment. All entrances or walkways located 2 m above the ground or lower level platform heights shall provide a regulatory handrail of 1m high.

Mobile elements and transmissions will be screened in the areas subjected to possible entrapment step or failing will be found clearly marked.

The electrical installation shall comply with the specifications of the Low Voltage Electrical Regulations.

The preventive maintenance of machinery shall be made in accordance with the manufacturers or importer.

The emissions of dust, fibers, smokes, gases, vapors or mists, provide local exhaust and as far as possible, shall be avoided its diffusion through the atmosphere. In closed workshops, provision of clean fresh air per hour of at least 30 to 50 m$^3$ will be provided, unless a complete renewal of air several times an hour (not less than 10 times) is made.

1.7.2 Storage rooms

The materials stored at the site, will have to be included among the "minimum-maximum" values, as proper planning, to prevent parking of materials and/or equipment that may be inactive.

Temporary warehousing zones are marked, signposted and adequately lighted.

Generally work staff (both their own and outsourced) have received adequate training on the principles of manual handling of materials. More singularized way responsible for maneuvering mechanically, qualified workers shall have developed their roles and responsibilities during training maneuvers.

1.8 WASTE

The Contractor is responsible for the management of leftovers of the work in accordance with the guidelines of D. 201/1994, of 26 July, and R. D. 105/2008, of February 1, regulator of demolition and other construction waste, in order to minimize the generation of construction waste. As a result of the forecast of certain aspects of the process, it is necessary to consider both the phase project and in the material execution of the work and/or the demolition or deconstruction.

The waste shall be delivered to an authorized dump, by the Contractor, with its respective costs.
If excavations and emptied land old tanks or pipes appear and which are not detected previously, containing or having been contained toxins and pollutants, they shall be previously emptied and the products of the excavation will be isolated to be evacuated independently of the rest and will be delivered to an authorized agent.

1.9 TREATMENT OF MATERIALS AND / OR HAZARDOUS SUBSTANCES

The Contractor is responsible for ensuring an area of Industrial Hygiene which will provide prevention service control management of possible contaminating effects of waste or materials used in the work, which can generate potentially disease or occupational diseases to workers and / or others exposed to its contact and / or manipulation.

The Counseling of Industrial Hygiene include the identification, quantification, assessment and proposals for solution of environmental, physical, chemical and biological materials and / or hazardous substances, to be compatible with the adaptability of most (almost all) workers and / or third parties exposed. For the purposes of this project, the measurement parameters will be set by setting the Threshold Limit Values that refer to the pollution levels of physical or chemical agents, under which workers can be exposed without danger for their health. The TLV is expressed with a level of pollution for the average time of 8 h / day and 40 h / week.

1.9.1 Manipulation

Depending on the pollutant, its TLV exposure levels and the possible routes of entry to the human body, the Contractor shall at its Health and Safety Plan provide corrective measures to establish acceptable conditions of work for exposed workers and staff so singular to:

- Asbestos.
- Lead, Chromium, Mercury, Nickel.
- Silica.
- Vinyl.
- Urea formaldehyde.
- Cement.
- Noise.
- Radiation.
- Thyrotrophic products (betonies).
- Paints, solvents, hydrocarbons, glue, epoxy resins, fats, oils.
- Liquefied petroleum gas.
- Low levels of breathable oxygen.
- Animals.
- Habitual drug environment.

1.9.2 Delimitation / Conditioning tank areas

Substances and / or preparations will be received in the work labeled clearly, indelibly and at least with text in English language.
The label must contain:

a. Designation of the substance in accordance with applicable law or otherwise IUPAC nomenclature. If a preparation, the name or business name.
b. Common name, if applicable.
c. Concentration of the substance, if necessary. If it is a mixture, the chemical name of the substances present.
d. Name, address and telephone number of the manufacturer, importer or supplier of the substance or dangerous preparation.
e. Pictograms and warning indicators in accordance with current legislation.
f. Specific risks in accordance with current legislation
g. Precautionary statements in accordance with applicable law.
h. The EC number, if any.
i. The nominal amount of content (for mixtures).

The manufacturer, importer or distributor will have to provide to the Contractor, the material safety data sheet and / or dangerous substance before or at the time of the first delivery.

The basic conditions of storage, stacking and handling of these materials and / or hazardous substances shall be properly assessed in the Contractor Safety Plan, based on the following premises:

- Explosives

  Storage shall be in powder kegs that meet the requirements of laws and regulations. Shall be properly marked the presence of explosives and the smoking will be banned.

- Oxidizers, extremely flammable and highly flammable

  Storage in a well ventilated area. Shall be properly marked the presence of oxidizing and the smoking will be banned.

  Be separated from flammable oxidizing products.

  The nearest possible point of ignition is sufficiently far from the stacking area.

- Toxic, very toxic, harmful, carcinogenic, mutagenic products

  Shall be properly marked their presence and shall have adequate ventilation.

  It should be handled with appropriate personal and protective equipment to ensure the security of the user.

- Corrosives, Irritants, sensitizers

  Shall be properly marked their presence.

