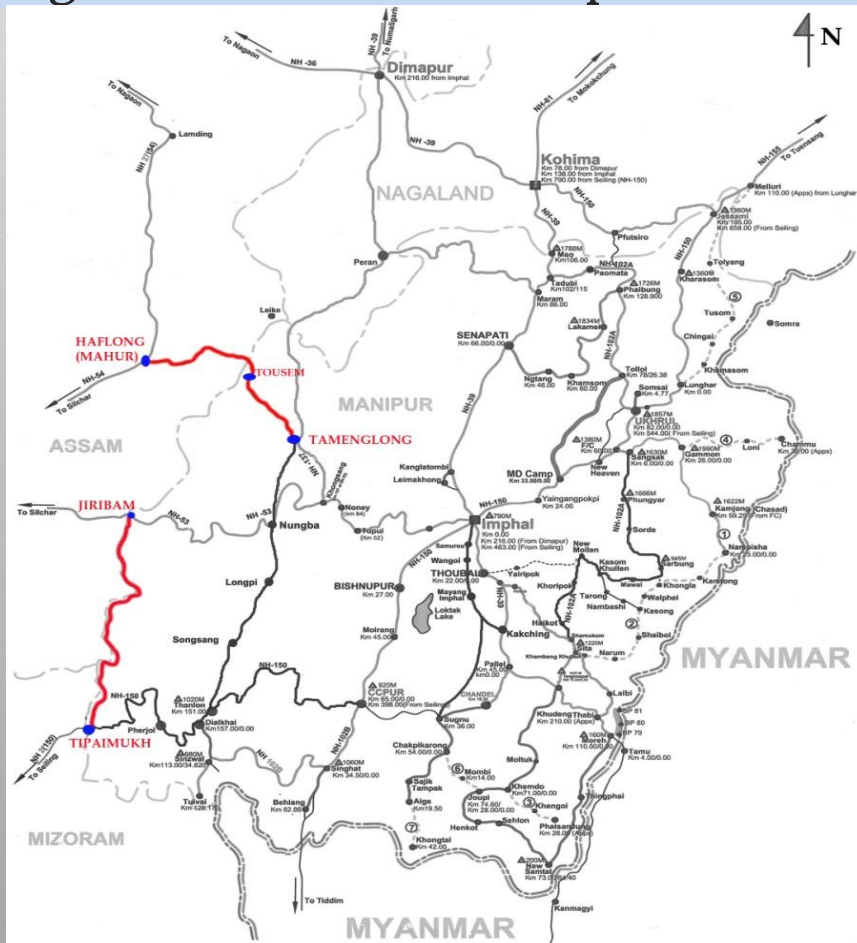




NATIONAL HIGHWAY INFRASTRUCTURE DEVELOPMENT CORPORATION LIMITED

Consultancy Services for preparation of Feasibility Study and Detailed Project Report for Two Lane with Paved Shoulders of Tamenglong-Tousem-Haflong Road in the State of Manipur and Assam.



DRAFT DETAILED PROJECT REPORT VOL-II DESIGN REPORT PKG-3

**OLD TAMENGLONG-PHELONG SECTION
(FROM KM 20+500 TO KM 30+800) LENGTH-10.3KM**



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FINAL DESIGN REPORT

1.0 HIGHWAY & STRUCTURE DESIGN

Following is a summary of the recommended design standards proposed to be adopted for the project road other than service road and intersections:

Table 6.1: Draft Design Standards

Sr. No.	Element	Terrain					
		Rural (Non Urban)		Urban Area	Hilly		
1	Width of Carriageway (m)	Intermediate Lane	: 5.5	2-Lane	: 7	2-Lane	: 7
		2-Lane	: 7.0	2-Lane+ Paved Shoulder	: 10	2-Lane+ Paved Shoulder	: 10
2	Shoulders (Earthen)	2-Lane	: 2.50			2-Lane	: Valley Side 1.0
		2-Lane+Paved Shoulders	12.0			2-Lane+ Paved Shoulders	: Valley Side 1.0
3	Formation Width (m)	Intermediate Lane	: 10.0	2-Lane+Paved Shoulder	: 13.0	Intermediate Lane:	: 10
		2-Lane	: 14.0	(inclusive 2X1.5m of Drain/Foot path)		2-Lane+ Paved Shoulders	: 11
4	Camber/ Cross Fall	Bituminous	: 2.5%	Bituminous	: 2.5%	Bituminous:	: 2.5%
		Concrete Pavement	: 2.5%	Concrete Pavement	: 2.5%	Concrete Pavement	: 2.5%
		Earthen Shoulder	: 3.5% (min)			Earthen	: 3.5%
						Shoulder	: Min
5	Design Speed (km/h)	<u>Plain Rolling</u>					
		Ruling	100	Ruling	: 60	Ruling	: 60
		Mm:	80	Minimum	: 40	Minimum	: 40

1.1 Geometric Design

1.1.1 General

Geometric design of a highway is the process whereby the layout of the road in specific terrain is designed to meet the needs of the road users keeping in view the road function, type and volume of traffic, potential traffic hazards and safety as well as convenience of the road users. The principal areas of control for fulfilment of this objective are the horizontal alignment, vertical alignment and the road cross-section.

The Consultants have referred to the latest IRC publications and MoRT&H circulars regarding design standards to be applied for state highways in India. After careful review of all available data and requirements of the project road the proposed Design Standards for adoption on the project road have been recommended.

1.1.2 Design Speed

The project road passes through plain, rolling and hilly terrain. For geometric design of the highway, design speed is used as an index which links road function, traffic flow and terrain. An appropriate design speed should correspond to general topography and adjacent land use. The speed selected for design should also cater to travel needs and behaviour of the road users. Rural highways, except expressways, are normally designed for speed of 80 km/hr, however depending on terrain and whether the design is for new alignment or reconstruction of an existing facility, the design speed is determined to the site requirement.

The ruling design speed corresponding to the type of terrain as per IRC:SP 79-2018, are as follows:

Table 6.2: Design Speed Standards

Terrain	IRC SP:73:2018
Plain/Rolling	80-100
Mountainous	40-60

Assuming a diverse mix of traffic on the project roads, a ruling design speed of 80-100 km/h for plain, rolling terrain and 40-60 km/h for hilly terrain is proposed to be adopted. Use of speed regulatory sign is proposed at locations such as hairpin bends, urban areas and other sharp curves where design speed cannot be maintained.

1.1.3 Levels of Service (LOS)

The Level of Service (LOS) characterizes the operating conditions on the roadway in terms of traffic performance measures related to speed and travel time, freedom to manoeuvre, traffic interruptions, and comfort and convenience. The levels of service range from level-of-service A (least congested) to level-of-service F (most congested). The Highways Capacity Manual (HCM) provides the following levels of service definitions:

Table 6.3: Standards for Level of Service

Level of Service (LOS)	General Operating Conditions
A	Free flow
B	Reasonably free flow
C	Stable flow
D	Approaching unstable flow
E	Unstable flow
F	Forced or breakdown flow

Considering the importance of the highway Level of Service (LOS) 'B' is proposed.

1.1.4 Cross Sectional Elements

1.1.4.1 Roadway Width for Multilane Highways

Adequate roadway width will be provided for the requisite number of traffic lanes besides the shoulders and a central median dividing the traffic flow directions. As specified in the IRC 73-2015, in general, for multilane highways, the shoulder width should be 2.5 m and lane width 3.5 m per lane. Based on a comparative review of international standards and safety, the values proposed to be adopted for the roadway elements by the Consultants for the project highway are as follows:

Table 6.4: Road Cross Section

Item	Two-Lane with Earthen Shoulder	Two-Lane with Paved Shoulder	
		Plain/Rolling Terrain	Hilly Terrain
Carriageways	2 X 3.5 m	2 X 3.5 m	2 X 3.5 m
Paved shoulder	N.A.	2 X 1.5m	2 X 1.5
Unpaved shoulder Plain/ rolling terrain Hilly terrain :	2 X 2.5 m	2 X 2	1x 1.0m
Hill Side	2 X 1.0 m		
Valley Side	2 X 2.0 m		
Total Formation width Plain/rolling terrain Hilly terrain	12 m 10 m	14m	11m
Total Formation width in Urban Area(inclusive Foot path/Drain)	13 m (Inclusive of 2X1.5m of Footpath/Drain)	14m	11m

As the proposed road is a national highway, total carriageway width of 7.0 m i.e. two lane with 1.5m Paved shoulders & 2.0m earthen shoulders has been proposed with the formation width of 14m in plain/rolling terrain and 7.0m carriageway with 1.5m paved shoulder and 1.0m valley side earthen shoulder has been proposed with the formation width of 11m in hilly terrain.

1.1.4.2 Lane Width

Lane width has a significant influence on the safety and comfort of the road. The capacity of a roadway is markedly affected by the lane width. In general, safety increases with wider lanes up to a width of about 3.5 m. **The lane width as per IRC:SP 73-2018 is 3.5 m.**

1.1.4.3 Shoulders

Shoulders are a critical element of the roadway cross section. Shoulders provide recovery area for errant vehicles; a refuge for stopped or disabled vehicles; and access for emergency and maintenance vehicles. Shoulders can also provide an opportunity to improve sight distance through cut sections.

IRC: SP 73-2018 recommends a paved outer shoulder of 1.5 m together with an earthen shoulder of 2.0 m for multilane highways. For mountainous terrain, the recommended earthen shoulder width is 1.0 m valley side.

1.1.4.4 Pavement Camber (Cross-fall)

IRC:SP 73-2018 recommends the following camber for various surface types:

Table 6.5: Provision for Cross-fall

Surface type	Camber
High Type Bituminous Surfacing	1.7% - 2.0 %
Thin Bituminous Surfacing	2.0 % - 2.5 %
Water Bound Macadam, Gravel	2.5 % - 3.0 %
Earth	3.0 % - 4.0 %

Considering the bituminous surfacing (bituminous concrete) the Consultants propose to provide a camber of 2.5 % for the main carriageway as well as paved shoulders and 3.5 % for the unpaved shoulder (granular).

1.1.4.5 Embankment Slopes

The side slope shall not be steeper than 2H:1V unless soil is retained by suitable soil retaining by structure.

1.1.5 Typical Cross-sections

The proposed cross-section in rural sections consists of two lane with paved shoulder configuration during the service life of the project. Concentric widening is proposed to minimize land acquisition issues and to ensure maximum utilisation of existing carriageway.

1.1.6 Horizontal Alignment

1.1.6.1 General

For balance in highway design, all geometrical elements should be determined for consistent operation under the design speed in general. A horizontal alignment should be as smooth and consistent as possible with the surrounding topography. To achieve that, an appropriate blending with the natural contours is preferable to the one with long tangents through the terrain.

1.1.6.2 Sight Distances

Sight distance is a direct function of the design speed. Safe stopping distances corresponding to various design speeds are given below:

Table 6.6: Sight Stopping Distance Criteria

Design Speed Km/h	IRC SP:73:2018
100	180
80	120
60	90
40	45

It is desirable to design the highway for more liberal values for operational convenience. An appropriate allowance would be considered to take care of the effect of adverse incidents. The value recommended by IRC & guidelines are proposed to be adopted in design.

1.1.6.3 Horizontal Curve

The minimum horizontal curve radius is the limiting value of curvature for a given design speeds and is determined from the maximum rate of super elevation and the side friction factor. As per the IRC: 73 - 2018 the minimum ruling radii of Horizontal curve for National Highways corresponding to different terrain conditions are as follows:

Table 6.7: Horizontal Radii Criteria

Type of Terrain	Minimum Radii of Horizontal Curve	
	Two Lane	
	Ruling Minimum	Absolute Minimum
Plain	400	150
Rolling	400	150
Mountainous	150	75

Absolute minimum and ruling minimum radii are corresponding to the minimum design speed and the ruling design speeds respectively.

On new roads, horizontal curves are designed with liberal radius provision that blends well the overall geometry and topography. However, for locations with constraints and to make use of available roadway, it is proposed to keep minimum radius in accordance with the IRC recommendations.

Table 6.8: Adopted Horizontal Radii

Speed (km/h)	Absolute Minimum Radius Two lane (m)
80	250
65	150
40	75

1.1.6.4 Transition (Spiral) Curves

The purpose of a transition (spiral) curve is to provide a smooth and aesthetically pleasing transition from a tangent and a circular curve. In addition the transition curves provide the necessary length for attainment of super-elevation runoff. It is proposed to adopt transition curve lengths provided above for minimum recommended moves.

1.1.6.5 Super-elevation

The IRC: SP 73-2018 design standards propose a maximum super-elevation rate of 7 % for plain and rolling terrains, and 10% for the mountainous terrain.

The limiting value of the super-elevation on the project road in both plain/rolling and hilly terrain is proposed to be 7%.

1.1.7 Vertical Alignment

1.1.7.1 General

The vertical alignment should produce a smooth longitudinal profile consistent with standard of the road and of the terrain. Horizontal and Vertical curvature should be so combined that the safety and operational efficiency of the road is enhanced.

1.1.7.2 Gradients

The IRC: SP 73-2018 geometric design standards propose ruling vertical grades of 3.3% to 5.0% for plain and rolling terrains; and 5.0% to 6.0% for hilly terrain.

Table 6.9 : Vertical Gradient

Terrain	Ruling (%)	Limiting (%)
Plain/Rolling	2.5%	3.3%
Hilly	5.0%	6.0%
Steep	6.0%	7.0%

To ensure adequate drainage, roadways typically have a minimum longitudinal grade of 0.5% to 0.6%, depending on the terrain. The minimum longitudinal grades as per IRC: SP 73-2018 design standards are 0.5% for lined side ditches, and 1.0% for unlined side ditches.

1.1.7.3 Vertical Curves

As per IRC: SP 73-2015 design standards, the minimum lengths of vertical curves are 60 m and 50 m for design speeds of 100 km/h and 80 km/h respectively. The length of a vertical curve is calculated using the following equation:

$$L = K \times A,$$

Where L = Length of vertical curve in metres;

K = Coefficient, a measure of the flatness of a vertical curve; and
A = Algebraic difference of grade lines (%)

Summit or Crest Curves

According to AASHTO (2001) design guidelines, the minimum K values for stopping sight distance requirements are 52, 26 and 7 for design speeds of 100 km/hr, 80 km/h and 50 km/hr respectively.

According to TAC (1999) design guidelines, the minimum K valves for stopping sight distance requirements are 45 to 80, 24 to 36 and 6 to 16 for design speeds of 100 km/hr, 80 km/hr and 50 km/hr respectively.

