DETAILED EXECUTION DESIGN OF ENFORCEMENT TECHNOLOGY

Multi Lane Free Flow Toll Collection in Indonesia

Feasibility Study Annex

April 2020

1. INTRODUCTION

In order to evaluate whether the Project is competitive and achievable in engineering terms, a certain level of feasibility work has been required.

As an annex of the feasibility study of the Multi Lane Free Flow Toll Collection in Indonesia (Project), this document presents the feasibility study and the engineering requirements and constraints associated with the steel portal frame.

Detailed information about the whole project can be found in:

"Multi Lane Free Flow Toll Collection In Indonesia: Feasibility Study"

The number of the required portals has been defined based on a preliminary demand survey.

A total of 448 portals are required with the following road lane layouts:

- 2 traffic lanes + 1 emergency lane (230 portals)
- 3 traffic lanes + 1 emergency lane (180 portals)
- 4 traffic lanes + 2 emergency lanes (32 portals)
- 5 traffic lanes + 2 emergency lanes (6 portals)

The above listed types and situations should be investigated as part of the feasibility study.

2. APPROACH OF THE FEASIBILITY STUDY

In order to cope with the demands related to the project, the key structural engineering requirements and constraints have to be taken into account during the design of the portal frames.

The main elements of the built infrastructure are broken down into groups, with particular emphasis on the physical implementation and the standards applied during construction.

The mechanical components of the installation consist of two main groups:

- Portal frame (load bearing structure)
- Safety barrier (protective system)

Geometrical constraints are defined by the type of the road, location and natural environment.

Using a pragmatic approach, the feasibility study has been split into the following sections:

Section 3 Applicable standards

Section 4 Portal frame

- Geometrical constraints
- Engineering requirements
- Design issues
- Execution

Section 5 Safety barrier

- General requirements
- Execution
- Local application

Section 6 Concept design

3. APPLICABLE STANDARDS

In close consultation with the local authorities, the applicable standards for the project have been defined. Since the design is of European origin, the design has to be carried out according to the relevant European standards. Nonetheless, harmonization between these and the local standards has to be done; and if required, Indonesian equivalents may also be used.

<u>European harmonized standards; Eurocodes:</u>

EN 1990	Eurocode 0: Basis of structural design
EN 1991	Eurocode 1: Actions on structures
EN 1992	Eurocode 2: Design of concrete structures
EN 1993:	Eurocode 3: Design of steel structures
EN 1997:	Eurocode 7: Geotechnical design
EN 287-1	Qualification test of welders - Fusion welding - Part 1: Steels
EN 1090	Execution of steel structures and aluminium structures
EN 1418	Welding personnel
EN 10080	Steel for the reinforcement of concrete - Weldable reinforcing steel
EN 10219	Cold formed welded structural steel hollow sections
EN ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles
EN ISO 10684	Fasteners - Hot dip galvanized coatings

<u>Hungarian standards:</u>

ÚT 2-1.161	Road restraint systems

4. PORTAL FRAME

4.1. Geometrical constraints

The main geometrical constraint is the road width. One traffic lane is taken as 3.5-3.6 m, and the emergency lane is taken into account with 3.00 m. The safety barriers and the curbs need an additional 0.5 m to 1.5 m, respectively. Considering the 4 road layouts presented in Section 1, leads to the following min. required crown widths:

- 2 traffic lanes + 1 emergency lane w=2x3.5-3.6+1x3.00+2x0.5-1.50 = 11.0-13.2 m
- 3 traffic lanes + 1 emergency lane w=3x3.5-3.6+1x3.00+2x0.5-1.50 = 14.5-16.8 m
- 4 traffic lanes + 2 emergency lanes w=4x3.5-3.6+2x3.00+2x0.5-1.50 = 21.0-23.4 m
- 5 traffic lanes + 2 emergency lanes w=5x3.5-3.6+2x3.00+2x0.5-1.50 = 24.5-26.5 m

Additional distance may be required due to the specifications of the safety barrier or to provide space for other objects.

The constraint regarding the height of the portal frame is defined by the minimal clearance under the frame. On highways/expressways, a min. clearance of 5.1 m has to be provided between the track and the lowest point of the mounted equipment/device.

Other importants parameters, that may vary from location to location:

- Environment
- Geometry of the slopes
- Distance between the two highway directions (enough space for the column?)
- Closeness of the built environment (buildings, bridges etc.)

These contraints are the key elements of defining the layout and geometry of the portal frame.

4.2. Engineering requirements

The structural system has been chosen based on various aspects presented later in this section in order to arrive at an optimal solution. The load bearing structure is a steel portal frame. The portal is made of cold-formed rectangular hollow sections (RHS) welded and galvanized. They are pre-fabricated and constructed with standardized details and on-site bolted connections.