  It shall be handled with appropriate personal and protective equipment (especially gloves, goggles and breathing mask) to ensure the safety of the user, in anticipation of contact with skin and mucous membranes of the respiratory tract.
1.10 SYSTEMS AND / OR SAFETY ITEMS RELATED TO HEALTH INHERENTS OR INCORPORATED TO THE BUILDING PROCESS

All construction project or equipment design, auxiliary means or machine tools used in the work integrated into the construction process are covered by this Health and Safety Study, and it will be always in accordance with the "Principles of Preventive Action" (Art. L. 15 31/1995 of 8 November), the "Applicable during the execution of the Works Principles" (Art. 10 RD. 1627/1997 of 24 October) "general safety rules for machines" (Art.18 RD. 1495/1986 of 26 May), and Basic Construction Standards, among other related regulations, and meeting the standards of Building Technology, Technical Instructions and UNE Standards or European Standards, mandatory and / or recommended application.

1.11 ENVIRONMENT WORK

1.11.1 Lighting

Although the generality of the construction work is done with natural light should be present in the Health and Safety Plan some considerations regarding the use of artificial lighting required in pits, workshops, night work or underground.

Shall be ensured that the light intensity in each work area is uniform, avoiding reflections and abrupt changes in intensity.

Stored substances in dangerous environments will be flameproof of electric lighting.

In workplaces where a failure of the normal lighting endangers workers, there will be a lighting emergency evacuation and safety.

The minimum intensities of artificial lighting for different works related to construction, shall be:

- 25-50 lux: In courtyards, galleries and places of passage according to their occasional use.
- 100 lux: Operations in which the distinction of details is not essential, such as bulk material handling, stacking materials or mixing of hydraulic binders. Low visual requirements.
- 100 lux: When a high distinction of detail is not required, such as work in engine rooms, boiler, elevators, warehouses, dressing and personal hygiene local small dimensions. Low visual requirements.
- 200 lux: If moderate distinction details such as assemblies in simple workbenches work in machine work, flooring and plastering of mechanical seals is essential. Moderate visual demands.
- 300 lux: Average distinction of details like work order means workbenches or work machines and general office whenever essential.
500 lux: Transactions in which an average distinction of details, such as medium duty workbenches order or machines and general office work needed. High visual demands

1000 lux: In works where a accurate distinction of detail is necessary under constant contrast for long periods of time like delicate assemblies, fine work on workbenches or machines, office machines and linear technical or artistic drawing. Very high visual demands.

Prevention services will be responsible for estimating the magnitude or level of risk, the situations in which it occurs, and periodically monitor conditions, the organization of the working methods and health of workers in order to take decisions to eliminate, control or reduce risk through prevention at source, organizational, collective prevention, personal protective equipment, training and information.

1112 Noise

To facilitate its development, the Health and Safety Plan of the Contractor shows a table about the generated noise levels usually in the construction industry:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Noise Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>82-94 dB</td>
</tr>
<tr>
<td>Pile-driving equipment (a 15 m distance)</td>
<td>82 dB</td>
</tr>
<tr>
<td>Concrete small &lt; 500 lts,</td>
<td>72 dB</td>
</tr>
<tr>
<td>Concrete median &gt; 500 lts</td>
<td>60 dB</td>
</tr>
<tr>
<td>Jackhammer (in confined space)</td>
<td>103 dB</td>
</tr>
<tr>
<td>Jackhammer (outdoor)</td>
<td>94 dB</td>
</tr>
<tr>
<td>Grinding standing</td>
<td>60-75 dB</td>
</tr>
<tr>
<td>Trucks and dumpers</td>
<td>80 dB</td>
</tr>
<tr>
<td>Excavator</td>
<td>95 dB</td>
</tr>
<tr>
<td>Freestanding Crane</td>
<td>90 dB</td>
</tr>
<tr>
<td>Jackhammer</td>
<td>110 dB</td>
</tr>
<tr>
<td>Scraper</td>
<td>105 dB</td>
</tr>
<tr>
<td>Crawler Tractor</td>
<td>100 dB</td>
</tr>
<tr>
<td>Crawler Loader</td>
<td>95-100 dB</td>
</tr>
<tr>
<td>Loader tires</td>
<td>84-90 dB</td>
</tr>
<tr>
<td>Impact Guns nails fixed</td>
<td>150 dB</td>
</tr>
<tr>
<td>Portable radial Grinding</td>
<td>105 dB</td>
</tr>
<tr>
<td>Wood cutting machine table</td>
<td>105 dB</td>
</tr>
</tbody>
</table>

Measures to be adopted, which must be adequately covered in the Health and Safety Plan by the contractor, for the prevention of risks caused by noise are, in order of effectiveness:

1. Elimination of the risk at source.
2. Isolation of the sound part.
3. Individual Protection Equipment (IPE) by earplugs or earmuffs.