As per IRC-SP-23-1993 design Guidelines the Consultant propose minimum summit curve K values of 75, 45, and 25 for design speeds of 100 km/hr, 80 km/hr, 65 km/hr respectively.

Valley or Sag Curves

The minimum K values for valley or sag curves, in accordance with AASHTO (2001) design guidelines are 45, 30 and 13 for design speeds of 100 km/hr, 80 km/hr and 50 km/hr respectively. The minimum K values for valley or sag curves, in accordance with TAC (1999) design guidelines are 37 to 50, 25 to 32 and 7 to 16 for design speeds of 100 km/hr, 80 km/hr, 50 km/hr and 40 km/hr respectively.

As per IRC-SP-23-1993 design Guidelines the Consultant propose minimum valley curve K values of 42, 26 and 15 for design speeds of 100 km/hr, 80 km/hr, 65 km/hr respectively.

1.2 Bridges and Cross Drainage Structures

1.2.1 General

The bridge having total length more than 60 m is termed as major bridge and bridge length between 6 m to 60 m as minor bridge. The culvert is the structure having length less than 6 m between inner faces of dirt wall or extreme vent way boundaries measured at right angles thereto.

1.2.1.1 Bridges and Culvert

For major and minor bridges the minimum overall width between the outermost faces of the bridge shall be equal to 16m comprising of 13m carriageway and 0.45m RCC barrier on each side. Width of culverts shall be equal to 12m.

1.3 Hydrological and Hydraulic Investigations

Hydrological Data

The hydraulic condition of each structure was assessed thoroughly by visual observations and details are collected from the local offices of PWD, Tripura and BRO department, wherever available to collect the available hydrological data.

For the existing major and minor bridges the Topographic maps obtained from Survey of India has been utilized for the Hydrological Calculations.

Topographic maps, obtained from Survey of India, on 1:50,000 scales, have been utilized for the hydrological study in the corridor, accordingly for entire project Corridor, are prepared and attached as Annexure 5.5 "Abstract of Hydraulic Calculations".

1.4 Hydrological Design Methodology

For the calculation of discharge of the stream by the Area-Velocity method, topographical survey including leveling surveys have been carried out across and along the water courses to determine the cross-section and the slope. A number of cross-sections have been taken at regular intervals on both upstream and downstream side of the structure, including one at the proposed location of the structure in accordance with IRC specifications.

The following assumptions have been made during peak discharge calculation:

For locations where water spreads over the banks, the cross-sections were extended up to the HFL, in order to calculate the effective cross-section of flow.

The longitudinal section to determine the bed slope have been taken at an approximate regular interval of 100 m following the channel course extending on both the upstream and the downstream sides of the structure. Caution is taken by following the curved flow line for longitudinal gradient, rather than a straight line.

1.4.1.1 Assessment of Peak Discharge

The peak discharge and the HFL have been calculated by the following methods.

Dickens Method to find discharge from catchment, and Area velocity methods at the bridge site, the upstream and the downstream sections.

Dickens Method

Dickens's Formula is proposed as Empirical formulae in entire road stretch, which is as below.

$$Q = CM (0.75)$$

Where,

Q = the peak run-off in cu.m/sec.

M Is the catchment area in sq.km and

C = 11-14, where the annual rainfall is 60-120 cm;

14-19, in Madhya Pradesh; and

32, in Western Ghats.

Area – Velocity Method (Manning's Formula)

$$Q = A \times V \\ = A \times [(1/n) \times (R)^{2/3} \times (S)^{1/2}]$$

Where, Q = the discharge in cumecs ;

A = Area of the cross section in sq. m.;

V = Velocity in m/sec;

R = Hydraulic mean depth in m. = A / P;

P = Wetted perimeter of the stream in m.;

S = Bed slope of the stream; and

n = Rugosity Co-efficient.

The Design Discharge has been taken as the maximum of peak discharges at different cross sections.

1.4.1.2 Hydraulic Analysis for Design HFL

In hydraulic analysis, the Design HFL has been calculated corresponding to the Design Discharge by Manning's Equation at the bridge site, as described above.

1.4.1.3 Afflux Calculation

When the waterway area of the opening of a bridge is less than the unobstructed natural waterway area of the stream, i.e. when bridge contracts the stream, afflux occurs. The afflux will be calculated using Molesworth's formula as given below: -

$$h = \left(\frac{V^2}{17.88} + 0.01524 \right) \{ (A/a)^2 - 1 \}$$

Where, h = Afflux in meters;

V = Average velocity of water in the river prior to construction in m/sec;

A = Unobstructed sectional area of the river at proposed site in sq m;
and
a = Constricted area of the river at the bridge in sq m.

1.4.1.4 Scour Depth Calculation

To provide an adequate margin of safety for design of foundation, a further increase by 30% has been made over the design discharge as per IRC: 78-2000, thus obtaining the final design discharge for the design of foundation.

By IRC: 5-1998 / IRC: 78-2000

As per IRC: 5-1998 or IRC: 78-2000, the mean depth of scour below the highest flood level, D_{sm} , will be given by the following equation:

$$D_{sm} = 1.34 \times (D_b^2 / K_{sf})^{1/3}$$

Where, D_b = the discharge in cumecs per meter width and K_{sf} = Silt Factor.

The value of ' D_b ' shall be the total design discharge divided by the effective linear waterway between abutments.

For most of the bridges, the silt factor, K_{sf} , has been calculated as per guidelines given in IRC-78: 2000 (Clause 703.2) otherwise it has been assumed as 1.5 due to absence of soil distribution curve.

1.4.1.5 Maximum Depth of Scour for Design of Foundation

The maximum depth of scour below the Highest Flood Level (HFL) for the design of piers (d_{smp}) and abutments (d_{sma}), having individual foundations without any floor protection are as follows:

In the vicinity of pier: $d_{smp} = 2 \times D_{sm}$

In the vicinity of abutment: $d_{sma} = 1.27 \times D_{sm}$

For the design of floor protection works for rafts or open foundations, the following values of maximum scour depth may be adopted:

In a straight reach: $1.27 \times D_{sm}$

In a bend: $1.50 \times D_{sm}$

For the RCC Box type structures proper scour protection is given in the form of floor apron and flexible apron both on the up-stream and downstream sides. No scour will be allowed to occur in the RCC Box type structures.

1.4.1.6 Additional Balancing Culvert on Main Carriage Way

Additional balancing culvert on Main Carriage Way has been provided if it is required for planning of adequate drainage system. Also additional culvert of 1.2m diameter HP (NP-4) for field channel (farm) shall be provided at bypasses to allow the water to pass from one side to other side, if the lands on both side of the road belong to the same owner.

1.4.1.7 Pipe Culvert

The existing pipe culverts that are hydraulically adequate and functional will be widened to full formation width. Pipe culverts having less than 0.90 m dia pipe will be replaced. Based on proposed finish levels if pipe culverts do not have adequate cushion, they shall be encased all round in M15 grade cement concrete with 200 mm thick slab and in M20 grade cement concrete over top of the pipe.

1.4.1.8 Various Codes and Publication to be adopted

The bridges shall be designed as per various IRC codes and special publications wherever required. For conditional cases, if IRC code does not specify anything then relevant BIS code will be followed. The following IRC codes shall be adopted for bridge design.

IRC: 5-1998	General features of design
IRC: 6-2014	Loads and Stresses
IRC: 18-2000	Design criteria for PSC Road Bridges
IRC: 21-2000	Cement concrete plain and reinforced
IRC: 22-2008	Composite Construction
IRC: 40-2002	Brick, stone and block masonry
IRC: 45-2015	Design of well foundation of bridges
IRC: 54-2000	Lateral and Vertical clearances at underpasses
IRC: 78-2000	Foundation and substructure
IRC: 83-1999	(Part I) Metallic Bearings
IRC: 83-1987	(Part II) Elastomeric Bearings
IRC: 83-2002	(Part III) POT PTFE Bearings
IRC: 89-1997	Guidelines for river training and control works
IRC: SP: 13:2004	Guidelines for the design of small bridges and culverts
IS 2911-2010	code of practice for design and construction of pile foundations

1.4.1.9 Design Live Load

The two-lane with paved shoulder carriageway shall be designed with loading combination of Class A, Class 2A, Class 3A and 70R two-lane load or IRC 70 R single lane whichever produces severe effects.

1.4.1.10 Vertical Load

The various components of bridge will be designed for self weight of structure as well as live load with buoyancy effect through pore pressure as well as uplift at base of foundation with appropriate factors depending upon the founding strata.

1.4.1.11 Longitudinal Forces

The bridge will be designed for longitudinal forces on account of tractive and braking action, wind force, seismic force as well as forces due to longitudinal movement of superstructure generated due to creep, shrinkage or temperature. All longitudinal forces will be considered as stipulated in various IRC codes.

1.4.1.12 Seismic Zone

The project road is located in a seismic zone V. It is proposed to design the bridges for seismic forces as mentioned in modified clause 222 of IRC: 6-2000.

1.4.1.13 Condition of Exposure

Since the project road is away from marine environment, a moderate condition of exposure will be adopted.

1.4.1.14 Grade of Concrete

The following minimum grade of concrete will be adopted for major and minor bridges as well as ROB, Flyover and Underpass.

Sr. No.	Type of Concreting	Major Bridge/	Minor Bridge and Culverts
1	Plain Cement Concrete (PCC)	M-20	M-20
2	Reinforced Cement Concrete (RCC)	M-35	M-30/M-35

1.5 Miscellaneous

1.5.1 Road Signs

Road signs are proposed to be placed according to IRC: 67:2012. The signs are to be placed on embankment such that extreme edge of sign would be 2.0m away from the edge of the carriageway. The location of each sign is to be decided in accordance with the guidelines therein.

The sheeting shall be provided of Super High Intensity Micro Prismatic sheets Type IX as per ASTM D 4956 for all types of road sign boards as well as Over Head Signs.

1.5.2 Road Markings

Road markings will be made for centre and edge lines using reflective thermoplastic paints. Appropriate road markings will also be provided at junctions and crossings.

1.5.3 Traffic Barriers

Traffic barriers are protective devices that are placed between traffic and a potential hazard off the roadway, with the intention of reducing the severity of a collision when an errant vehicle leaves the travelled portion of the roadway. Barriers are to be provided at high embankments, sharp curves and bridge approaches. The barrier is to be located in unpaved shoulders.

1.5.4 River Training work

River training works will be provided in accordance with IRC 89-1997 and designed as per forces and loads stipulated for respective components as per the site specific requirements.

2.0 PAVEMENT DESIGN

2.1 General

2.1.1 Objectives

The main objective of this Project is preparation of Detailed Project Report for the improvement of the given set of roads in Manipur, based on the investigations, studies and analysis.

The studies are to be carried out with a view to upgrade the road geometrics and to improve the pavement structure. However, only minor re-alignments to improve the road geometry are envisaged. In general the existing single-lane road pavements are to be widened Intermediate pavement. The road stretches which need further widening based on the traffic requirement are to be identified. On the stretches where the traffic during the design period exceed the capacity of two-lane carriageway.

There are road stretches with inadequate height of road formation with reference to the high flood level or level of adjoining irrigated fields or general ground level or water table. These stretches are likely to be submerged under water during monsoon or be subjected to water-logging conditions resulting in extensive damages to the road structure, year after year. Also there are number of locations where the streams cross the road at low level causeways, limiting the un-interrupted traffic movement along these roads. Thus there is a need to identify the stretches where

The formation is to be re-constructed due to minor re-alignment to improve the road geometry.

The formation height is to be raised to prevent the problem of submergence or water-logging or over flowing of water from the crossing streams.

On the re-aligned stretches of the road and the stretches where the formation is to be raised, there will be need to construct new pavement, starting from the subgrade level. While considering various design alternatives and specifications for pavement layers and materials, it is very important to make full use of experience in this country. Therefore the accepted methods of investigations, design and specifications as given in the Guidelines of the Indian Roads Congress (IRC) and the MOST Specifications for Roads and Bridges have been generally followed during the investigation and design of pavements.

2.1.2 Scope

Basically the "Pavement Design" chapter of this report deals with two categories of design work:

Design of Flexible Pavement Overlays, to strengthen existing stretches of flexible pavement
Design of new flexible pavement, for construction of new pavement and for widening of existing pavement including construction of paved shoulders.

Apart from the above, a typical design for the CC pavement is also presented so that if required, this may be considered as a possible option at least at some problematic stretches.

2.2 Analysis Of Data For Pavement Design

2.2.1 General

The pavement condition survey data are made use of to identify the stretches, which need different types of pavement improvement measures mentioned above. The analysis of traffic study data are made use of to work out the initial volume of classified traffic and their growth during the design life. The analysis of Axle load studies are needed to work out the values of Vehicle Damage Factor (VDF) of different categories of commercial / heavy vehicles on different corridors and the values of Cumulative Standard Axle Load (CSA) for design of pavements. The spectrum of wheel loads also are made use of for the design of CC pavements. The results of Benkelman Beam Deflection (BBD) studies and the analysis are needed for the structural evaluation of flexible pavements which need strengthening and for the design of overlays. The analysis of soil test results and the soaked CBR values are made use for the design of new flexible pavements including pavement widening.

2.2.2 Pavement Condition Study Data

Preliminary pavement condition survey was carried out on the entire length of Morvan-jawad road, before starting the actual deflection studies using Benkelman beam. The stretches of the existing road pavement were subdivided into sub-stretches based on the type and extent of cracking, rutting and other pavement distress as per the IRC Guidelines, IRC : 81 - 1997. The sub-stretches with uniform pavement condition which could be strengthened by suitable overlays were identified in order to carry out Benkelman beam rebound deflection studies.

Based on the analysis of pavement condition studies, the road corridors and the different sections there-of have been sub-divided into set of sub- stretches with fairly uniform characteristics. These have been re-grouped into the following four categories for the purpose of proposing the different types of pavement improvement programmers.

Sub-stretches for strengthening of the existing pavement by suitable Overlays

Sub-stretches for widening of carriageway including shoulders, using pavement layers as per "Design of New Pavements"

Sub-stretches for the construction of new pavement layers starting from the subgrade, as per "Design of New Pavements" on the stretches needing

"Reconstruction" and newly constructed formation, due to raising or re-alignment.