4.2.1. Foundation

The best solution is the shallow pad foundation. The foundation may be made monolithically by on-site concreting or using prefabricated foundation delivered from the prefabrication factory to the site.

When determining the depth of the foundation, in addition to the strength checks, the geotechnically necessary cover height in case of slopes, ditches and cuts in the installation cross-section has to be ensured.

Special attention has to be paid to the exploration of utilities at the installation site. If the foundation to be designed is in the path of a pipeline, it may be necessary to lead through the utility pipeline in a protective pipe or to use a deep foundation method, such as drilled piles or micropiles, instead of a shallow foundation. The foundation is either on the first load bearing layer or on the compacted soil prepared for the pavement. The dimensioning of the foundation can be done on the basis of geotechnical data provided by the field surveys and tests.

The anchors of the steel portal frame columns have to be integrated in the foundation. The wires necessary for the electrical supply of the control structures have to be also led through the foundation, using protective plastic curved and straight pipes.

The foundation has to be made of concrete with waterproof properties.

Min. material concrete and reinforcing steel grades to be used (EN 1992):

- blind concrete:	C10/12-XN (H)-32/F1
- foundation concrete:	C35/45-XC4-XD3-XV2
- reinforcing steel (EN 10080:2005):	B500B

4.2.2. Steel portal frame

The following aspects has to be considered for the design of the steel portal frame:

- the primary function is to provide easy attachment of the equipments/devices and their control system;
- the attachment points and the receiving structural elements of the devices have to be designed taking into account the requirements of the device supplier and installer;
- a clearance of 5.1 m has to be provided between the track and the lowest point of the mounted equipment/device (as it is already defined in Section 4.1).

While fully meeting the strength criteria (load bearing capacity, stability, deformation), further requirements must be met during the design phase, in accordance with certain manufacturing/assembly aspects, such as:

- application of easy-to-get or readily available cross-sections
- optimization and utilization of pre-fabrication
- use of galvanization
- simplifying on-site assembly
- elimination of corrosion centers.

Recommended material grades: S235 JRG2 for flat plates, S355 cold-formed profiles. The use of 8.8 grade bolts is recommended.

The following requirements have to be met related to the main parts of the frame:

- Columns: Prismatic bars made of cold-formed rectangular cross-section according to EN 10219 with hot-rolled base for securing anchors and plate for bolting to the beam. The large holes in the base element also allow the columns to be adjusted horizontally within certain limits. On the web of one of the columns, on the opposite side to the direction of the traffic, receiving elements are provided at the appropriate locations for securing the cover plate for the protective conduits of the electric wires.
- Beams: Prismatic bars made of cold-formed rectangular cross-sections according to EN 10219. The beams are connected to the columns and other beams using end-plate bolted connection. At the lower plane of the beams, plates with drilled holes are welded to the structure to be able to receive the electrical devices to be installed.
- Anchoring elements: S355 JR threaded stud bolts incorporated in the concrete foundation, with washers and counter nuts, providing height adjustability for columns. Unlike all other elements, they are not galvanized; the corrosion protection is solved by greasing.

4.3. Design issues

4.3.1. Loads

The structural design of the structural elements has to be carried out fully in accordance with the relevant standards presented in Section 3.

4.3.1.1. Permanent loads

The weight of the structure can be calculated using the dimensions and densities of the structural elements.

4.3.1.2. Live loads

The weights of the devices can be provided by the supplier of these products. An additional distributed live load should consider further installations in the future.

4.3.1.3. Snow load

Snow loads are not relevant.

4.3.1.4. Wind load

In addition to the permanent and live loads (installation, devices etc.), special care should be taken on the wind load, especially its global and local dynamic effects. The parameters for the wind loads should be obtained from local authorities or from the relevant Indonesian standard.

The wind pressure should be determined assuming a wind base speed of 90 to 126 km/h. Wind loads must be assumed to be evenly distributed on the surface exposed to the wind. Conservatively, the external contour of the portal frame (neglecting the space between the devices) should be used to calculate the wind load.

The planned wind speed, V_{DZ}, must be calculated with the following equation:

$$V_{DZ} = 2.5 \cdot V_0 \cdot \left(\frac{V_{10}}{V_B}\right) ln \left(\frac{Z}{Z_0}\right)$$

where:

V_{DZ} - planned wind speed at plan elevation, Z (km/h);

V_{10} - wind speed at elevation 10 m above ground level (km/h)

V_B - planned wind speed of 90 to 126 km/h at 1 m elevation;

Z - structural elevation is measured from ground level

V_0 - wind friction speed, which is a meteorological characteristic (km/h)

Z_0 - friction height (m).