Prevention services will be responsible for estimating the magnitude or level of risk, the situations in which it occurs, and periodically monitor conditions, the organization of the working methods and health of workers in order to take decisions to eliminate, control or reduce risk through prevention at source, organizational, collective prevention, personal protective equipment, training and information.
decisions to eliminate, control or reduce risk through prevention at source, organizational, collective prevention, personal protective equipment, training and information.

1.11.3 Dust

The permanence of workers in dusty environments can cause the following conditions:

- Rhinitis.
- Bronchial asthma.
- Bronchitis.
- Chronic bronchitis.
- Pulmonary emphysema.
- Pneumoconiosis.
- Asbestosis (asbestos - cement - asbestos).
- Lung Cancer (asbestos - cement - asbestos).
- Mesothelioma (asbestos - cement - asbestos).

The pathology will be one kind or another, depending on the nature of the powder concentration and exposure time.

In construction is often the existence of dust containing free silica (SiO2) which is the component that makes it particularly harmful, to cause pneumoconiosis. The problem of massive presence of asbestos fibers in suspension, need a specific plan of removal exceeding the powers of this Health and Safety Study, which must be done by specialized companies.

The maximum permissible concentration of dust in an environment, to which workers are exposed for 8 hours per day, 5 days a week, is based on the content of silica in suspension, which is given by the formula:

\[
10 \frac{C}{\% \text{ SiO}_2 + 2} \text{ mg/m}^3
\]

Taking into account that the collected sample will respond to so-called "breathable fraction", which corresponds to the powder actually inhaled, and that existing in the environment, larger particles are retained by the pituitary and finer are expelled with the breathed air without lungs have noticed.

The work in which usual dust production is primarily:

- Sweeping and cleaning services.
- Management rubble.
- Wrecking.
- Drilling work.
- Manipulation of concrete.
- Sandblasting.
- Cutting ceramic and lithic materials with chainsaw.
- Dust and sawdust due to mechanical wood cutting.
- Grinding materials.
- Dust and smoke metal particles suspended in welding.
- Crushing and sorting plants.
- Earthworks.
- Movement of vehicles.
- Polished surfaces.
- Asphalt plants.

In addition to the required personal protective equipment such as masks and goggles dust will necessary take into account the following preventive measures:

<table>
<thead>
<tr>
<th>PREVENTIVE ACTIVITY</th>
<th>MEASURE ACTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning of facilities</td>
<td>Using vacuum and washed down prior</td>
</tr>
<tr>
<td>Debris Management</td>
<td>Watered prior</td>
</tr>
<tr>
<td>Wrecking</td>
<td>Watered prior</td>
</tr>
<tr>
<td>Drilling</td>
<td>Impounding cars located in the drilling of injection water.</td>
</tr>
<tr>
<td>Concrete manipulation</td>
<td>Filters in silos or confined facilities.</td>
</tr>
<tr>
<td>Sandblasting or granulated</td>
<td>Equipment semi-independent breathing</td>
</tr>
<tr>
<td>Cutting or polishing of ceramic or stone materials.</td>
<td>Adding water mist about the cutting area.</td>
</tr>
<tr>
<td>Wood work and electric welding</td>
<td>Localized suction</td>
</tr>
<tr>
<td>Movement of vehicles</td>
<td>Watered track</td>
</tr>
<tr>
<td>Plants milling and asphalt plants</td>
<td>Localized suction</td>
</tr>
</tbody>
</table>

Prevention services will be responsible for estimating the magnitude or level of risk, the situations in which it occurs, and periodically monitor conditions, the organization of the working methods and health of workers in order to take decisions to eliminate, control or reduce risk through prevention at source, organizational, collective prevention, personal protective equipment, training and information.

1.11.4 Housekeeping

The Health and Safety Plan shall include the basic housekeeping activities in the realization of this project, especially with regard to:

1 - Removing objects and unnecessary things.
2 - Sifting of necessary things in their respective stacking places.
3 - Internal standardization work of various types of vessels and platforms transport of bulk materials. Internal Plan for work maintenance.
4 - Locating downspouts of debris and stacking containers for waste and utilization. Evaluation plan of debris.
5 - Cleaning nails and remains of formwork.
6 - Avoidance of walkways, cables, hoses, strips and scrap material. Sufficient lighting.
7 - Removal of equipment and fittings, just resting on surfaces for interim support.
8 - Drainage discharges in the form of fuel or grease puddles.
9 - Marking of the punctual specific risks due to lack of housekeeping.
10 - Daily maintenance of conditions of order and cleanliness. Maid Brigade.
11 - Required information and the unions or the different participants in the direct and indirect jobs for each item included in the project with regard to the maintenance of order and cleanliness inherent in the operation on training.

At points of radiation, the consultant should identify possible jobs which they can give this type of radiation and indicate the protective measures to take.

1.11.5 Non-ionizing radiation

Non-ionizing radiation is that whose wavelength is between 10 and 10 cm, 6 cm, approximately.

Do not normally cause separation of the electrons of the atoms of which they are part, but no longer dangerous. Include: Ultraviolet (UV), infrared (IR), laser, microwave, ultrasound and radio frequency.