2.2.3 Classified Traffic Volume Data

2.2.3.1 Vehicle Classes Considered for Pavement Design

The consolidated values Classified Traffic Volume Studies and the analysis of data are presented in Chapter 4 of main report and the relevant annexure. The following vehicle classes have been considered and suitably re-grouped for the determination of CSA values and design of pavements :

Heavy Commercial vehicles consisting of heavy trucks with two axles
Heavy Commercial vehicles consisting of heavy trucks with rigid body and tandem axles
Heavy Commercial Vehicles, such as tractor-trailer units with Multiple Axles and agricultural tractors with trailers and other heavy vehicles , Buses , Light Commercial Vehicles of gross weight exceeding 3 t and mini-buses.

The average volume of the above groups of vehicles on different sections of each corridor as on the year 2014 were made use of for determining the initial traffic by the year 2017, when the pavement improvement works of the project roads are expected to be completed.

2.2.3.2 Traffic Growth Rate

The mean growth rate of the above groups of vehicle classes for the Manipur as a whole have been worked out and presented in Chapter 4, "Traffic Survey Analysis and Forecast". It was observed that the traffic growth rates were different for the periods

As already mentioned, it was decided to consider the initial traffic as on the year 2017 for pavement design. The fifteen year design period considered for design of flexible pavement overlays and for the design of new flexible pavement is :

20 years life, for the period 2020 to 2040

Therefore the weighted average growth rates were worked out for the above five vehicle groups in order to work out the CSA values of each vehicle class during the respective design periods.

2.2.5 Design C.S.A. Values

The CSA values were calculated using the relationship given below :

$$N_s = [365 A D F \{ (1 + r)^x - 1 \} / r] , \text{ msa}$$

Design CSA on the design - lane = Tf. Ns, msa

Where,

Ns = Cumulative Standard Axles (CSA) on the road section during the design period (2014to 2029), msa

A = the initial traffic (number of the particular vehicle class per day) on the road section under consideration by the year 2009

r = the rate of growth of the vehicle class during the design life of 15 years

x = design life, years (15 years)

F = Vehicle Damage Factor (VDF) determined from axle load studies on the respective corridor

D = Lane Distribution Factor

Tf = Traffic Distribution Factor on the design lane

= 0.75 for intermediate-lane, two-way traffic road

Axle Load Survey has been carried out in order to estimate vehicle damage factor (VDF) for using in design of overlay on existing pavement and new pavement design for additional lanes

2.3.2 Calculation of VDF

The vehicle damage factor is a multiplier for converting the number of commercial vehicles of different axle loads to the number of standard axle load repetitions. Design of new pavement for additional lane or strengthening of existing pavement is based upon the cumulative number of 8.17 tonne equivalent standard axles (ESA) that will pass over during the 15 year design period. The classes of traffic which lead to significant axle loads (or damage) to the pavement and accordingly considered for design are: LCVs, two / three axle and multi axle trucks. Cumulative standard axles (CSA) are calculated in accordance with the guidelines provided in IRC: 37 – 2019 and IRC: 81 - 1997. The overloaded vehicles have serious adverse impact on performance of pavement. It has been ascertained that the damaging effect of axles on flexible pavement is approximately proportional to the fourth power of the axle load.

Equivalency factors as recommended by IRC have been used to convert the axle load spectrum into an equivalent number of standard axles. The computations of VDF for each type of vehicle in each direction are given in tabular forms in Annexure of this report.

Equivalency factors as recommended by IRC have been used to convert the axle load spectrum into an equivalent number of standard axles. The equivalency factors are derived for each axle load category from the fourth power rule. The product of frequency of axles for each axle load category and corresponding equivalency factors gives the ESA for corresponding axle load category. The VDF is calculated by dividing the total number of ESA by the number of vehicles weighed.

2.3.3 Computation of design traffic

The design traffic is considered in terms of the CSA to be carried during the design life on the road. MSA for new pavement design is worked out considering that the construction of the project road would be completed by the year 2016 and traffic will start using the facility from the year 2017 onwards. The MSA for overlay design is worked out considering the present traffic on existing pavement and projected traffic based on growth rates. Its computation involves the initial volume of commercial vehicles per day, lateral distribution of traffic, the growth rate, the design life in years and the vehicle damage factor (number of standard axle per commercial vehicle) to convert commercial vehicles to standard axles.

The following equation has been used to calculate the cumulative number of standard axles in accordance with IRC: 81 – 1997 and IRC: 37 – 2012.

$$N_s = \frac{365 \times A [(1+r)^x - 1]}{r} \dots\dots\dots \text{Eqn. 5.1}$$

Where
 N_s = the cumulative number of standard axles to be catered for in the design.

A = Initial traffic, in the year of completion of construction, in terms of the number of commercial vehicles per day duly modified to account for lane distribution.

r = Annual growth rate of commercial vehicles, %

x = Design life in years

F = Vehicle Damage Factor (number of standard axles per commercial vehicle)

The Million Standard Axles (MSA) for the base year 2016 and horizon year for commercial traffic has been estimated using VDF values derived from axle load survey for LCV, 3 and multi axle trucks.

1.6 PAVEMENT DESIGN OF PROJECT ROAD

To comprehensively appreciate the traffic and travel characteristics on the project corridor from Tamenglong-Haflong Via Tousem & Lisang. The type of surveys, locations and duration, as identified at the inception stage of the study have been followed during data collection exercise with minor modifications on account of the project corridor.

The traffic characteristics on the project road for the base year are essential for formulating improvement programs. The objectives of the traffic study are:

- Traffic estimation in terms of volume on various sections.
- Growth factor estimation for traffic forecasting.
- Capacity assessment based on traffic forecasting for next 30 years.
- Pavement and intersection design

1.7 Average Annual Daily Traffic and it Composition

The Average Annual Daily Traffic (AADT) obtained from the volume count surveys for all the locations are given in **Table no. 1.4**. To study the variation in the intensity of traffic, consultants have analyzed the variation of traffic along the project road. The following observations are made from the analysis for each location along the project stretch.

Table 1.4: Annual Average Daily Traffic (AADT)

Categories	PCU Factor	Km. 0+300 at Tamenglong town Location-1		Km. 136+650 Near Mahur town Location-2		Average of all locations	
		Vehicles	PCUs	Vehicles	PCUs	Vehicles	PCUs
Car/Jeep/Van	1.0	109	109	634	634	372	372
3 Wheeler	1.0	127	127	710	710	419	419
Mini Bus	1.5	7	11	13	20	10	15

Standard Bus	3.0	5	15	13	39	9	27
LCV / Tempo	1.5	43	64	124	186	84	126
2-Axle	3.0	42	126	35	105	39	117
3-Axle	3.0	0	0	11	33	6	18
MAV (4-6)	4.5	0	0	0	0	0	0
Two Wheeler	0.5	109	54	682	341	396	198
Animal Cart	6.0	0	0	0	0	0	0
Cycle	0.5	46	23	138	69	92	46
Tractor with trolley	4.5	0	0	0	0	0	0
Tractor	1.5	0	0	0	0	0	0
Hand Cart	6.0	0	0	0	0	0	0
EME/HCV	4.5	2	9	6	27	4	18
Total Traffic		490	538	2366	2164	1431	1356

Traffic growth rate during the design life in percentage

It is learnt that the National Highways and Infrastructure Development Corporation Limited (NHIDCL) did not carried out traffic volume count on the project road. Therefore, no previous data has been provided to Consultant.

IRC:37-2019 stated" If the data for the annual growth rate of commercial vehicles is not available or if it is less than 5 per cent, a growth rate of 5 per cent should be used".

Hence traffic growth rate is adopted 5% for projection of present traffic.

Vehicle Damage Factor

As per IRC: 37-2019 clause 4.4.6 stated" where the sufficient information on axle loads is not available the default values of vehicles of vehicle damage factor as given in table 4.2 may be used".

As per table 4.2 for CVPD more than 1500 adopted VDF should be 2.5 for Hilly terrain.

Hence, The Adopted VDF is 2.5.

Cumulative Mean Standard Axles (CMSA)

Summary of CMSA By Assumed Traffic		
Year	Pkg-1	Design year
2017 to 2020	Project Clearance	
2021	0.21	1
2022	0.43	2
2023	0.67	3
2024	0.91	4
2025	1.17	5
2026	1.44	6
2027	1.73	7
2028	2.03	8

2029	2.35	9
2030	2.68	10
2031	3.02	11
2032	3.39	12
2033	3.77	13
2034	4.17	14
2035	4.59	15
2036	5.04	16
2037	5.50	17
2038	5.99	18
2039	6.50	19
2040	7.04	20
2041	7.60	21
2042	8.20	22
2043	8.82	23
2044	9.47	24
2045	10.16	25

Adopted MSA is 20 as per IRC SP 73:2018

For Details of Traffic Surveys and Analysis Please refer Chapter-5

1.4. PAVEMENT DESIGN

As per plate No.-4 of IRC-37:2019 the Pavement Design is:-

Design crust thickness for the flexible pavement for 20 years as arrived is given below in **table 1.5**

Table 1.5

Homogenous Section (Km)			CBR (%)	MSA	Adopted Pavement Composition (mm)			
From	To	Length (in Km)		Adopted	BC	DBM	WWM	GSB
20+500	30+800	10.300	8	20	30	90	250	200

As Per test results the average CBR Varies from 8-12%. So, the value of adopted CBR is 8%.

DESIGN OF CULVERTS & BRIDGES

**Design note
for
RCC BOX OF SIZE 1 x 2 x 2**

	Project		Designed by:	KB
	Client		Checked by:	
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	

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	Project	0	Designed by:	KB
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	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0-Jan-00

1.0 Design Report

The following report represents the design note of RCC BOX of clear span 1 x 2 x 2

1.1 Introduction:-

Design is presented consistently in SI units; the following apply unless mentioned specifically otherwise:

Length	m
Force	kN
Stress	MPa
Bearing Pressure	kN/m ²
Hog Mom/Com Str	-ve
Sag Mom/Ten Str	+ve

1.2 Reference documents :-

- 1 IRC codes /guidelines/special publications
- 2 MORTH specification
- 3 Specialised literature as relevant

1.3 Assumptions:-

The following assumptions have been taken while designing the Box.

- 1 Structure is designed for per metre width.
- 2 On top slab 75 mm thick wearing coat is considered for SIDL.
- 3 Deck width taken 12 m
- 4 Carriageway width- 11 m
- 5 Modulus of subgrade reaction (Assumed) - 2500 KN/m³
- 6 Shear value is taken at dist. 0.15m from the face of the slab.
- 7 In case of load dispersion wearing coat thickness, fill thickness and top slab thickness is considered wherever applicable.
- 8 In case of design sheet under summary of moments, only magnitude of force has been considered.
- 9 In case of earth pressure and LL surcharge governing case out of Normal earth pressure, Fluid pressure and Normal earth pressure + hydrostatic fluid pressure is taken.
- 10 Structure is designed for standard earth pressure without weep holes.

	Project	0	Designed by:	KB
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	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0-Jan-00

1.4 Loads:-

The different types of loads used as per IRC 6 : 2014 are.

- 1 Dead load.
- 2 In SIDL fill, crash barrier, and wearing coat load is considered.
- 3 Normal Earth pressure with hydrostatic pressure.
- 4 Live load -70R Track, 40 T Boggie, 70R Wheel load in case of top slab.
- 5 Live load surcharge.
- 6 Braking load is taken as 20% of the live load on top slab.
- 7 1.25 of Impact factor is considered.
- 8 Temperature loading for uniform rise and temperature gradient is considered.
- 9 The Earth pressure coefficient at rest 0.5 is considered.

1.5 Load combinations

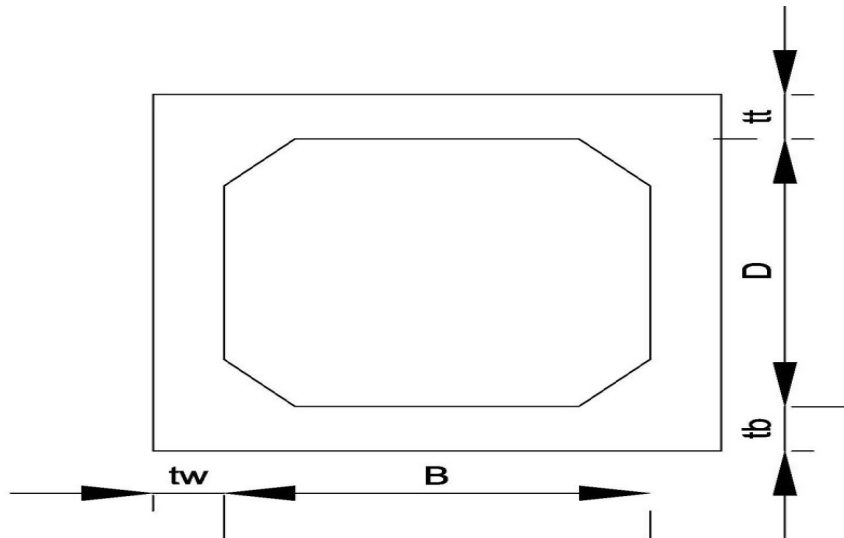
Load combinations as per IRC 6: 2014 have been considered in staad load combination.

1.6 Material properties

- 1 Grade of Concrete M30
- 2 Grade of Steel Fe 500.