The direction of the wind plan must be assumed to be horizontal, unless otherwise specified. In the absence of more precise data, the planned wind pressure in kN/m^2 can be determined using the following equation:

$$P_D = P_B \left(\frac{V_{DZ}}{V_B}\right)^2$$

where P_B is the basic wind pressure as determined as follows:

Components	Compressive wind (kN/m^2)	Suction wind (kN/m^2)
Frames, columns and arches	2.4	1.2
Beams	2.4	N/A
Flat surfaces	1.9	N/A

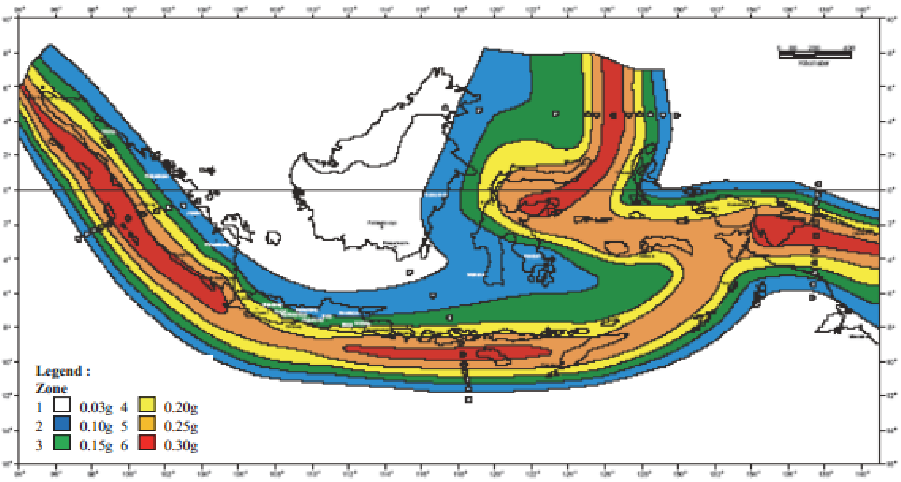
The total force of the wind load must not be taken less than 4.4 kN/m in the compressive plane and 2.2 kN/m in the suction plane in the frame and arch structure, and not less than 4.4 kN/m on the beam or girder.

4.3.1.5. Vehicle Collision

Among accidental loads, impact loads do not have to be taken into consideration, at least not directly, if appropriate safety barriers defined in Section 5 are installed.

4.3.1.6. Eathquake load

The seismic hazard should be determined according to the Indonesian sesmic standard SNI-03-1726-2002, using the seismic hazard map of Indonesia. The return period of the peak base acceleration with 475 years ranging between 0.03 g and 0.30 g is in line with the Eurocode 8 standard, but further check is needed to ensure that the seismic characteristics and the proper shape of the seismic response spectrum are identical or at least are on the safe side. If required, the Indonesian sesmic standard may be used.



Gambar 2.1. Wilayah Gempa Indonesia dengan percepatan puncak batuan dasar dengan perioda ulang 500 tahun

Fig seismic hazard map of Indonesia for return period 475 years, for bedrock condition

4.3.2. Optimization and automatization

Regarding the fact that a great amount of portal frames has to be designed/constructed, optimization and an automated design procedure are required.

The automated design has to consider at least the following parameters:

- Type of the frame (mechanical system)
- Required equipments/intallations (permanent loads)
- Location (wind load, earthquake load)
- Road width (span length of the frame)
- Height of column 1
- Height of column 2
- Soil parameters

This way, the majority of the portals should be designed and optimized. Special cases may be investigated separately.

4.4. Execution

4.4.1. General requirements

Only welders who have a valid qualification in accordance with EN 287-1:2007 may work on the structure. Machine operators has to be certified in accordance with the procedure of EN 1418:2000.

4.4.2. Foundation

Reinforced concrete surfaces exposed to direct corrosion (direct salting, misting, dripping, other aggressive effects, etc.) has to be protected by a B-5 and B-4 protective coating on the whole contact surface to protect it appropriately.

The positioning of prefabricated elements is done controlled by geodesic measurements. The excavation is done by using an excavator creating a slope, and then the earth mirror is manually created, on which 15 cm crushed stone 0/22 bedding is made.

Only fully intact, certified foundation elements can be installed. The horizontal and vertical planes of the built-in elements have to be checked by measurements. On the compacted crushed stone bedding, the axes of the foundation have to be marked, and then the prefabricated block of reinforced concrete is placed on the bedding. The operation is performed under continuous geodesic control. The ends of the lifting tubes are sealed with a plastic plate. The soil is then compacted in 25 cm layers to fill the construction pit and to restore the slope. After the completion of the foundations, a protocol/report has to be made about the height level of the foundation top and the position of the acnhor bolts.