Non-ionizing radiation are those regions of the electromagnetic spectrum where the energy of the emitted photons is insufficient. It is considered that the lower wavelength limit for these non-ionizing radiation is 100 nm (nanometer) included in this category are those commonly known as infrared, visible and ultraviolet bands regions.

Most frequent and intensely subjected to these risks workers are welders, especially those welds.

Infrared radiation

This type of radiation is rapidly absorbed by the superficial tissues, producing a heating effect. In the case of the eyes, the heat absorbed by the lens and not readily dispersed, may cause cataracts. This type of injury is considered more likely in occupational disease blacksmiths, glass blowers and furnace operators.

All sources of intense IR radiation must be equipped with protection systems, as close to the source as possible, for maximum heat absorption and prevent radiation entering the eyes of the workers. For use standard goggles, must be properly increased lighting enclosure, so that the dilation of the pupil of the eye is avoided.

In construction, workers who are more frequently exposed to these radiations are welders, especially when performing electric welding. Also, consider the work environment as a possible source of radiation.
The primary response to these removals type thermal energy is mainly affecting the skin as: acute burns, increased dilation of blood vessels and increased pigmentation may be persistent.

Generally, all those industrial processes carried out in hot to the point of releasing light, generate these types of radiation.

Visible radiation

The most important affected organ is the eye, being these wavelengths transmitted through the ocular media without appreciable absorption before reaching the retina.

Ultraviolet radiation

The UV radiation is one that has a wavelength between 400 nm (nanometer) and 10nm. Is included in the sunlight, and artificially generated for many purposes in industries, laboratories and hospitals. Is conventionally divided into three regions:

UVA: 315 - 400 nm of wavelength
UVB: 280 - 315 nm of wavelength
UVC: 200 - 280 nm of wavelength

The radiation in the UVA, the nearest UV spectrum region is widely used in industry and poses little risk; however the UVB and UVC radiation are more dangerous. The U.S. standard is complete and is accepted by the WHO (World Health Organization).

Radiation in the UVB and UVC regions have biological effects that vary strongly with wavelength, with maximum around 270 nm (the quartz lamp with mercury vapor at low pressure has an emission at approximately 254 nm). Also vary with the time of exposure and the intensity of the radiation. The radiant exposure of unprotected eyes or skin, for a period of eight hours must be limited.

Protection from exposure to a strong source may constitute risks should be carried out by combining organizational measures of shields or guards and personal protection. Not to mention that you should try replacing the dangerous by involving little or no risk, according to the Law on Prevention of Occupational Risks.

It should place special emphasis on cable and replacement measures, to minimize the third, which implies the need for personal protection. All users of UV radiation generating equipment should be fully aware of the nature of the risks involved. On the computer, or near it, warning signs should be provided appropriate to the case. Limiting access to the installation, the user's distance from the source and limiting exposure time, are organizational measures to consider.

UV radiation cannot be issued indiscriminately in the workplace. The work must be carried out, for example, in a confined enclosure or in a protected area. Within the protected area should be reduced the intensity of the reflected radiation, using matt black paint. For strong sources, where it can be suspected that an exposure above the permissible limit possible should be means of protection and make it impossible to hinder free radiant flux, direct and reflected. Where the nature of the work requires the user to operate with a source of unprotected UV radiation should be use of personal protective equipment. The eyes are protected by goggles or face shield, so that the
radiation is absorbed impinge on them. Similarly, they will protect your hands using cotton gloves, and face, using any type of facial protection.

Exposure of unprotected eyes and skin to UV radiation can lead to tissue inflammation, temporary or prolonged, with varying risks. In the case of the skin may lead to similar to a sunburn erythematic and, in the case of eyes, conjunctivitis and keratinize one (or inflammation of the cornea), with unpredictable results.

The source is basically the sun but also in industrial construction activities: fluorescent, incandescent and gas discharge lights, welding operations (TIG, MIG), blower electric arc and laser.

Control measures to prevent undue exposures to non-ionizing radiation are focused on the use of screens, shields and personal protective equipment (for example, welding screen viewer with photosensitive cell), trying to maintain appropriate distances (taking into account the effect inversely proportional to the square of the distance) to reduce the intensity of the radiant energy emitted from sources that propagate in different wavelength.

Laser

The mission of a laser is to produce a beam of high density and has been used in diverse fields such as surgery, topography or communication. Units with continuous or pulsed radiation, both visible and invisible force was built. Such units, if sufficiently strong, can harm the skin and in particular, whether the eyes are exposed to radiation. The high energy pulse unit is particularly dangerous when the short pulse of radiation hits causing widespread tissue damage there around. Continuous wave lasers can also cause damage to the eyes and skin. The V-IR and present danger to the retina in the form of burns, the UV and IR radiation can pose a risk to the cornea and lens. In general, the skin is less sensitive to the laser radiation and in the case of units V and IR radiation of major powers can cause burns.