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	Job Name	RCC BOX OF SIZE 1 x 2 x 2		Date & Rev.	0

BOX (1 Cell 2m wide x 2m height)



2.1 Dimensions of Box

No. of Cell	=	1	Clear Width of cell	=	2.00 m
Top Slab Thick. (tt)	=	0.300 m	Clear Height of Cell	=	2.00 m
Bot. Slab Thick. (tb)	=	0.325 m	C/C Width of structure	=	2.300 m
Side Wall Thick. (tw)	=	0.300 m	C/C Height of structure	=	2.313 m
Int. wall Thickness (ti)	=	0.000 m	Total length of Structure at top =	=	2.600 m
Total Deck width	=	12.00 m	Total length of Structure at bottom =	=	2.600 m
Carriageway Width	=	11.00 m	Total Height of Structure	=	2.63 m
water above bott. Slab	=	1.375 m	Footpath Dimensions	=	0.00 m
			Crash barrier width	=	0.50 m
Wearing coat for SIDL	=	75mm	Height of fill =	=	0.00 m
Haunch size	=	150mm x150mm			

SIDL (Top Slab)

Crash barrier	=		10	kN/m ²
Due to earth fill	=	0 x20 =	0	kN/m ²
			10	kN/m ²
Due to wearing coat	=	0.075 x 22 =	1.65	kN/m ²

2.2 Basic Parameters

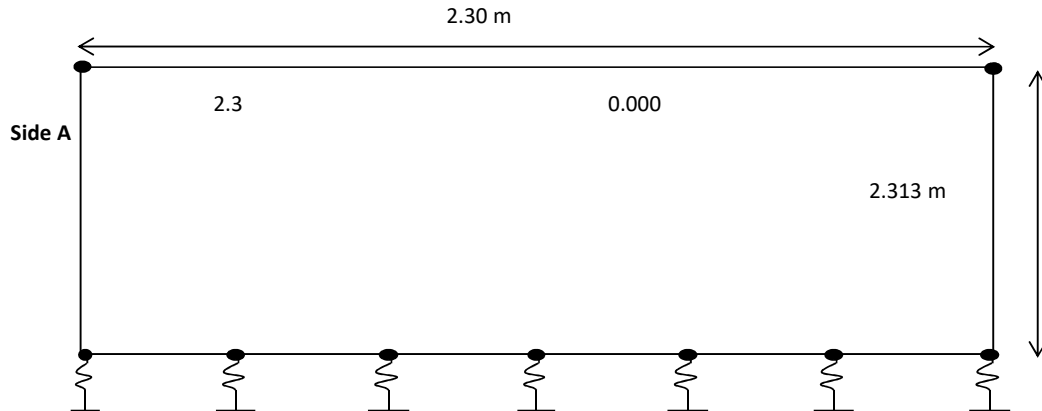
Coefficient of Active Earth Pressure	=	0.279
Earth Pressure at rest $K_0 = (1 - \sin\phi)$	=	0.5
Factor of Earthpressure/Active earthpres:	=	1.793
Saturated Density of fill	=	20 kN/m ³
Submerged Density of fill	=	10 kN/m ³
Dry Density of fill	=	20 kN/m ³
Density of Concrete	=	25 kN/m ³
Live Load Surcharge	=	1.2 m

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Safe Bearing Pressure = 100 kN/m²
 Fluid Pressure as per cl. 214.1 of IRC 6 2010 = 4.71 kN/m²

2.3 Idealised Structure for Staad Analysis

(Analysis is done for 1m Strip)



Nos. of beam for one span at bottom = 10
 Spacing between Springs = 0.230 m
 Modulus of Subgrade Reaction (Assumed) = 2500 kN/m³
 Spring Constant at End Support = 288 kN/m
 Spring Constant at intermediate Support = 575 kN/m

3.1 Earth Pressure and Live Load Calculation

1) a Earth Pressure (Normal Condition)

Earth Pressure	Height
0.84 kN/m ²	0.150 m
13.74 kN/m ²	2.463 m

1) b Fluid Pressure

Fluid Pressure	Height
0.71 kN/m ²	0.150 m
11.60 kN/m ²	2.463 m

1) c Earth Pressure (Normal Condition+Full hydrostatic pressure)

Earth Pressure	Height
1.92	0.15
31.50	2.463 m

1) d Earth Pressure at rest $K_0 = (1 - \sin \phi) =$

LWL	HFL	Earth Pressure	Height
1.50	2.25	1.50	0.150 m
24.63	36.94	24.63	2.463 m

2) a Live Load Surcharge (Normal Condition)

Live Load Surcharge = 6.696 kN/m

2) b Live Load Surcharge (Fluid Pressure) as per cl. 214.1 of IRC 6 2014

Live Load Surcharge = 5.651 kN/m

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

2) c Live Load Surcharge (Normal Condition+Full hydrostatic pressure)

Live Load Surcharge = 15.348 kN/m

2) d Live Load Surcharge at rest

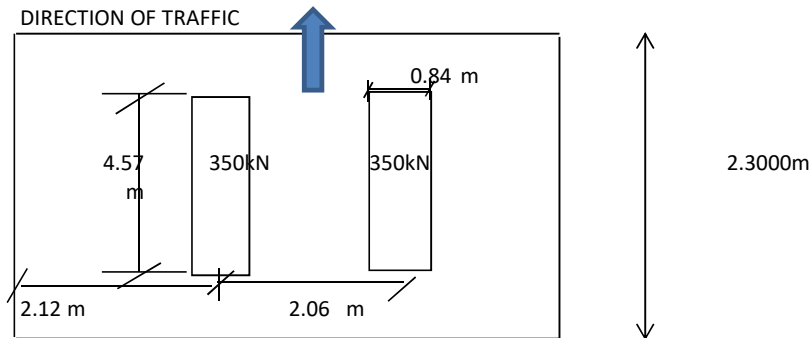
Live Load Surcharge = 12.000 kN/m

2) e Load due to water on Bottom Slab

Uniform Load = 13.75 kN/m²

3) Live Load on Top Slab

A) 70R Track at Mid Span



Total Load = 700kN
 153.17 KN/m
 352.3 KN

4.57 2.3000m

Effective width of Loading

a = 1.15 m
 b1 = 0.99 m
 b/lo = 5.22
 a = 2.60
 beff = 2.49 m

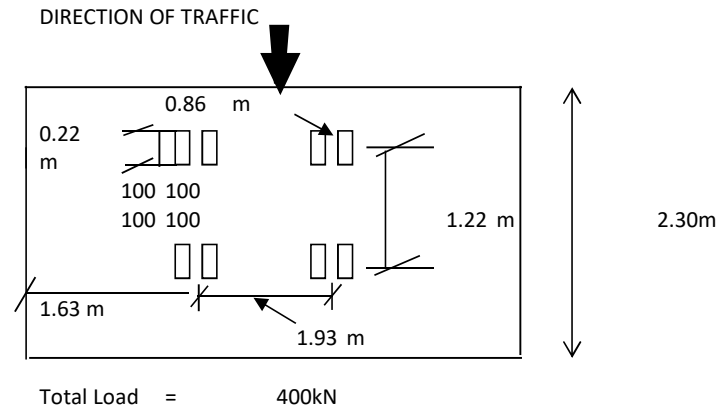
2.06 < 2.49

Therefore overlapping due to load dispersion occurs

Effective width = 4.55 m
 Width along span = 2.3 m
 Load Intensity = 33.66 kN/m²
 Increase due to impact = 42.08 kN/m²
 Say **42.10 kN/m²**

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

B) 40T Boggie Load at Mid Span



Effective width of Loading

a	=	1.15 m
b1	=	1.01 m
b/lo	=	5.22
a	=	2.60
beff	=	2.51 m

1.93 < 2.51 *Therefore overlapping due to load dispersion occurs*

Effective width	=	4.44 m
Width along span	=	2.19 m
Load Intensity	=	41.14 kN/m ²
Increase due to impact	=	51.43 kN/m ²
Say	=	51.50 kN/m²

C) 40T Boggie Load at Support

Effective width of Loading

a	=	0.61 m
b1	=	1.01 m
b/lo	=	5.22
a	=	2.60
beff	=	2.18 m

1.93 < 2.18 *Therefore overlapping due to load dispersion occurs*

Effective width	=	4.11 m
Width along span	=	1.815 m
Load Intensity	=	53.62 kN/m ²
Increase due to impact	=	67.03 kN/m ²
Say	=	67.10 kN/m²

D) 70R Track at Support

Effective width of Loading

a	=	1.15 m
b1	=	0.99 m
b/lo	=	5.22
a	=	2.60
beff	=	2.49 m

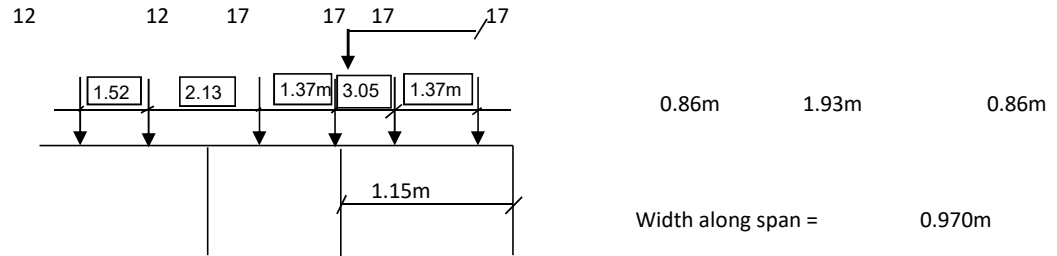
2.06 < 2.49 *Therefore overlapping due to load dispersion occurs*

Effective width	=	4.55 m
Width along span	=	2.300 m
Load Intensity	=	33.66 kN/m ²

	Project		0	Designed by:	KB
	Client		0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2		Date & Rev.	0

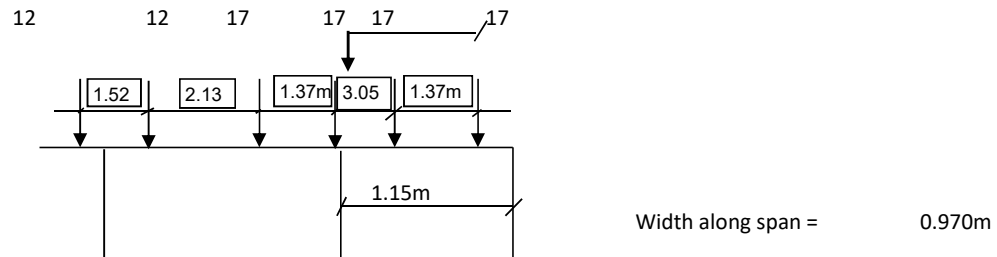
Increase due to impact = 42.08 kN/m²
 Say 42.10 kN/m²

F) 70R Wheel Case 1



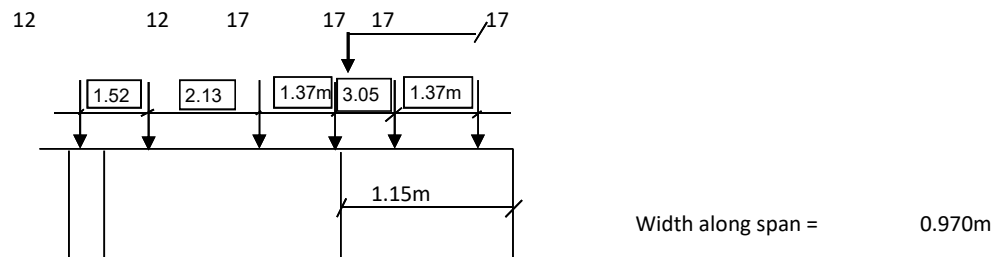
S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	0.49m	2.60	2.01m	Yes	3.94m	43.7 kN/sqm	55 kN/sqm
2	166.77	0.45m	2.60	1.94m	Yes	3.87m	44.4 kN/sqm	55 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

F) 70R Wheel Case 2



S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	0.485	2.60	2.01m	Yes	3.94m	43.7 kN/sqm	55 kN/sqm
2	166.77	0.445	2.60	1.94m	Yes	3.87m	44.4 kN/sqm	55 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

G) 70R Wheel Case 3

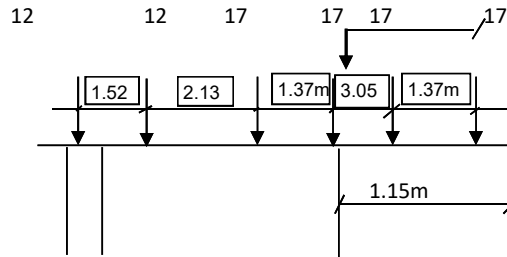


S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	0.485	2.60	2.01m	Yes	3.94m	43.7 kN/sqm	55 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

	Project		0	Designed by:	KB
	Client		0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2		Date & Rev.	0

0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

H) 70R Wheel Case 4



Width along span = 0.970m

S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	0.000	2.60	1.01m	No	1.01m	85.1 kN/sqm	106 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

G) Braking load		20%	Av. Eff. Width	Load per meter
Load on the span 70R Wheel	334 kN	67 kN	3.90m	17 kN/m
Load on the span 70R Track	352 kN	70 kN	4.55m	15 kN/m
Max. force				17 kN/m

Project	0	Designed by:	KB
Client	0	Checked by:	0
Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

3.2 Temperature load calculation

Effective Bridge Temperature

Maximum Air Shade temperature	=	47.9	/oC (as per Annexure F of IRC:6-2014)
Minimum Air Shade temperature	=	0.2	/oC (as per Annexure F of IRC:6-2014)
Mean of max and min temperature	=	23.85	/oC (as per clause 215.2 of IRC:6-2014)
Bridge temperature to be assumed	=	33.85	
TEMPERATURE RISE		33.85	
TEMPERATURE FALL		-34.05	

Effect of temperature gradient

The box has been checked for temperature differential.