4.4.3. Steel portal frame

The structures are made of S355 quality cold-formed profiles, with on-site bolted connections. The entire structure and the fasteners used for its on-site assembly shall be hot dip galvanized in accordance with EN ISO 1461:2009 and EN ISO 10684. Due to the use of hot-dip galvanizing, on-site welding is forbidden!

Only quality-controlled steel structures may be delivered to the site. Conformity of structural elements shall be ensured in accordance with EN 1090-1:2010, technical requirements of steel structures shall be ensured in accordance with EN 1090-2:2009. The registration, inspection and certification of measuring instruments used in the manufacture have to be specified by the local authorities. Lifting above the carriageway can only be performed with full lane lock. For on-site assembly, large steel structures have to be lifted and moved, therefore, special care should be taken in these situations! The most important safety requirement for easily removable elements/connections is that there should be no loose elements or fasteners anywhere that could pose a risk to the traffic under the structure!

The steel column of the frame has to be equipped with a lightning protection probe.

5. SAFETY BARRIER

5.1. General requirements

The columns of the portal frame have to be protected against vehicle impact.

The relevant parts of the ÚT 2-1 standard have to be used, and a safety barrier system which provides a level of protection higher than that prescribed by the local road traffic administration against collision effects has to be applied. Retention class of the safety barrier has to be specified according to ÚT 2-1.161-Section 4.1.

Generally used retention classes:

- Outer side of the highway/expressway: H1
- Highway/expressway separation lane: H2 (two sided)
- **Highway/expressway – protection for the portal: H2-2 (double row)**
- Adjecent engineering structure: H2-2 (double row)
- Other roads
  - road body heights of 3.00 to 7.00 m: N2
  - road body heights of 7.00 to 12.00 m: H1

Spacing of posts/columns:

- N2: 4.00 m
- H1: 2.00 m
- **H2: 2.00 m**

5.2. Proposed system

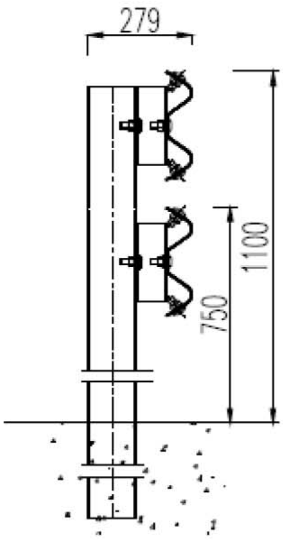
The most widespread safety barrier system in Hungary is that of the DAK Steel Structure Ltd. The development of the system is based not only on the Hungarian, but also on the European standards and experiences. Depending on the degree of protection (retention class), the following barrier types are used:

Típuskód	Megnevezés
DAK-N2S-L	N2 retention class
DAK-H1S	H1 retention class
DAK-H2S-S	H2 retention class – one row
DAK-H2S-L	**H2 retention class – double row**
DAK-H2S-H	H2 retention class – mounted on the curb
DAK-H3S-L	H3 retention class

Based on the previously presented requirements, the DAK-H2S-L system is proposed to be used as the safety barrier of the portal frame.