Lasers have been classified according to the risks associated with their use, in the two groups and four following classes:

j)  Group A: intrinsically safe units and those that fall into classes I and II.
    • Class I: the maximum permissible exposure levels can not be exceeded.
    • Class II: low-risk, limited to 1 mW emission in less than 0.25 s, between 400 nm and 700 nm, risks are prevented by diverting the reflected radiation including scintillation response.

k)  Group B: all lasers present or continuous wave with a power greater than 1 mW, as defined by the IIIa, IIIb and IV classes respectively.
    • Class IIIa: low risk, limited issue to 5 times the amount of the class II, use of optical instruments can be dangerous.
    • Class IIIb: medium risk, greater emission limit, the impact on the eye can be dangerous, but not with respect to the diffuse reflection.
    • Class IV: high risk, higher emission limit, the impact of diffuse reflection can be dangerous, can cause fire and burn the skin. The degree of protection required depends on the wavelength and the energy emitted by radiation. Any basic unit must be designed
accordance with appropriate security measures, such as: boxing protector, plug issue, automatic transmission signal, etc

Lasers may produce visible light (400-700 nm), a UV radiation (200-400 nm), or commonly IR radiation (700 nm - 1 m).

Then a guide specific risk associated with laser units is presented below:

a) With laser IIIa (<5 mW) class, be only prevent direct viewing of the beam.
b) With Class IIIb and power between 5 mW and 500 mW, we must prevent the impact of direct radiation and specular reflection in the eyes unprotected, which can be dangerous.
c) With laser class IV and higher than 500 mW powers should prevent the impact of direct radiation, secondary reflections and diffuse reflections, which can be dangerous. In addition to the risks associated with this type of radiation, must be taken into account due to the units of electricity used to power the laser equipment. Then a code of practice that covers personal, workspace, equipment and operation, respectively, in the use of lasers is given.

All users must undergo periodic ophthalmologic examination, with special emphasis on the condition of the retina. People working with class IIIb and IV, have both a medical examination inspection skin damage.

d) With priority to any approval, the contractor shall ensure that licensed operators are properly trained both in safe working procedures and knowledge of the potential risks associated with radiation and equipment that generates it.
e) Any accidental exposure impact involving eyes should be recorded and reported to the health department.
f) The practice of group B laser requires general measure of eye protection, but will never be used for direct viewing of the beam.

- **Workspace:**

  a) The laser equipment is installed in a properly controlled area or enclosure. The lighting of the enclosure should be avoided so that the dilation of the pupil of the eye thus reducing the possibility of damage.
  b) The reflected laser beam can be as dangerous as direct, so it should be removed and polished reflective surfaces.
  c) In the work area should periodically investigate the presence of any toxic gas that may be generated during operation, such as ozone.
  d) Illuminated warning signs should be placed in all areas of entry to the premises in operating lasers. When the signal is in action access to it should be prohibited. Team of the laser power supply has to have special protection.
  e) When and where necessary, the possibility must be prevented beam deflection outside the control area through protection and shielding. In the case of IR radiation, no combustible materials should be used to provide these physical barriers around the laser. In these cases, the vicinity of flammable or explosive materials be avoided

- **Equipment:**
a) All maintenance operations must be carried out only if the power is disconnected.

b) All lasers must have warning labels that take into account the laser class and corresponds to what type of visible or invisible radiation generated by the device.

c) When equipment belonging to group B are not used, they must remove the ignition control keys as well as the force control, which will be guarded by the authorized person responsible for working with lasers in the lab.

d) Standard safety glasses should be regularly tested and selected according to the wavelength of the radiation emitted by the laser in use.

e) Any screen protector is used, must be of absorbent material that prevents secular reflection.

- Operation:

  a) Only be found within the control area the minimum number of people required in the operation, however, in the case of Class IV laser, at least two people will always be present during the operation.

  b) Only authorized personnel will be allowed to assemble, adjust and operate the laser equipment.

  c) The laser equipment shall operate the minimum time required to perform the work and should not run it without being watched.

  d) As a method of general protection goggles to prevent eye damage risk should be used.

  e) The laser equipment must be mounted at a height never exceeds the corresponding operator of the chest.

  f) Special care must be taken with invisible laser radiation, the use of a protective shell along the entire path is essential.

  g) Since the laser pulse are at increased operator risk, to guide beam alignment, laser must be employed in low power helium or neon are in Class II, and never settle for only a rough indication of the take the beam direction. In these cases, you should always be used eye protection.

Prevention services will be responsible for estimating the magnitude or level of risk, the situations in which it occurs, and periodically monitor conditions, the organization of the working methods and health of workers in order to take decisions to eliminate, control or reduce risk through prevention at source, organizational, collective prevention, personal protective equipment, training and information.

In building used to be used in establishing a monograph alignments and topographic levels.

For his extreme danger, when the laser is focused parallel to the ground, the area should be cordoned off danger. The Personal Protective Equipment against lasers is full protective glasses and visor fitted the correct filter type of laser in question.
1.11.6 Ionizing radiation

Exist within the field of building own very few jobs where such risks are generated, although there are situations where you can give this type of radiation, such as:

- Detection of weld defects or cracks in pipes, structures and buildings.
- Density Control "in situ" by the nuclear method.
- Irregularities control the filling level of containers or reservoirs.
- Paths identification using hydraulic currents tracers, sediment, etc.