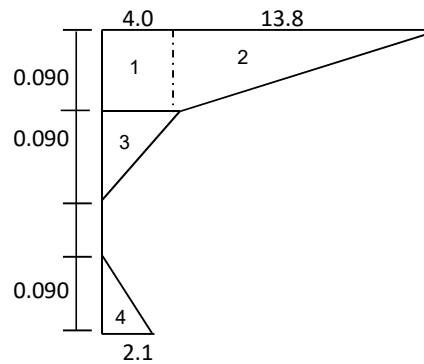
$$F = E_c aDt A$$

E_c = Modulus of Elasticity of Concrete	=	3.21E+06	t/m ²
a = Coefficient of Thermal expansion	=	1.20E-05	/oC (as per IRC:6)
Dt = Temperature differential			
A = X sectional Area of section where temperature differential is Dt			

Average thickness of Deck slab =

300 mm

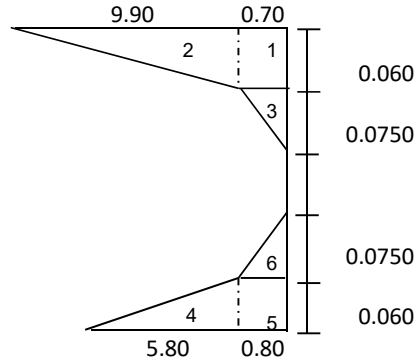
EFFECT OF TEMPERATURE RISE



Sr. No.	Dt	b	t	A = b x t	F (force)	Acting at	Eccentricity e*
1	4.0	1.0	0.090	0.090	13.88	0.045 m from top	0.105
2	$\frac{13.8}{2}$	1.0	0.100	0.100	26.60	0.033 m from top	0.117
3	$\frac{4.0}{2}$	1.0	0.090	0.090	6.94	0.120 m from top	0.030
4	$\frac{2.1}{2}$	1.0	0.090	0.090	3.64	0.030m from bottom	-0.120
					SF = 51.07	M = 4.332	

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

EFFECT OF TEMPERATURE FALL



Sr. No.	Dt	b	t	A = b x t	F (force)	Acting at	Eccentricity e*
1	0.70	1.0	0.060	0.060	1.62	0.03 m from top	0.120
2	$\frac{9.90}{2}$	1.0	0.060	0.060	11.45	0.020 m from top	0.130
3	$\frac{0.70}{2}$	1.0	0.0750	0.0750	1.01	0.085 m from top	0.065
4	$\frac{5.80}{2}$	1.0	0.060	0.060	6.71	0.020 m from bottom	-0.130
5	0.80	1.0	0.060	0.060	1.85	0.030 m from bottom	-0.120
6	$\frac{0.80}{2}$	1.0	0.0750	0.0750	1.16	0.085 m from bottom	-0.065
					SF = 23.80	M = 0.579	

Project	0
Client	0
Job Name	RCC BOX OF SIZE 1 x 2 x 2

3.3 Summary of factored moments

Grade of Concrete = M30
Grade of Steel = Fe500

Summary of factored moments

Load Case	Top slab			Bottom slab			Outer wall			
	Moment in Mid-Span	Moment at End Support	Top slab shear at	Moment in Mid-Span	Moment at End Support	Bottom slab shear	Min. Axial force	Moment at top	Moment at bottom	Wall shear at deff
	kN-m	kN-m	kN	kN-m	kN-m	kN	kN	kN-m	kN-m	kN
Basic Combination (33 - 62)	48.3	57	30	-	-	-	17	55	80	93
Rare Combination (63 -122)	33	42	206	43	65		14	39	62	70
Frequent Combination (123 - 182)	-	-	-	-	-	-	-	-	-	-
Quasi Static (183 - 186)	10	15		6	15			14	13	
Combination 1	-	-	-	65	86	123	-	-	-	-
Combination 2	-	-	-	58	80	122	-	-	-	-
	-	-	-	58	80	122	-	-	-	-

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

4.0 Partial Safety Factors

Material Parameters

Concrete

Refer Table 6.5, IRC:112-2011

Grade		=	M30
Cube strength of concrete at 28 days	f_{ck}	=	30 MPa
Design value of concrete compressive strength	f_{cd}	=	$\alpha f_{ck} / \gamma_m$
			a = 0.67
			Refer cl. 6.4.2.8 of IRC:112-2011
		f_{ctm}	= 2.5 MPa
For Basic Combination	f_{cd}	=	13.40 MPa
For Accidental Combination	f_{cd}	=	16.75 MPa
For Seismic Combination	f_{cd}	=	13.40 MPa
Modulus of Elasticity	E_c	=	31000 MPa
Mean value of axial tensile strength of concrete	f_{ctm}	=	2.5 MPa
Density		=	2.50 t/m ³
Grade		=	Fe500
Characteristics yield strength	f_{yk}	=	500 MPa
Design yield strength	f_{yd}	=	f_{yk} / γ_m
For Basic Combination	f_{yd}	=	434.78 MPa
For Accidental Combination	f_{yd}	=	500 MPa
For Seismic Combination	f_{yd}	=	434.78 MPa
Modulus of Elasticity	E_s	=	2.0E+05 MPa
Density		=	7.85 t/m ³

Partial Safety Factor for Materials

Material	Partial Safety Factor g_m			
	Basic Combination	Accidental Combination	Seismic Combination	
Concrete	1.5	1.2	1.5	Cl 6.4.2.8, IRC:112-2011
Steel	1.15	1	1.15	Cl 6.2.2, IRC:112-2011

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

Partial Safety Factor for Loads

Ultimate Limit State

Partial Safety for Verification of Structural Strength

Table 3.1, Annex B, IRC:6-2014

Also refer IRC Amendment dated 28th July, 2012

Loads	Partial Safety Factor					
	Basic Combination		Accidental Combination		Seismic Combination	
(1)	(2)	(3)	(4)	(5)	(4)	(3)
	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect
Permanent Loads:	1.05	0.95	1.00	1.00	1.05	0.95
Dead Load, SIDL except surfacing, Backfill Weight, Settlement, Creep and shrinkage effect						
Surfacing	1.35	1.00	1.00	1.00	1.35	1.00
Earth Pressure due to Backfill	1.50	0.00	1.00	0.00	1.00	0.00
Variable Loads:						
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:						
a) Leading Load	1.50	0.00	0.75	0.00	0.00	0.00
b) Accompanying Load	1.15	0.00	0.20	0.00	0.20	0.00
c) Construction Live Load	1.35	0.00	1.00	0.00	1.00	0.00
Thermal Loads						
a) As Leading Load	1.50	0.00	0.00	0.00	0.00	0.00
b) As Accompanying Load	0.90	0.00	0.50	0.00	0.50	0.00
Wind						
a) As Leading Load	1.50	0.00	0.00	0.00	0.00	0.00
b) As Accompanying Load	0.90	0.00	0.00	0.00	0.00	0.00
Live Load Surcharge (as accompanying load)	1.20	0.00	0.00	0.00	0.00	0.00
Accidental Effects:						
i) Vehicle Collision						
ii) Barge Impact	0.00	0.00	1.00	0.00	0.00	0.00
iii) Impact due to floating bodies						
Seismic Effect						
a) During Service	0.00	0.00	0.00	0.00	1.50	0.00
b) During Construction	0.00	0.00	0.00	0.00	0.75	0.00
Construction Condition:						
Counter Weights:						
a) When density or self weight is well defined	0.00	0.90	0.00	1.00	0.00	1.00
b) When density or self weight is not well defined	0.00	0.80	0.00	1.00	0.00	1.00
c) Erection effects	1.05	0.95	0.00	0.00	0.00	0.00
Wind						
a) As Leading Load	1.50	0.00	0.00	0.00	0.00	0.00
b) As Accompanying Load	1.20	0.00	0.00	0.00	0.00	0.00
Hydraulic Loads:						
(Accompanying Load):						
Water Current Forces	1.00	0.00	1.00	0.00	1.00	0.00
Wave Pressure	1.00	0.00	1.00	0.00	1.00	0.00
Hydrodynamic Effect	0.00	0.00	0.00	0.00	1.00	0.00
Buoyancy	1.00	0.00	1.00	0.00	1.00	0.00

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.:	0

Partial Safety for Verification of Structural Strength
Also refer IRC Amendment dated 28th July, 2012

Table 3.2, Annex B, IRC:6-2014

Loads	Partial Safety Factor		
	Basic Combination	Accidental Combination	Seismic Combination
(1)	(2)	(3)	(4)
Permanent Loads:			
Dead Load			
SIDL except surfacing			
a) Adding to the effect of variable loads	1.35	1.00	1.35
b) Relieving the effect of variable loads	1.00	1.00	1.00
Surfacing:			
a) Adding to the effect of variable loads	1.75	1.00	1.75
b) Relieving the effect of variable loads	1.00	1.00	1.00
Backfill Weight	1.50	1.00	1.00
Earth Pressure due to Backfill			
a) Leading Load	1.50	0.00	1.00
b) Accompanying Load	1.00	1.00	1.00
Variable Loads:			
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:			
a) Leading Load	1.50	0.75	0.00
b) Accompanying Load	1.15	0.20	0.20
c) Construction Live Load	1.35	1.00	1.00
Wind during service and construction			
a) Leading Load	1.50	0.00	0.00
b) Accompanying Load	0.90	0.00	0.00
Live Load Surcharge (as accompanying load)	1.20	0.20	0.20
Erection effects	1.00	1.00	1.00
Accidental Effects:			
i) Vehicle Collision			
ii) Barge Impact	0.00	1.00	0.00
iii) Impact due to floating bodies			
Seismic Effect			
a) During Service	0.00	0.00	1.50
b) During Construction	0.00	0.00	0.75
Hydraulic Loads (Accompanying Load):			
Water Current Forces	1.00	1.00	1.00
Wave Pressure	1.00	1.00	1.00
Hydrodynamic Effect	0.00	0.00	1.00
Buoyancy	0.15	0.15	0.15

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.:	0

Serviceability Limit State

Partial Safety for Verification of Serviceability Limit State **Table 3.3, Annex B, IRC:6-2014**

Loads	Partial Safety Factor		
	Rare Combination	Frequent Combination	Quasi-permanent
(1)	(2)	(3)	(4)
Permanent Loads:			
Dead Load	1.00	1.00	1.00
SIDL including surfacing	1.00	1.00	1.00
Backfill Weight	1.00	1.00	1.00
Shrinkage and Creep Effects	1.00	1.00	1.00
Earth Pressure due to Backfill	1.00	1.00	1.00
Settlement Effects			
a) Adding to the permanent loads	1.00	1.00	1.00
b) Opposing the permanent loads	0.00	0.00	0.00
Variable Loads:			
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:			
a) Leading Load	1.00	0.75	0.00
b) Accompanying Load	0.75	0.20	0.00
Thermal Loads:			
a) Leading Load	1.00	0.60	0.00
b) Accompanying Load			
Wind			
a) Leading Load	1.00	0.60	0.00
b) Accompanying Load	0.60	0.50	0.00
Live Load Surcharge (Accompanying load)	0.80	0.00	0.00
Hydraulic Loads (Accompanying Load):			
Water Current Forces	1.00	1.00	0.00
Wave Pressure	1.00	1.00	0.00
Buoyancy	0.15	0.15	0.15

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.:	0

Combination for Base Pressure and Design of Foundation

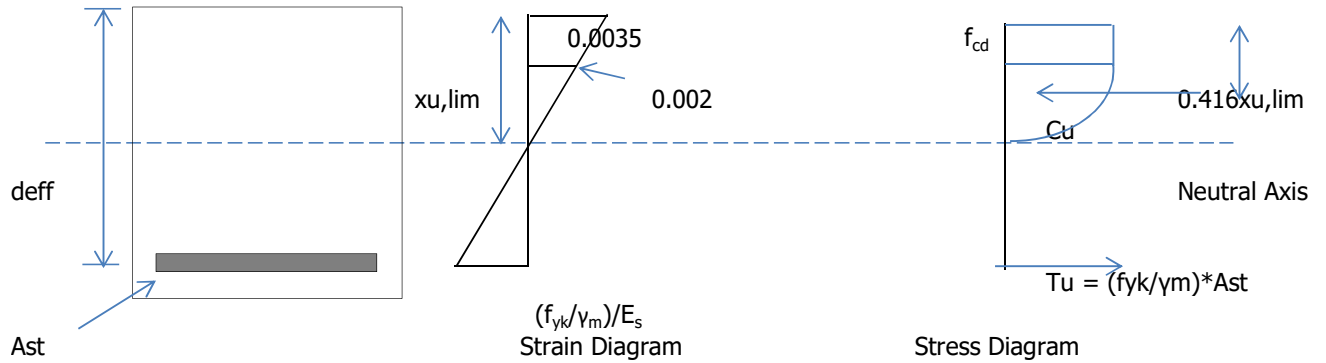
Table 3.4, Annex B, IRC:6-2014

Also refer IRC Amendment dated 28th July, 2012

Loads	Partial Safety Factor			
	Combination (1)	Combination (2)	Seismic Combination	Accidental Combination
(1)	(2)	(3)	(4a)	(4b)
Permanent Loads:				
Dead Load, SIDL except surfacing, Backfill earth filling	1.35	1.00	1.35	1.00
SIDL Surfacing	1.75	1.00	1.75	1.00
Settlement Effect	1.0 or 0	1.0 or 0	1.0 or 0	1.0 or 0
Earth Pressure due to Backfill				
a) Leading Load	1.50	1.30	0.00	0.00
b) Accompanying Load	1.00	0.85	1.00	1.00
Variable Loads:				
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:				
	1.50	1.30	(0.75 if applicable) or 0	(0.75 if applicable) or 0
a) Leading Load			0	or 0
b) Accompanying Load	1.15	1.00	0.20	0.20
Thermal Loads as accompanying load	0.90	0.80	0.50	0.50
Wind				
a) Leading Load	1.50	1.30	0.00	0.00
b) Accompanying Load	0.90	0.80	0.00	0.00
Live Load Surcharge (as accompanying load if applicable)	1.20	1.00	0.20	0.20
Accidental Effects or Seismic Effect:				
a) During Service	0.00	0.00	1.50	1.00
b) During Construction	0.00	0.00	0.75	0.50
Erection effects	1.00	1.00	1.00	1.00
Hydraulic Loads:				
Water Current	1.0 or 0	1.0 or 0	1.0 or 0	1.0 or 0
Wave Pressure	1.0 or 0	1.0 or 0	1.0 or 0	1.0 or 0
Hydrodynamic Effect	0.00	0.00	1.0 or 0	1.0 or 0
Buoyancy:				
For Base Pressure	1.00	1.00	1.00	1.00
For Structural Design	0.15	0.15	0.15	0.15

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

5.1.1 Verification of structural strength for top slab



ULTIMATE LIMIT STATE

Grade of Concrete	f_{ck}	=	30	N/mm ²	
As per clause 6.4.2.8, IRC:112-2011					
	f_{cd}	=	13.40	N/mm ²	For Basic Combination
	f_{cd}	=	16.75	N/mm ²	For Accidental Combination
	f_{cd}	=	13.40	N/mm ²	For Seismic Combination
	E_c	=	31000	MPa	
Grade of steel	f_y	=	500	N/mm ²	
	f_{yd}	=	435	N/mm ²	For Basic Combination
	f_{yd}	=	500	N/mm ²	For Accidental Combination
	f_{yd}	=	435	N/mm ²	For Seismic Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement = $\frac{0.87 f_y}{E_s} = \frac{0.87 \times 500}{2.0 \times 10^5} = 2.15 \times 10^{-3}$

$C_u = \frac{f_{cd} \cdot b \cdot (3/7 x_{u,lim} + 2/3 \cdot 4/7 x_{u,lim})}{17/21 \cdot f_{cd} \cdot b \cdot x_u} = 0.8095 \cdot f_{cd} \cdot b \cdot x_u$

cg of compression block from top = $0.416 x_u$

$T_u = f_{yd} \cdot A_{st}$

$R_{lim} = \frac{M_{u,lim}}{b d^2} = 0.8095 f_{cd} \cdot (x_{u,lim}/d) \cdot (1 - 0.416 \cdot x_{u,lim}/d)$