DAK-H2S-L

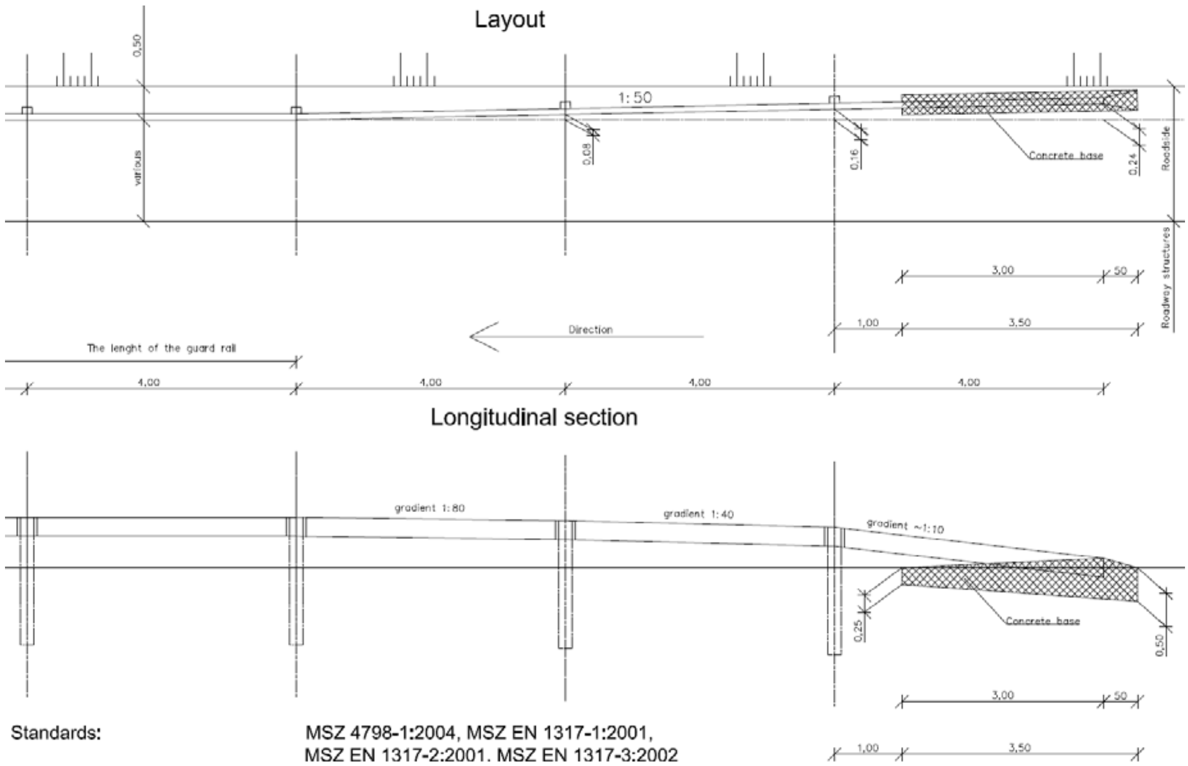
DAK-H2S-L	
Construction form	
Identification mark	DAK-H2S-L
Application	Public road
Execution method	1 side construction
Number railing lines	2 row
Railing height	First row: 750 mm Second row: 1100 mm
Fixing railing	Fixed to the column with deformation element
Columns Distance	2000 mm
Fixing columns	Placed in the ground
Length of column	1900 mm
Starting and closing elements	800 mm closing element + rail element with unique angle End closing element (carp tail)
Steel quality	S235JRG2-MSZ EN10025
Galvanizing	MSZ EN ISO 1461
Test results	
Accident acceleration coefficient	A
Widht of the work	W5



5.3. Execution

The railings are overlapped, so that the front railing element in the direction of the traffic overlaps the following one.

The start and end of the safety barrier have to be led down into the ground on a 12 m transitional length. Anchoring is solved with pre-fabricated steel brackets with a concrete block.



The posts are placed at a minimum depth of 1.05 m in the ground. The post shall be positioned with a vertical and horizontal accuracy of ± 2 cm.

The edge of the safety barrier column shall be at least 0.30 m from the edge of the crown. For distances less than this, the manufacturer's statement of positioning is required. If the width of the existing curb does not meet the above requirement, it is necessary to widen the curb.

During widening, the current mirror surface is dewatered. Compacting is done layer-by-layer in accordance with ÚT 2-1. The incline of the resulting slope is max. 1:1.5. If the slope touches the bottom of the drainage ditch, it must be adjusted and modified. The curb widening is done by machines and/or hand tools. The surface of the new curb has to be mechanically and extra hand-adjusted and then a 15 cm top-soil layer should be be applied.

Optical elements (prisms) have be mounted on the safety barrier every 50 m in prismatic brackets made of galvanized sheet steel. The prisms must be red/white on the right side of the road, and red/red in the separation lane. A one-way junction branch requires a red prism on the left and right sides and a white prism on the back.

5.4. Local application

The presented and proposed safety barrier is quality controlled and tested to have the required retention class according to European and Hungarian standards and regulations.

A thourough investigation should be carried out regarding the applicability of the proposed safety system in Indonesia, in close consultation with local authorities and road operators.

Special attention should be made on the local parameters, such as:

- generally used steel sheets, plates, profiles and material grades
- allowable element sizes due to transport
- retention classes
- traffic volume
- legal and patent issues in case of a foreign product etc.

Nontheless, the proposed system provides guidance of designing safety barriers for steel portal frames installed on highways and expressways.

It should also be mentioned, that a concrete barrier system can be as effective as the presented steel type. If local authorities or investors prefer the concrete version, a solution can be delivered in this case as well! If there is an existing steel/concrete barrier at the installation site, its load bearing capacity and retention class should be determined and compared to the required one. The existing structure can remain, can be reinforced, or worst-case scenario, must be removed and replaced with an adequate new barrier system.