Shall be the duty of the contractor with the collaboration of service prevention; determine safe working procedure for such operations.

You can also consider a possible risk generation work done within an environment or in proximity of certain facilities, such as:

- Facilities where tests are carried suitcases and packages at airports, bomb detection cards.
- Medical facilities where therapy practices are carried by ionizing radiation.
- Medical facilities where diagnostic practices are carried out with X -rays whose potential for equipment operation by design, is greater than 70 kilovolts .
- Medical facilities where radioactive material handling or question in the form of unsealed sources for use in therapy or diagnosis techniques "in situ" .
- Industrial facilities where concerned or handle radioactive material.
- Particle accelerators research or industrial use.
- The facilities and equipment for industrial radiography or spelling range , either through the use of radioactive sources or X-ray emitting equipment
- Radioactive waste deposits, both transients as definitive.
- Facilities where produced, manufactured, repair or maintenance of supplies or equipment generating ionizing radiation is made.
- Control irregularities in the thickness of block paper, plastic sheets and metal sheets or on the filling level of containers or reservoirs.
- Estimation Antique substances, using carbon-14 and other isotopes, such as argon -40 and phosphorus -32.
- Passive lighting, clock or emergency exits.

Radiation protection functions are the responsibility of the owner of the facility , with the Nuclear Safety Council will decide whether they should be assigned a service itself Radiological Protection holder or a Technical Unit Radiation Protection hired thereto .

The reaction of an individual to radiation exposure depends on: the dose, volume and type of tissue irradiated.

Although they can occur in combination, usually a fundamental distinction between two kinds of radiation accidents is done:

a) Accidental external irradiation (eg radiography welding work) .
b) Accidental Radioactive Contamination.
The maximum allowable dose levels were fixed by taking into account that the human body can tolerate a certain amount of radiation without compromising the performance of your body in general. These levels are for people working in Controlled Areas (e.g., containment building of nuclear power plant) and taking into account the cumulative effect of radiation on the body 5 rems per year or 300 millirems per week. To detect and measure levels of radiation, Geiger counters are used.

To control the dose, you should take into account three factors:

a) working time.

b) distance from the radiation source.

c) shielding.

The working time allowed is obtained by dividing the maximum authorized by the dose received at one time dose. The dose received is inversely proportional to the square of the distance from the radiation source. Materials that are commonly used as shielding bars are concrete and lead, although others are also used such as steel, clay solid brick, granite, limestone, etc. Generally necessary thickness is a straightforward function of the bulk density.

To verify radiation doses, individual dosimeters which may consist of a dosimetric film. Whenever you specify otherwise, the individual dosimeter will be in the front pocket or work clothes, taking care not to place dosimeters on any object that can absorb radiation (Ex. metallic objects).

A log book shall be kept, which shall contain the doses received for each of the workers occupationally exposed to radiation.

1.12 MANIPULATION OF THE MATERIALS

Any support material involves a risk, therefore, from the preventive point of view; it should aim to avoid any manipulation that is not strictly necessary, under known security axiom that says "the safer work is the one that is not performed".

To manipulate materials is mandatory to take the following simple precautions:

- Start by loading or material that appears on the surface, which is the first and most accessible.
- Provide material not throw it.
- Place the materials ordered and, in case of stacking it, make stable piles away from corridors or places where it can be hit.
- Use work gloves and safety shoes with steel toe and quilted on instep and ankle.
- In handling long loads between two or more persons, cargo can stay in the hand with the arm stretched along the body, or on the back.
- Appropriate tools and auxiliary means for transporting each type of material shall be used if necessary.
- During the loading and unloading is prohibited to be placed between the back of the truck and a platform, post, pillar or vertical fixed structure.
- If during discharge tools must be used, as lever arms, claws, or the like crowbars, the maneuver must be available so as to ensure that the load does not come up and does not slip.

Regarding the handling of materials, the contractor, while the development of the Health and Safety Plan should take into account the following assumptions:

Try to avoid the manual handling of loads by:

- Automation and mechanization of processes.
- Organizational measures that eliminate or minimize transport.

Preventive measures when you cannot avoid manipulation as:

- Use of mechanical aids.
- Reduction or redesign of the load.
- Acting on work organization.
- Improved working environment.

Provide workers with training and information on topics including:

- Correct use of mechanical aids.
- Correct use of personal protective equipment.
- Safe for cargo handling techniques.
- Information about weight and center of gravity.

The basic principles of materials handling are:

1. The time spent on material handling is directly proportional to the exposure to risk of accidents arising from such activity.
2. Ensure that the different materials as well as the support platform and operator's work, are at the same height to be working with them.
3. Avoid depositing the materials directly over the ground, always pass on buckets or containers that allow transfer in abundance.
4. Shorten as much as possible the distance covered by the material handled, avoiding parking intermediate between the place of departure manipulated material and the final location.
5. Always carry the materials in abundance, by buckets, containers or pallets, instead of taking them one by one.
6. Don't reduce the number of assistants to collect and gather up the materials, if this involves occupy official or team leaders in maintenance operations, overlapping strips of perfectly usable for the advancement of the production time.
7. Maintain clarified, marked and lighted, places of passage of materials to be handled.