	Basic Comb	Accidental Comb	Seismic Comb
$x_{u,lim}/d$	0.62	0.58	0.62
$R_{lim} = M_{u,lim}/bd^2$	4.97	5.99	4.97

Here R_{lim} is in MPa

Calculation of Reinforcement

Width of section b	=	1000 mm
Depth of section D	=	300 mm
Clear cover	=	50

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

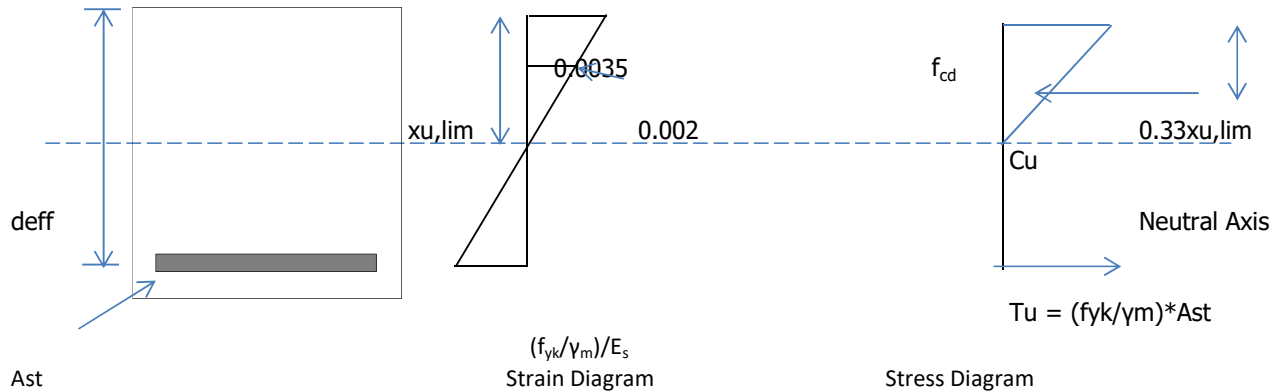
Moment on the section	Top slab Top End support			Top slab Bottom Mid Span		
	Basic Comb			Basic Comb		
Actual moment (KNm)	57.0			48.3		
b	1000			1000		
D	300			300		
c	50			50		
d	232.0			233.0		
f_{cd}	13.40			13.40		
f_{yd}	435			435		
$x_{u,lim}/d$	0.62			0.62		
$R_{sls} = M_{u,sls}/bd^2$	4.97			4.97		
$M_{u,Lim}$ (KNm)	268			270		
	OK			OK		
Ast Req.	590			494		
Dia of bar (main tension) (mm)	12			10		
Spacing (mm)	140			140		
+ dia of bar (main tension) (mm)	12			10		
Spacing (mm)	140			140		
Ast provided (sq mm)	1616			1122		
Dia of bar (main compression) (mm)	10			12		
Spacing (mm)	140			140		
Area of main compression (mm ²)	561			808		
f_{ctm}	2.5			2.5		
f_{yk}	435			435		
cl. 16.6.1 (2) of IRC :112-2011						
$A_{s,min} = 0.26 f_{ctm} b_t d / f_{yk} \geq 0.0013 b_t d$	347			348		
A_{ct}	235240			255028		
$f_{ct,eff}$	2.9			2.9		
$k_c = 0.4 \{ 1 - s_c / (k_1 f_{ct,eff} h/h^*) \} \leq 1$	0.4			0.4		
For Bending or bending combined with axial force						
k	1.0000			1.0000		
s_s	435			435		
$A_{s,max} = 0.025 A_c$ (main tension)	7500			7500		
cl. 16.5.1.1 (2) of IRC :112-2011	OK			OK		
$A_{s,max} = 0.04 A_c$ (tension + compression)	12000			12000		
x (mm)	65			45		
x/d	0.279			0.193		
	OK			OK		
z (mm)	205			214		
MR (KNm)	144			105		
	OK			OK		

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

Shear on the section	Top slab Top End support		
Actual shear V_{Ed} (KN)	30.0		
Actual shear stress (N/mm ²)	0.144		
Max shear capacity, $0.135 f_{ck}(1-f_{ck}/310)$	3.7		
	OK.		
Min shear capacity, $0.0924 f_{ck}(1-f_{ck}/310)$	2.5		
$\Theta = 0.5 \times \sin^{-1}$ (Applied shear stress / $0.135/f_{ck}/(1-f_{ck}/310)$)			
Min angle of inclination, Θ (deg)	21.8		
cl. 10.3.2(2) Eq. 10.2 of IRC :112-2010			
$K = 1 + \sqrt{200/d} \leq 2.0$	1.928		
cl. 10.3.2(2) Eq. 10.3 of IRC :112-2010			
$\eta_{min} = 0.031 K^{3/2} f_{ck}^{1/2}$	0.455		
cl. 10.3.1 of IRC :112-2011			
$r_1 = A_{sl}/(b_w d) \leq 0.02$	0.007		
	OK		
$0.12 K (80 r_1 f_{ck})^{0.33}$	0.586		
Axial compressive force N_{Ed} (KN)	0		
$s_{cp} = N_{Ed} / A_c \leq 0.2 f_{cd}$	0.0		
cl. 10.3.2(2) Eq. 10.1 of IRC :112-2010			
$V_{Rd,c} = [0.12K(80\rho_1 f_{ck})^{0.33} + 0.15\sigma_{cp}]b_w d \leq (n_{min} + 0.15 s_{cp}) b_w d$ (KN)	105		
	OK.		
Min shear stress	0.455		
Min shear force for providing reinf., V_E (N)	94945.5		
No. of link for shear reinf.	4		
Dia. of bar for shear reinf.	12		
$S = A_{sw} \times 0.9 \times d \times \cot \Theta \times f_y / V_E$	1081		
A_{sw}	452		
cl. 16.5.2(7) Eq. 16.6 of IRC :112-2011			
$S_{l,max} = 0.75 d$	174		
Spacing provided in Long. Direction (mm)	174.0		
cl. 16.5.2(9) Eq. 16.8 of IRC :112-2011			
$S_{t,max} = 0.75 d \leq 600\text{mm}$	174		
Spacing provided in Trans. Direction, S_t mm	150		
	OK		

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

5.1.2 Verification for serviceability limit state for top slab



SERVICEABILITY LIMIT STATE

Grade of Concrete
As per clause 12.2.1, IRC:112-2011

$$f_{ck} = 30 \text{ N/mm}^2$$

$$f_{cd} = 14.40 \text{ N/mm}^2 \text{ For Rare Combination}$$

$$f_{cd} = 14.40 \text{ N/mm}^2 \text{ For Frequent Combination}$$

$$f_{cd} = 10.80 \text{ N/mm}^2 \text{ For Quasi-Perma. Combination}$$

As per clause 12.2.2, IRC:112-2011

Grade of steel

$$f_y = 500 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2 \text{ For Rare Combination}$$

$$f_{yd} = 300 \text{ N/mm}^2 \text{ For Frequent Combination}$$

$$f_{yd} = 300 \text{ N/mm}^2 \text{ For Quasi-Perma. Combination}$$

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

$$\text{Minimum strain in steel reinforcement} = 0.87 f_y / E_s$$

$$E_s = 2.0E+05 \text{ MPa}$$

$$E_c = 31000 \text{ MPa}$$

$$C_u = 1/2 * f_{cd} * b * x_u$$

$$= 0.5 * f_{cd} * b * x_u$$

cg of compression block from top

$$= 0.33 x_u$$

$$T_u = f_{yd} * A_{st}$$

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

$$R_{sls} = M_{u,sls} / b d^2 = 0.5 f_{cd} * (x_u/d) * (1 - 0.33 * x_u/d)$$

	Rare Comb	Frequent Comb	Quasi-Perma. Comb
$x_{u,sls}/d$	0.70	0.70	0.70
$R_{sls} = M_{u,sls} / b d^2$	3.88	3.88	2.91

Here R_{sls} is in MPa

Calculation of Reinforcement

Width of section b = 1000 mm

Depth of section d = 300 mm

Clear cover = 40

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

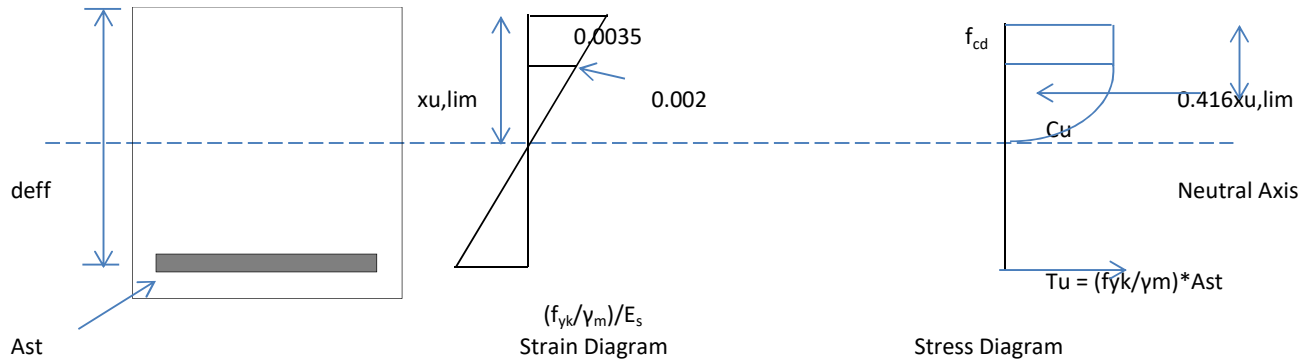
Moment on the section	Top slab Top End support			Top slab Bottom Mid Span		
	Rare Comb		Quasi-Perma. Comb	Rare Comb		Quasi-Perma. Comb
Actual moment (KNm)	42.0		15.0	33		10
b	1000		1000	1000		1000
D	300		300	300		300
c	40		40	40		40
d	242.0		242.0	243.0		243.0
f_{cd}	14.40		10.80	14.40		10.80
f_{yd}	300		300	300		300
$x_{u,sls}/d$	0.70		0.70	0.70		0.70
$R_{sls} = M_{u,sls}/bd^2$	3.88		2.91	3.88		2.91
$M_{u,sls}$ (KNm)	227		170	229		172
	OK		OK	OK		OK
Ast Req.	599		210	465		139
Dia of bar (main tension) (mm)	12		12	10		10
Spacing (mm)	140		140	140		140
+ dia of bar (main tension) (mm)	12		12	10		10
Spacing (mm)	140		140	140		140
Ast provided (sq mm)	1616		1616	1122		1122
Dia of bar (main compression) (mm)	10		10	12		12
Spacing (mm)	140		140	140		140
Area of main compression (mm ²)	561		561	808		808
f_{ctm}	2.5		2.5	2.5		2.5
x (mm)	67.3		89.8	46.7		62.3
x/d	0.278		0.371	0.192		0.257
	OK		OK	OK		OK
z (mm)	220		212	228		222
MR_{sls} (KNm)	107		103	77		75
	OK		OK	OK		OK
$s_{sc} = M/(A_s z)$	118		44	129		40
	OK		OK	OK		OK
$s_{ca} = M/(0.8095 z b x_u)$	5.68		1.57	6.20		1.44
	OK		OK	OK		OK

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

Calculation of crack width	Top slab Top End support		Top slab Bottom Mid Span	
n_1		7		7
n_2		7		7
$f_{eq} = (n_1 f_1^2 + n_2 f_2^2) / (n_1 f_1 + n_2 f_2)$		12		10
cl. 12.3.4 (3) of IRC :112-2011				
c		40		40
k_1		0.8		0.8
k_2		0.50		0.50
For skew slab refer eq. 12.10 of IRC :112-2011				
$r_{p,eff} = A_s / A_{c,eff}$		0.014		0.010
$S_{r,max} = \{ 3.4 c + (0.425 k_1 k_2 f) / r_{p,eff} \}$		281		306
cl. 12.3.4 (3) of IRC :112-2011				
k_t		0.5		0.5
$f_{ct,eff}$		2.90		2.90
E_s		200000		200000
E_{cm}		31000		31000
$a_e = E_s / E_{cm}$		6.45		6.45
$(e_{sm} - e_{cm}) = (s_{sc} - k_t f_{ct,eff} (1 + a_e r_{p,eff}) / r_{p,eff}) / E_s$ $\geq 0.6 s_{sc} / E_s$		0.0001		0.0001
cl. 12.3.4 (2) of IRC :112-2011				
$W_k = S_{r,max} (e_{sm} - e_{cm})$		0.037		0.04
cl. 12.3.4 (1) of IRC :112-2011				
		OK	OK	OK
Calculation of deflection				
Span (mm)				2300
span/800				2.9
cl. 12.4.1 (2) of IRC :112-2011				
Short term elastic deflection from STAAD				0.2
				OK

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

5.2.1 Verification of structural strength for bottom slab



ULTIMATE LIMIT STATE

Grade of Concrete	f_{ck}	=	30	N/mm ²	
As per clause 6.4.2.8, IRC:112-2011					
	f_{cd}	=	13.40	N/mm ²	Combination (1)
	f_{cd}	=	16.75	N/mm ²	Accidental Combi.
	f_{cd}	=	13.40	N/mm ²	Combination (2)
	E_c	=	31000	MPa	
Grade of steel	f_y	=	500	N/mm ²	
	f_{yd}	=	435	N/mm ²	Combination (1)
	f_{yd}	=	500	N/mm ²	Accidental Combi.
	f_{yd}	=	435	N/mm ²	Combination (2)

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement = $0.87 f_y / E_s$
 $E_s = 2.0E+05$ MPa

$E_c = 31000$ MPa

$$C_u = \frac{f_{cd} \cdot b \cdot (3/7 x_{u,lim} + 2/3 \cdot 4/7 x_{u,lim})}{17/21 \cdot f_{cd} \cdot b \cdot x_u} = 0.8095 \cdot f_{cd} \cdot b \cdot x_u$$

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

cg of compression block from top = $0.416 x_u$

$T_u = f_{yd} \cdot A_{st}$

$$R_{lim} = M_{u,lim} / b d^2 = 0.8095 f_{cd} \cdot (x_{u,lim} / d) \cdot (1 - 0.416 \cdot x_{u,lim} / d)$$

	Basic Comb	Accidental Comb	Seismic Comb
$x_{u,lim} / d$	0.62	0.58	0.62
$R_{lim} = M_{u,lim} / b d^2$	4.97	5.99	4.97