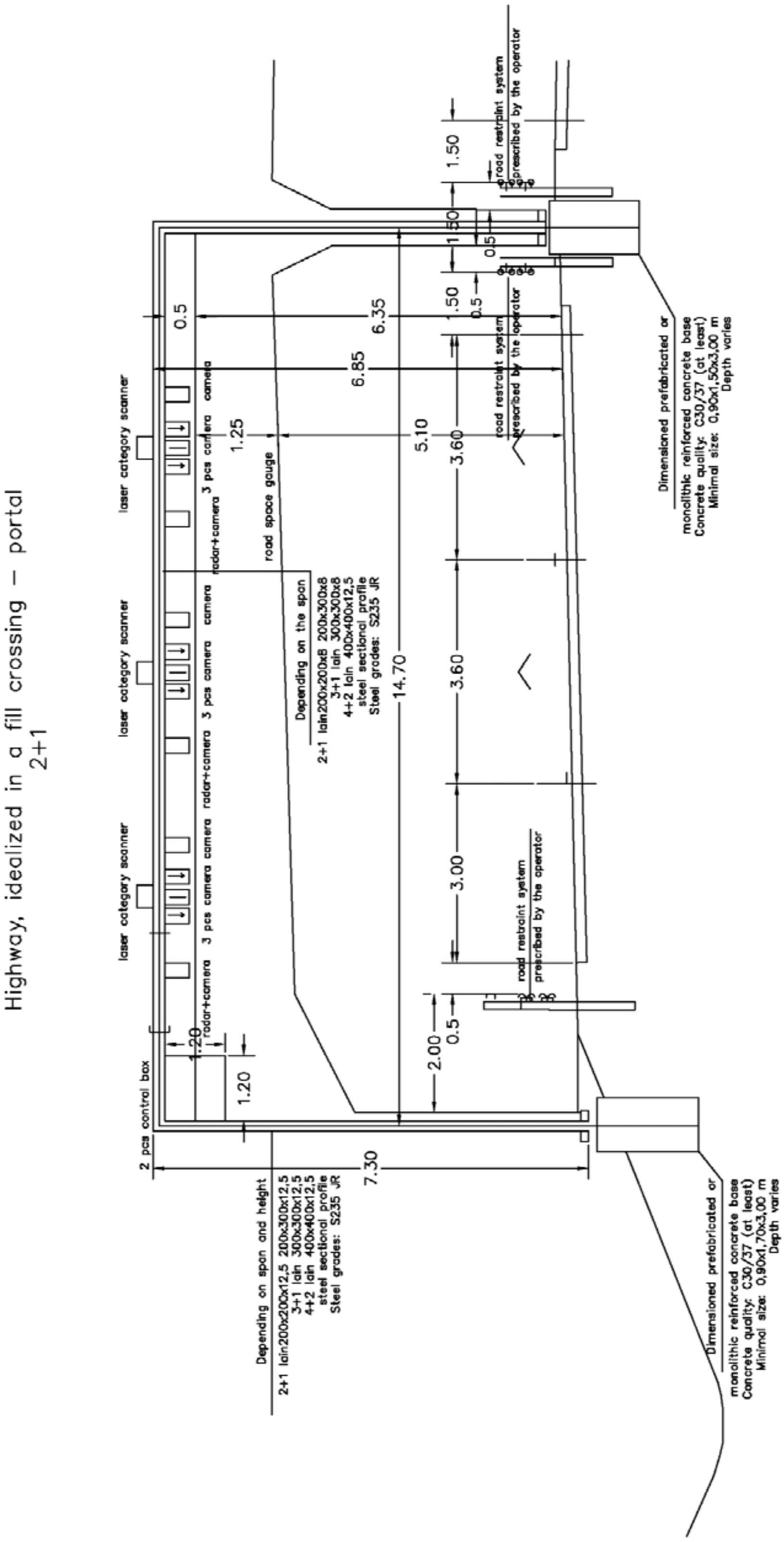
6. CONCEPT DESIGN

Various concepts for the portal frame were developed to demonstrate how the requirements and constraints presented in the previous sub-sections could potentially be addressed.