Handling loads without mechanical means

For manual lifting of loads the entire site personnel must receive the necessary basic training, promising to take the following steps:

1. As close as possible to the load.
2. Feet firmly Seat.
3. Crouching bending your knees.
4 - Keep your back straight.
5 - Grasp the object firmly.
6 - Effort of lifting loads should be on the leg muscles.
7 - During transport, the load should remain as close as possible to the body.
8 - To manage long pieces for one person will act according to the following preventive criteria:
   h) Maintain the inclined by one end, to the height of the back load.
   i) Moving the hands go forward along the object to the center of gravity of the load.
   j) The burden will be placed on back in balance.
   k) During transport, the load remain in a tilted position, with the front end up.

9 - Visual inspection of lifting heavy object to avoid the sharp edges is mandatory.
10 - Is Forbidden to lift more than 50 kg individually. The limit value is 30 kg for men, can be overcome promptly at 50 Kg when trying to download a material to be placed on a mechanical means of support. In the case of women, these values are reduced to 15 and 25 kg respectively.
11 - Is Compulsory to use a signal code, when is needed to lift an object among several individuals, to support the effort at the same time. It can be any system if it is known or agreed by the team.

### 1.13. COLLECTIVE PROTECTION SYSTEMS (SPC)

For the purposes of this Study of Safety and Health, shall be deemed Collective Protection Systems, the set of associated items, incorporated into the construction system, provisionally adapted to the lack of protection more effectively integrated (MAUP), intended to shield or condone the possibility of coincidence of any energy out of control present in the workplace, with workers, anyone other than the work and / or materials, machinery, equipment or near their area of influence fittings, canceling or reducing the consequences of accidents. Its operation ensures the integrity of the protected persons and objects, without the need for participation to ensure its effectiveness. This last aspect is establishing its difference with Personal Protective Equipment (PPE).

In the absence of approval or certification of preventive effectiveness of all these systems installed, the Contractor shall determine in its Health and Safety Plan, a reference list of Test Protocols, adopted Certificates or Certificates and / or required for installers and manufacturers / or suppliers to the above conglomerate Collective Protection Systems.

Most relevant SPC provided for the implementation of this project are listed in the annex to this report containing the chips RISK ASSESSMENT MEASURES

### 1.14. CONDITIONS OF PERSONAL PROTECTIVE EQUIPMENT (PPE)

For the purposes of this Study of Safety and Health, shall be considered personal protective equipment, those pieces of work that act as a cover or laptop screen, individualized for each user, to reduce the consequences of contact area protected with an energy out of control, less than the expected intensity endurance of PPE body.

Its use should be restricted to the absence of adequate preventive warranties, lack of MAUP, or failing SPC of equivalent effectiveness.
All personal protective equipment shall be properly certified as CE harmonized standards., Always in accordance with RD 1407-1492, and R. D. R.D.159/95 773/97.

The Prime Contractor shall keep a documentary check your individualized delivery personnel (own or subcontracted ) with the corresponding return receipt signed by the recipient .

In cases where there are no official standards approved , the personal protective equipment will be standardized by the manufacturer for use in this work, chosen from those available on the market and meet appropriate quality at the respective facilities . For this internal standardization must have the approval of the technician who monitors compliance with the Health and Safety Plan by the Project Manager or Project Manager.

The store will be permanently at work reserving these protective gear, so you can guarantee delivery to all staff without reasonably produce its lack.

Must be taken into account: the turnover, the life of the equipment and the expiration date , the need to provide them in the site visits , etc. .

Most Relevant PPE intended for the actual execution of this project are listed in the annex to this report containing the chips RISK ASSESSMENT MEASURES

1.15 PREVENTION RESOURCES

The legislation to be met for the presence of preventive resources at construction works is covered by Law 54/2003. According to this law, the presence of preventive resources at construction works is mandatory in the following cases:

1) When the risks may be aggravated or modified in the development process or activity, by the concurrence of several operations carried out successively or simultaneously and make precise control of the correct application of the methods of work. The presence of preventive resources of each contractor shall be required when, during construction, work with special hazards develop, as defined in the Royal Decree 1627/97.

m) When activities or processes that are statutorily considered hazardous or special risks are realized.

n) When the need for such presence is required by the Inspectorate of Works and Social Security, if the circumstances so require due to working conditions detected.

When coexist at construction works contractors and subcontractors, who successively or simultaneously may pose a special risk for interference activities, the presence of the ‘preventive Resources’ is required in such cases.

Preventive resources are required when work progresses at special risk, defined in Annex II of Royal Decree 1627/97:

1) Works with particularly serious risk burial, sinking or falling from a height, the particular characteristics of the activity, the procedures, or the environment of the workplace.