Here R_{lim} is in MPa

Calculation of Reinforcement

Width of section b	=	1000	mm
Depth of section D	=	325	mm
Clear cover at bott.	=	75	mm
Clear cover at top	=		40

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

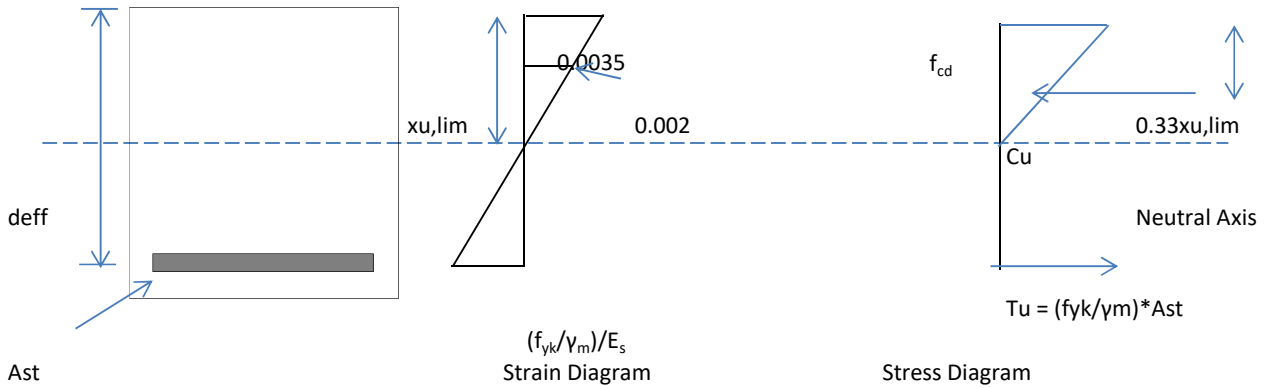
Moment on the section	Bottom End support		Top Mid Span		
	Combinatio n (1)		Combinatio n (2)	Combinatio n (1)	Combinatio n (2)
Actual moment (KNm)	86.0		80.0	65.0	58.0
b	1000		1000	1000	1000
D	325		325	325	325
c	75		75	40	40
d	232.0		232.0	268.0	268.0
f _{cd}	13.40		13.40	13.40	13.40
f _{yd}	435		435	435	435
x _{u,lim} /d	0.62		0.62	0.62	0.62
$R_{sls} = M_{u,sls}/bd^2$	4.97		4.97	4.97	4.97
M _{u,Lim} (KNm)	268		268	357	357
	OK		OK	OK	OK
Ast Req.	912		844	579	514
Dia of bar (main tension) (mm)	12		12	10	10
Spacing (mm)	140		140	140	140
+ dia of bar (main tension) (mm)	12		12	10	10
Spacing (mm)	140		140	140	140
Ast provided (sq mm)	1616		1616	1122	1122
Dia of bar (main compression) (mm)	10		10	12	12
Spacing (mm)	140		140	140	140
Area of main compression (mm ²)	561		561	808	808
f _{ctm}	2.5		2.5	2.5	2.5
f _{yk}	435		435	435	435
cl. 16.6.1 (2) of IRC :112-2011					
$A_{s,min} = 0.26 f_{ctm} b_t d / f_{yk} \geq 0.0013 b_t d$	347		347	401	401
A _{ct}	260240		260240	280028	280028
f _{ct,eff}	2.9		2.9	2.9	2.9
$k_c = 0.4 \{ 1 - s_c / (k_1 f_{ct,eff} h/h^*) \} \leq 1$	0.4		0.4	0.4	0.4
For Bending or bending combined with axial force					
k	0.9825		0.9825	0.9825	0.9825
s _s	435		435	435	435
A _{s,max} = 0.025 A _c (main tension)	8125		8125	8125	8125
cl. 16.5.1.1 (2) of IRC :112-2011	OK		OK	OK	OK
A _{s,max} = 0.04 A _c (tension + compression)	13000		13000	13000	13000
x (mm)	65		65	45	45
x/d	0.279		0.279	0.168	0.168
	OK		OK	OK	OK
z (mm)	205		205	249	249
MR (KNm)	144		144	122	122
	OK		OK	OK	OK

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

Shear on the section	Bottom End support		
Actual shear V_{Ed} (KN)	123.0		122.0
Actual shear stress (N/mm ²)	0.589		0.584
Max shear capacity, $0.135 f_{ck}(1-f_{ck}/310)$	3.7		3.7
	OK.		OK.
Min shear capacity, $0.0924 f_{ck}(1-f_{ck}/310)$	2.5		2.5
$\Theta = 0.5 \times \sin^{-1}$ (Applied shear stress / $0.135/f_{ck}/(1-f_{ck}/310)$)			
Min angle of inclination, Θ (deg)	21.8		21.8
cl. 10.3.2(2) Eq. 10.2 of IRC :112-2010			
$K = 1 + \sqrt{200/d} \leq 2.0$	1.928		1.928
cl. 10.3.2(2) Eq. 10.3 of IRC :112-2010			
$n_{min} = 0.031 K^{3/2} f_{ck}^{1/2}$	0.455		0.455
cl. 10.3.1 of IRC :112-2011			
$r1 = A_{sl}/(b_w d) \leq 0.02$	0.007		0.007
	OK		OK
$0.12 K (80 r1 f_{ck})^{0.33}$	0.586		0.6
Axial compressive force N_{Ed} (KN)	0		0
$s_{cp} = N_{Ed} / A_c \leq 0.2 f_{cd}$	0.0		0.0
cl. 10.3.2(2) Eq. 10.1 of IRC :112-2010			
$V_{Rd,c} = [0.12K(80\rho_1 f_{ck})^{0.33} + 0.15\sigma_{cp}]b_w d \leq (n_{min} + 0.15 s_{cp}) b_w d$ (KN)	105		105
	Provide Shear Reinf.		Provide Shear Reinf.

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

5.2.2 Verification for serviceability limit state for bottom slab



SERVICEABILITY LIMIT STATE

Grade of Concrete
As per clause 12.2.1, IRC:112-2011

f_{ck}	=	30	N/mm ²	
f_{cd}	=	14.40	N/mm ²	For Rare Combination
f_{cd}	=	14.40	N/mm ²	For Frequent Combination
f_{cd}	=	10.80	N/mm ²	For Quasi-Perma. Combination

As per clause 12.2.2, IRC:112-2011
Grade of steel

f_y	=	500	N/mm ²	
f_{yd}	=	300	N/mm ²	For Rare Combination
f_{yd}	=	300	N/mm ²	For Frequent Combination
f_{yd}	=	300	N/mm ²	For Quasi-Perma. Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement	=	0.87 f_y / E_s	
E_s	=	2.0E+05 MPa	$E_c = 31000$ MPa

$$C_u = \frac{1}{2} f_{cd} b x_u$$

$$= 0.5 f_{cd} b x_u$$

cg of compression block from top = 0.33 x_u

$$T_u = f_{yd} A_{st}$$

$$R_{s_{sls}} = M_{u,sls} / b d^2 = 0.5 f_{cd} (x_u/d) (1 - 0.33 x_u/d)$$

	Rare Comb	Frequent Comb	Quasi-Perma. Comb
$x_{u,sls}/d$	0.70	0.70	0.70
$R_{s_{sls}} = M_{u,sls} / b d^2$	3.88	3.88	2.91

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

Here $R_{s_{sls}}$ is in MPa

Calculation of Reinforcement

Width of section b	=	1000 mm	
Depth of section d	=	325 mm	
Clear cover at bott.	=	75	Clear cover at top = 40

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

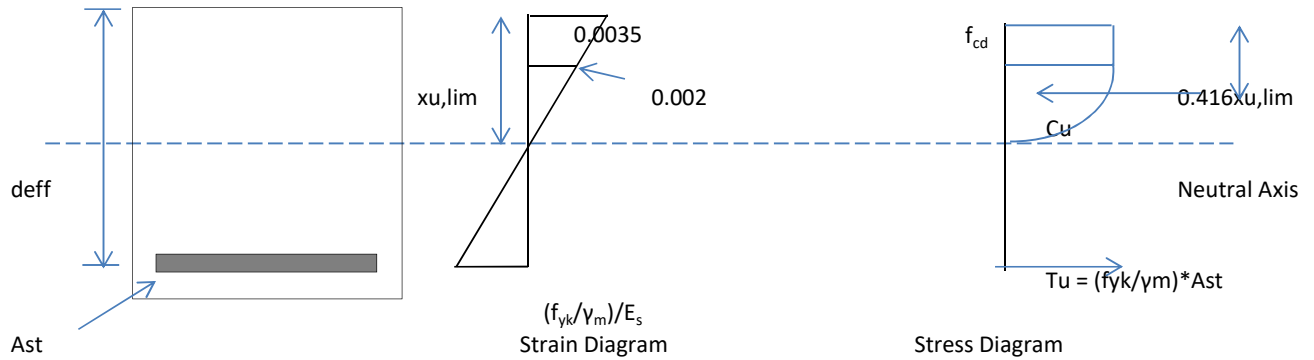
Moment on the section	Bottom End support			Top Mid Span		
	For Rare Combination		For Quasi-Perma. Combination	For Rare Combination		For Quasi-Perma. Combination
Actual moment (KNm)	65.0		15.0	43		6
b	1000		1000	1000		1000
D	325		325	325		325
c	75		75	40		40
d	232.0		232.0	268.0		268.0
f_{cd}	14.40		10.80	14.40		10.80
f_{yd}	300		300	300		300
$x_{u,sls}/d$	0.70		0.70	0.70		0.70
$R_{sls} = M_{u,sls}/bd^2$	3.88		2.91	3.88		2.91
$M_{u,sls}$ (KNm)	209		156	278		209
	OK		OK	OK		OK
Ast Req.	992		219	550		75
Dia of bar (main tension) (mm)	12		12	10		10
Spacing (mm)	140		140	140		140
+ dia of bar (main tension) (mm)	12		12	10		10
Spacing (mm)	140		140	140		140
Ast provided (sq mm)	1616		1616	1122		1122
Dia of bar (main compression) (mm)	10		10	12		12
Spacing (mm)	140		140	140		140
Area of main compression (mm ²)	561		561	808		808
f_{ctm}	2.5		2.5	2.5		2.5
x (mm)	67.3		89.8	46.7		62.3
x/d	0.290		0.387	0.174		0.233
	OK		OK	OK		OK
z (mm)	210		202	253		247
MR_{sls} (KNm)	102		98	85		83
	OK		OK	OK		OK
$s_{sc} = M/(A_s z)$	192		46	152		22
	OK		OK	OK		OK
$s_{ca} = M/(0.8095 z b x_u)$	9.21		1.65	7.28		0.78
	OK		OK	OK		OK

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

Calculation of crack width	Bottom End support		Top Mid Span	
n_1			7	7
n_2			7	7
$f_{eq} = (n_1 f_1^2 + n_2 f_2^2) / (n_1 f_1 + n_2 f_2)$			12	10
cl. 12.3.4 (3) of IRC :112-2011				
c			75	40
k1			0.8	0.8
k2			0.50	0.50
For skew slab refer				
$r_{p,eff} = A_s / A_{c,eff}$			0.010	0.010
$S_{r,max} = \{ 3.4 c + (0.425 k_1 k_2 f) / r_{p,eff} \}$			460	306
cl. 12.3.4 (3) of IRC :112-2011				
k_t			0.5	0.5
$f_{ct,eff}$			2.90	2.90
E_s			200000	200000
E_{cm}			31000	31000
$a_e = E_s / E_{cm}$			6.45	6.45
$(e_{sm} - e_{cm}) = (s_{sc} - k_t f_{ct,eff} (1 + a_e r_{p,eff}) / r_{p,eff}) / E_s$ $\geq 0.6 s_{sc} / E_s$			0.0001	0.0001
cl. 12.3.4 (2) of IRC :112-2011				
$W_k = S_{r,max} (e_{sm} - e_{cm})$			0.06	0.02
cl. 12.3.4 (1) of IRC :112-2011				
			OK	OK

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

5.3.1 Verification of structural strength for outer wall



ULTIMATE LIMIT STATE

Grade of Concrete	f_{ck}	=	30	N/mm ²	
As per clause 6.4.2.8, IRC:112-2011					
	f_{cd}	=	13.40	N/mm ²	For Basic Combination
	f_{cd}	=	16.75	N/mm ²	For Accidental Combination
	f_{cd}	=	13.40	N/mm ²	For Seismic Combination
	E_c	=	31000	MPa	
Grade of steel	f_y	=	500	N/mm ²	
	f_{yd}	=	435	N/mm ²	For Basic Combination
	f_{yd}	=	500	N/mm ²	For Accidental Combination
	f_{yd}	=	435	N/mm ²	For Seismic Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement = $0.87 f_y / E_s$
 $E_s = 2.0E+05$ MPa

$E_c = 31000$ MPa

$$C_u = \frac{f_{cd} \cdot b \cdot (3/7 x_{u,lim} + 2/3 \cdot 4/7 x_{u,lim})}{17/21 \cdot f_{cd} \cdot b \cdot x_u} = 0.8095 \cdot f_{cd} \cdot b \cdot x_u$$

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

cg of compression block from top = $0.416 x_u$

$T_u = f_{yd} \cdot A_{st}$

$$R_{lim} = M_{u,lim} / b d^2 = 0.8095 f_{cd} \cdot (x_{u,lim} / d) \cdot (1 - 0.416 \cdot x_{u,lim} / d)$$

	Basic Comb	Accidental Comb	Seismic Comb
$x_{u,lim} / d$	0.62	0.58	0.62
$R_{lim} = M_{u,lim} / b d^2$	4.97	5.99	4.97