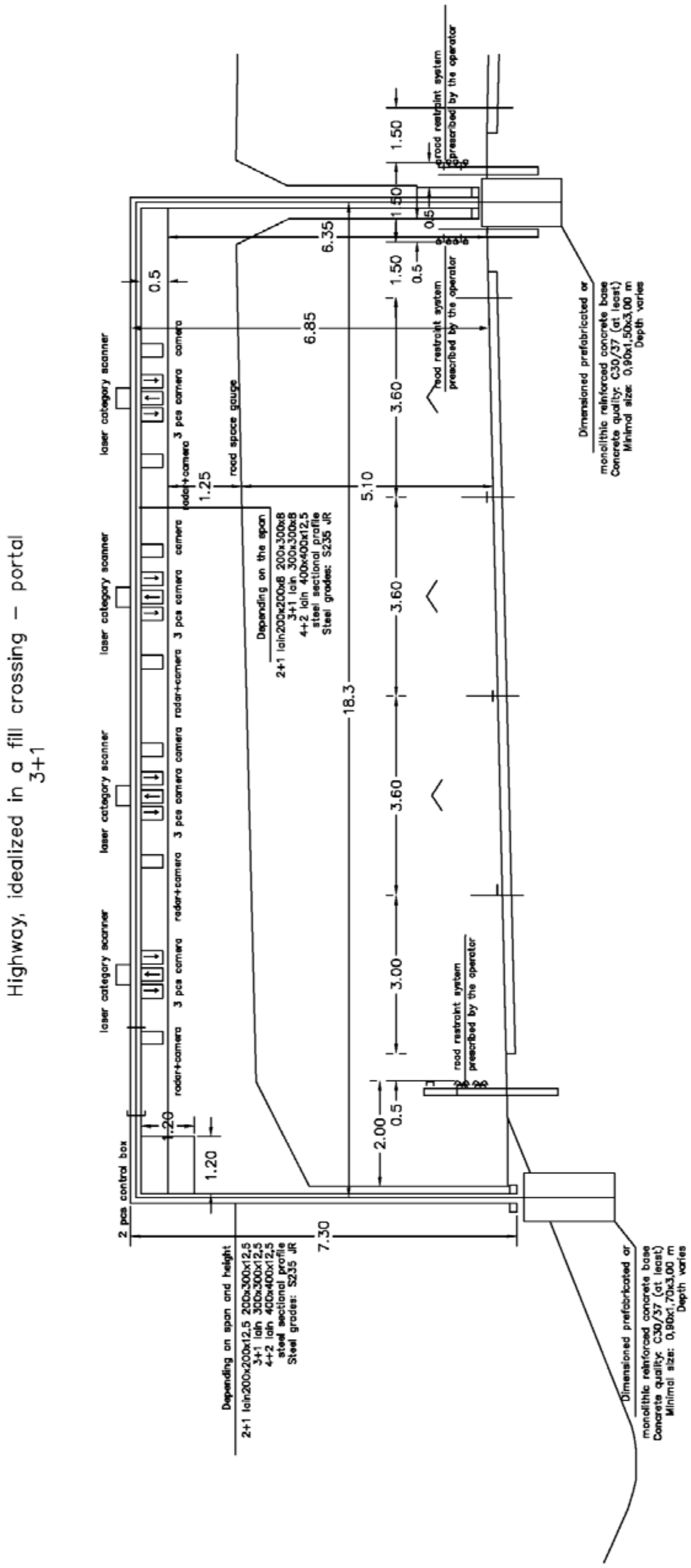
It should be emphasized, that these concepts show only the general layout; the design has to be individually refined based on local parameters and function (see also Section 4), such as:

- Type of the frame (mechanical system)
- Required equipments/intallations (permanent loads)
- Location (wind load, earthquake load)
- Road width (span length of the frame)
- Height of column 1
- Height of column 2
- Soil parameters
- Environment
- Geometry of the slopes
- Distance between the two highway directions (enough space for the column?)
- Closeness of the built environment (buildings, bridges etc.)