2) Jobs where exposures to chemical or biological agents pose a particularly serious risk, or for which specific health surveillance of workers is legally required.
3) Works with exposure to ionizing radiation for which specific regulations requires the delimitation of controlled or supervised areas.
4) Work in the vicinity of high voltage power lines.
5) Work involving exposure to the risk of drowning.
6) Digging of tunnels, shafts and other work involving underground earth movements.
7) Work in underwater dive team.
8) Work in caissons.
9) Work involving the use of explosives.
10) Work involving the assembly or dismantling of heavy prefabricated elements.

1.16 SIGNALING AND BUOYAGE

Regarding the signaling of work is necessary to distinguish between the terms at which demand attention from workers and that which correspond to the outer traffic affected by the work. In the first case apply the requirements laid down by Royal Decree 485/1997, of 14 April, while signaling and traffic marking are regulated, among other regulations, by the standard 8.3-IC the General Directorate of Roads and is not the subject of the Safety and Health. This distinction does not exclude the possible supplementation of signaling traffic during construction when it becomes chargeable for the safety of employees working in the immediacy of that traffic.

Should be taken into note that the signal itself does not eliminate the risks, but their observation when appropriate and well placed, causes the individual to adopt safer behaviors. Not enough to put a panel on the inputs of works, then if the work itself is not compulsory to use seat belts when placing order for façade cladding covers is signaled. The abundant signaling does not guarantee a good sign, since the worker ends up ignoring any signal.

The RD485/97 signaling states that safety and health at work should always be used to analyze the risks of foreseeable emergency situations and preventive measures, as to reveal the need for:

- Alert workers on the existence of certain risks, prohibitions or obligations.
- Alert workers when a particular emergency situation that requires urgent protection measures or evacuation occurs.
- Provide workers the location and identification of certain media or protection equipment, evacuation, emergency or first aid.
- Orient or guide workers to perform certain dangerous maneuvers.

The signaling shall not considered as an alternative measure of the technical and organizational measures of collective protection and should be used when using the latter has not been possible to eliminate or reduce risks sufficiently.

Neither should it be regarded as a surrogate measure of information and training of workers on safety and health at work.

Also, as stated in the R.D. 1627 to 1697, it must meet:

1. Specific routes and emergency exits must be indicated by signs in accordance with RD 485/97, considering that the signs must be placed at appropriate places and have sufficient strength.
2. Non-automatic firefighting devices shall be signaled in accordance with RD 485/97, considering that the signs must be placed at appropriate places and have sufficient strength.

3. The color used for artificial lighting may not alter or affect the perception of signals or signposts.

4. Transparent doors must have a marking to eye level.

When there are overhead electric power lines, in case that the work vehicles have to move under the laying a warning signal will be used.

Implementation of the signage and marking must be defined in the plans of the Safety and Health consider in the activity statements, at least with respect to the risks that have not been eliminated.

1.17 RISK OF INJURY TO OTHERS AND PROTECTION

1.17.1 Risk of harm to others

The risks that during the implementation stages of the work could affect people or falling objects annexes are:

- Fall on the same level.
- Runover
- Collisions with obstacles on the sidewalk.
- Falling objects.

1.17.2 Measures to protect third parties

The following protective measures are considered to cover the risk of people traveling through the work around:

15. Mounting the metal fence precast two meters (2 m.) High, separating the perimeter of the work of outside traffic areas.

16. For the protection of persons and vehicles traveling through the neighboring streets, consisting of a passage about the signaling structure, which should be bright in the optical and night, to indicate the gauge protections traffic will be installed. Occasionally, may be installed on the perimeter of the façade cantilevered marquee resistant material.

17. If necessary fill the sidewalk during the collection of materials on site, during the unloading maneuver pedestrian traffic inside the passage of pedestrians and vehicles will be channeled outside the areas of impact of the maneuver, with protection metal-based separation of areas and putting night lights gauge and signs to alert vehicles to the hazard bars.

18. Depending on the level of interference in the work of others, you can consider whether to hire a service access control to work, by a patrimonial Monitoring Service, exclusively for this function.
1.18 CATASTROPHIC RISK PREVENTION

The main foreseeable catastrophic risks considered remotely to this work are:
- Fire, explosion and/or explosion.
- Flood.
- Structural collapse failure by maneuvers.
- Seuity Attack on Property and/or contractors.
- Sinking loads or lifting equipment.

To cover the relevant contingencies, the Contractor shall draw up and annexed to its Safety and Health Plan a "Emergency Plan ", in which he explicitly specify the following minimum dimensions:

1. Order and clean up.
2. Access and internal circulation roads of the work.
3. Location of fire extinguishers and other fire extinguishing agents.
4. Appointment and training of the Brigade of First Responders.
5. Meeting Points.
6. First Aid assistance.

1.19 FORECASTS FOR SAFETY AFTER WORK

Forecast and information to make at the time, under proper conditions of health and safety, foreseeable future work (maintenance) shall apply art. 5.6 RD.1627/97.

1.20 SIGNATURES

Carla Comadran Casas

ENGINEER AUTHOR OF THE PROJECT

ENGINEER DIRECTOR OF THE PROJECT