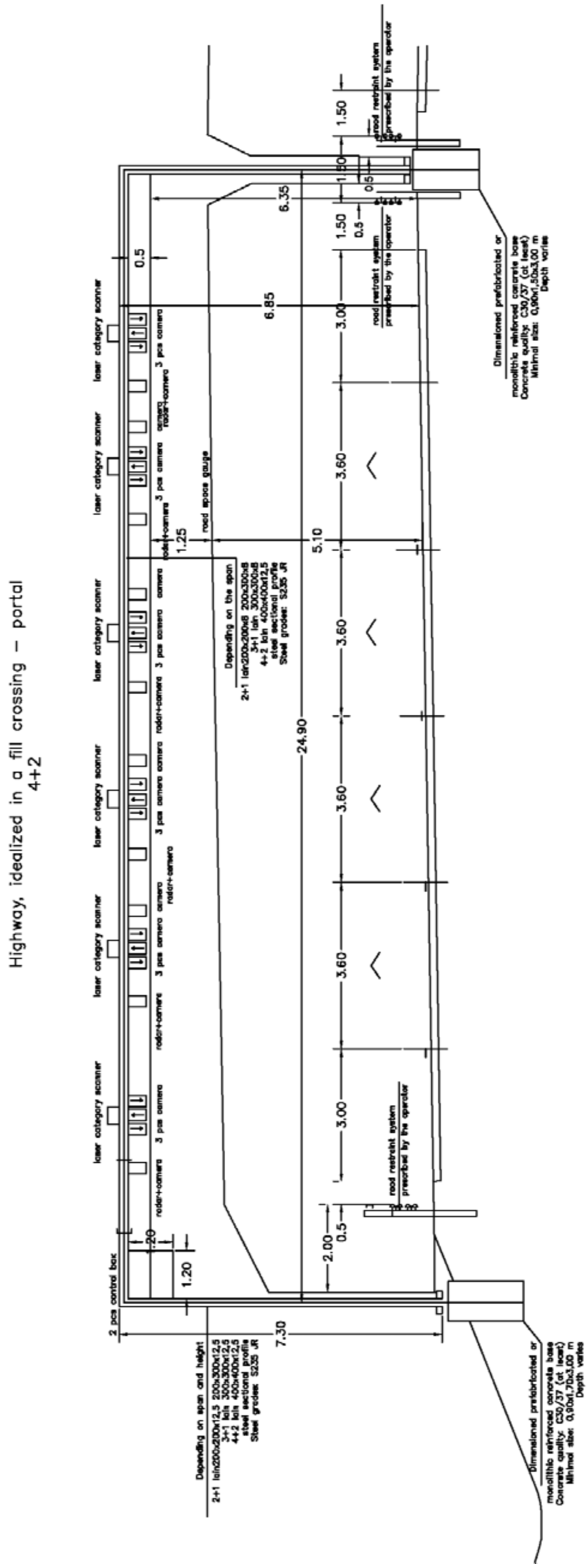
6.1.1. Portal frame 1



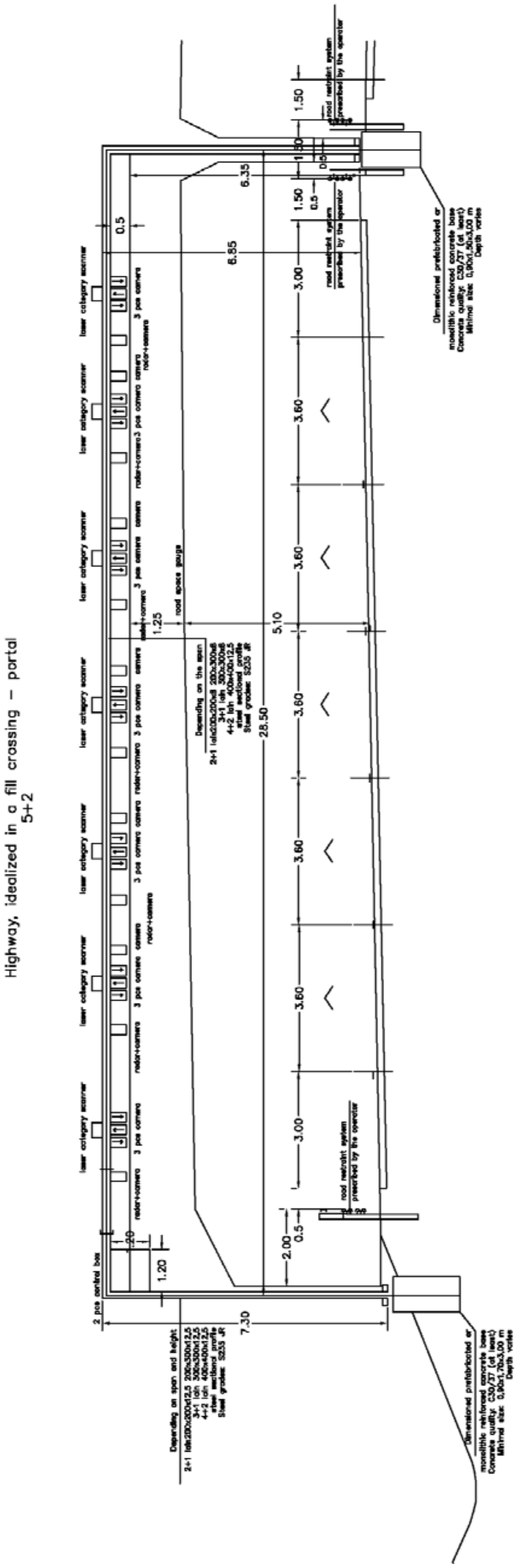
6.1.2. Portal frame 2



6.1.3. Portal frame 3



6.1.4. Portal frame 4



6.1.5. Portal frame 5