Here R_{lim} is in MPa

Calculation of Reinforcement

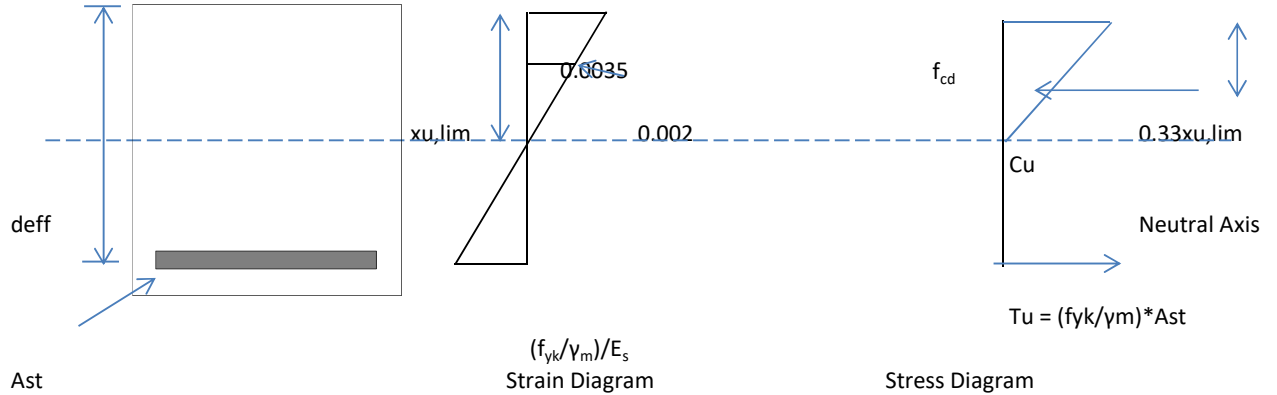
Width of section b	=	1000 mm
Depth of section D	=	300 mm
Clear cover	=	75

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

Moment on the section	Bottom End support			Top End support		
	Basic Comb			Basic Comb		
Actual moment (KNm)	80.0			55.0		
b	1000			1000		
D	300			300		
c	75			75		
d	207.0			207.0		
f_{cd}	13.40			13.40		
f_{yd}	435			435		
xu_{lim}/d	0.62			0.62		
$R_{sls} = M_{u,sls}/bd^2$	4.97			4.97		
$M_{u,Lim}$ (KNm)	213			213		
	OK			OK		
Ast Req.	964			645		
Dia of bar (main tension) (mm)	12			12		
Spacing (mm)	140			140		
+ dia of bar (main tension) (mm)	12			12		
Spacing (mm)	140			140		
Ast provided (sq mm)	1616			1616		
Dia of bar (main compression) (mm)	10			10		
Spacing (mm)	140			140		
Area of main compression (mm ²)	561			561		
f_{ctm}	2.5			2.5		
f_{yk}	435			435		
cl. 16.6.1 (2) of IRC :112-2011						
$A_{s,min} = 0.26 f_{ctm} b_t d / f_{yk} \geq 0.0013 b_t d$	309			309		
A_{ct}	235240			235240		
$f_{ct,eff}$	2.9			2.9		
$k_c = 0.4 \{ 1 - s_c / (k_1 f_{ct,eff} h/h^*) \} \leq 1$	0.4			0.4		
For Bending or bending combined with axial force						
k	1.0000			1.0000		
s_s	435			435		
As.max = 0.025 Ac (main tension)	7500			7500		
cl. 16.5.1.1 (2) of IRC :112-2011	OK			OK		
As.max = 0.04 Ac (tension + compression)	12000			12000		
x (mm)	65			65		
x/d	0.313			0.313		
	OK			OK		
z (mm)	180			180		
MR (KNm)	126			126		
	OK			OK		

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

5.3.2 Verification for serviceability limit state for outer wall



SERVICEABILITY LIMIT STATE

Grade of Concrete
As per clause 12.2.1, IRC:112-2011

$$f_{ck} = 30 \text{ N/mm}^2$$

$$f_{cd} = 14.40 \text{ N/mm}^2$$

$$f_{cd} = 14.40 \text{ N/mm}^2$$

$$f_{cd} = 10.80 \text{ N/mm}^2$$

For Rare Combination
For Frequent Combination
For Quasi-Perma. Combination

As per clause 12.2.2, IRC:112-2011

Grade of steel

$$f_y = 500 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

For Rare Combination
For Frequent Combination
For Quasi-Perma. Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement = $0.87 f_y / E_s$

$$E_s = 2.0E+05 \text{ MPa}$$

$$E_c = 31000 \text{ MPa}$$

$$C_u = 1/2 * f_{cd} * b * x_u$$

$$= 0.5 * f_{cd} * b * x_u$$

cg of compression block from top =

$$0.33 x_u$$

$$T_u = f_{yd} * A_{st}$$

$$R_{sls} = M_{u,sls} / b d^2 = 0.5 f_{cd} * (x_u/d) * (1 - 0.33 * x_u/d)$$

Refer Chapter 5 of Reinforced Concrete
Limit State Design by Ashok K. Jain

	Rare Comb	Frequent Comb	Quasi-Perma. Comb
$x_{u,sls}/d$	0.70	0.70	0.70
$R_{sls} = M_{u,sls}/bd^2$	3.88	3.88	2.91

Here R_{sls} is in MPa

Calculation of Reinforcement

$$\text{Width of section } b = 1000 \text{ mm}$$

$$\text{Depth of section } d = 300 \text{ mm}$$

$$\text{Clear cover} = 75$$

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

Moment on the section	Bottom End support			Top End support		
	Rare Comb		Quasi-Perma. Comb	Rare Comb		Quasi-Perma. Comb
Actual moment (KNm)	62.0		13.0	39		14
b	1000		1000	1000		1000
D	300		300	300		300
c	75		75	75		75
d	207.0		207.0	207.0		207.0
f_{cd}	14.40		10.80	14.40		10.80
f_{yd}	300		300	300		300
$x_{u,sls}/d$	0.70		0.70	0.70		0.70
$R_{sls} = M_{u,sls}/bd^2$	3.88		2.91	3.88		2.91
$M_{u,sls}$ (KNm)	166		125	166		125
	OK		OK	OK		OK
Ast Req.	1075		213	657		230
Dia of bar (main tension) (mm)	12		12	12		12
Spacing (mm)	140		140	140		140
+ dia of bar (main tension) (mm)	12		12	12		12
Spacing (mm)	140		140	140		140
Ast provided (sq mm)	1616		1616	1616		1616
Dia of bar (main compression) (mm)	10		10	10		10
Spacing (mm)	140		140	140		140
Area of main compression (mm ²)	561		561	561		561
f_{ctm}	2.5		2.5	2.5		2.5
x (mm)	67.3		89.8	67.3		89.8
x/d	0.325		0.434	0.325		0.434
	OK		OK	OK		OK
z (mm)	185		177	185		177
MR_{sls} (KNm)	90		86	90		86
	OK		OK	OK		OK
$s_{sc} = M/(A_s z)$	208		45	131		49
	OK		OK	OK		OK
$s_{ca} = M/(0.8095 z b x_u)$	9.97		1.63	6.27		1.76
	OK		OK	OK		OK

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

Calculation of crack width	Bottom End support		Top End support	
n_1			7	7
n_2			7	7
$f_{eq} = (n_1 f_1^2 + n_2 f_2^2) / (n_1 f_1 + n_2 f_2)$			12	12
cl. 12.3.4 (3) of IRC :112-2011				
c			75	75
k1			0.8	0.8
k2			0.50	0.50
For skew slab refer eq. 12.10 of IRC :112-2011				
$r_{p,eff} = A_s / A_{c,eff}$			0.011	0.011
$S_{r,max} = \{ 3.4 c + (0.425 k_1 k_2 f) / r_{p,eff} \}$			444	444
cl. 12.3.4 (3) of IRC :112-2011				
k_t			0.5	0.5
$f_{ct,eff}$			2.90	2.90
E_s			200000	200000
E_{cm}			31000	29626
$a_e = E_s / E_{cm}$			6.45	6.75
$(e_{sm} - e_{cm}) = (s_{sc} - k_t f_{ct,eff} (1 + a_e r_{p,eff}) / r_{p,eff}) / E_s$ $>= 0.6 s_{sc} / E_s$			0.0001	0.0001
cl. 12.3.4 (2) of IRC :112-2011				
$W_k = S_{r,max} (e_{sm} - e_{cm})$			0.06	0.07
cl. 12.3.4 (1) of IRC :112-2011				
			OK	OK

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2	Date & Rev.	0

6.0 Summary of provided Reinforcement

Provided Reinforcement

Top Slab

<u>At top of Mid Span</u>			Required
Area of Steel Provided	=	807.8 mm ² /m	347
12mm dia @		140mmc/c Top slab (Top main reinforcement)	
<u>At bottom of Mid Span</u>			
Area of Steel Provided	=	1122.0 mm ² /m	
10mm dia @		140mmc/c Top slab (Bottom main reinforcement)	
10mm dia @		140mmc/c Top slab (Bottom extra reinforcement)	OK
<u>At top of End Support</u>			
Area of Steel Provided	=	1615.7 mm ² /m	
12mm dia @		140mmc/c Top slab (Top main reinforcement)	
12mm dia @		140mmc/c Outer wall (Outer main reinforcement)	OK
0mm dia @		140mmc/c Top corner extra reinforcement	
<u>At bottom of End Support</u>			
Area of Steel Provided	=	561.0 mm ² /m	
10mm dia @		140mmc/c Top slab (Bottom main reinforcement)	OK
0mm dia @		140mmc/c	

Bottom Slab

<u>At top of Mid Span</u>			
Area of Steel Provided	=	1122.0 mm ² /m	
10mm dia @		140mmc/c Bottom slab (Top main reinforcement)	
10mm dia @		140mmc/c Bottom slab (Top extra reinforcement)	OK
<u>At bottom of Mid Span</u>			
Area of Steel Provided	=	807.8 mm ² /m	
12mm dia @		140mmc/c Bottom slab (Bottom main reinforcement)	
0mm dia @		140mmc/c Bottom slab (Bottom extra reinforcement)	
<u>At top of End Support</u>			
Area of Steel Provided	=	561.0 mm ² /m	
10mm dia @		140mmc/c Bottom slab (Top main reinforcement)	OK
0mm dia @		140mmc/c	
<u>At bottom of End Support</u>			
Area of Steel Provided	=	1615.7 mm ² /m	
12mm dia @		140mmc/c Bottom slab (Bottom main reinforcement)	
12mm dia @		140mmc/c Outer wall (Outer main reinforcement)	OK
0mm dia @		140mmc/c Bottom corner extra reinforcement	

	Project	0	Designed by:	KB
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Outer Wall

At outer face of top end

Area of Steel Provided	=	1615.7 mm ² /m	
12mm dia @ 140mmc/c		Outer wall (Outer main reinforcement)	
12mm dia @ 140mmc/c		Top slab (Top main reinforcement)	OK
0mm dia @ 140mmc/c		Top corner extra reinforcement	

At inner face of top end

Area of Steel Required	=	313.8 mm ² /m	
Area of Steel Provided	=	561.0 mm ² /m	
10mm dia @ 140mmc/c		Outer wall (Inner main reinforcement)	OK

At outer face of bottom end

Area of Steel Provided	=	1615.7 mm ² /m	
12mm dia @ 140mmc/c		Bottom slab (Bottom main reinforcement)	
12mm dia @ 140mmc/c		Outer wall (Outer main reinforcement)	OK
0mm dia @ 140mmc/c		Bottom corner extra reinforcement	

At inner face of bottom end

Area of Steel Provided	=	561.0 mm ² /m	
10mm dia @ 140mmc/c		Outer wall (Inner main reinforcement)	

Shear Reinforcement

Bottom Slab

12mm dia	225mmc/c (Long. Direc	0	198.304 kN
12mm dia	140mmc/c (Trans. Direction)		

Distribution Reinforcement

As per cl. 16.6.1.1 (3) of IRC :112-2011

Top Slab

Req. Reinforcement	=	174 mm ² /m	
Provided Reinforcement	=		
12mm dia @ 225mmc/c		502.7 mm ² /m	OK

Bottom Slab

Req. Reinforcement	=	200.3 mm ² /m	
Provided Reinforcement	=		
12mm dia @ 225mmc/c		502.7 mm ² /m	OK

Outer Wall

Req. Reinforcement	=	192.7 mm ² /m	
Provided Reinforcement	=		
12mm dia @ 225mmc/c		502.7 mm ² /m	OK

	Project	0		KB
	Client	0		0
	Job Name	RCC BOX OF SIZE 1 x 2 x 2		0

7.0 Base Pressure

L/C	Node											Total Wt (KN/m)	Base Pressure (KN/m ²)	
	1	2	5	6	7	8	9	10	11	12	13			
299	10	11	21	21	21	21	21	21	21	21	21	14	203	78
300	12	12	24	24	24	24	24	24	25	25	25	13	232	89

Max	89
Min.	78
	OK

Bearing capacity = 100 KN/sqm

**Design note
for
RCC BOX OF SIZE 1 x 3 x 3**

	Project		Designed by:	KB
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	Project	0	Designed by:	KB
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1.0 Design Report

The following report represents the design note of RCC BOX of clear span 1 x 3 x 3

1.1 Introduction:-

Design is presented consistently in SI units; the following apply unless mentioned specifically otherwise:

Length	m
Force	kN
Stress	MPa
Bearing Pressure	kN/m ²
Hog Mom/Com Str	-ve
Sag Mom/Ten Str	+ve

1.2 Reference documents :-

- 1 IRC codes /guidelines/special publications
- 2 MORTH specification
- 3 Specialised literature as relevant

1.3 Assumptions:-

The following assumptions have been taken while designing the Box.

- 1 Structure is designed for per metre width.
- 2 On top slab 75 mm thick wearing coat is considered for SIDL.
- 3 Deck width taken 12 m
- 4 Carriageway width- 11 m
- 5 Modulus of subgrade reaction (Assumed) - 2500 KN/m³
- 6 Shear value is taken at dist. 0.15m from the face of the slab.
- 7 In case of load dispersion wearing coat thickness, fill thickness and top slab thickness is considered wherever applicable.
- 8 In case of design sheet under summary of moments, only magnitude of force has been considered.
- 9 In case of earth pressure and LL surcharge governing case out of Normal earth pressure, Fluid pressure and Normal earth pressure + hydrostatic fluid pressure is taken.
- 10 Structure is designed for standard earth pressure without weep holes.

	Project	0	Designed by:	KB
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1.4 Loads:-

The different types of loads used as per IRC 6 : 2014 are.

- 1 Dead load.
- 2 In SIDL fill, crash barrier, and wearing coat load is considered.
- 3 Normal Earth pressure with hydrostatic pressure.
- 4 Live load -70R Track, 40 T Boggie, 70R Wheel load in case of top slab.
- 5 Live load surcharge.
- 6 Braking load is taken as 20% of the live load on top slab.
- 7 1.25 of Impact factor is considered.
- 8 Temperature loading for uniform rise and temperature gradient is considered.
- 9 The Earth pressure coefficient at rest 0.5 is considered.

1.5 Load combinations

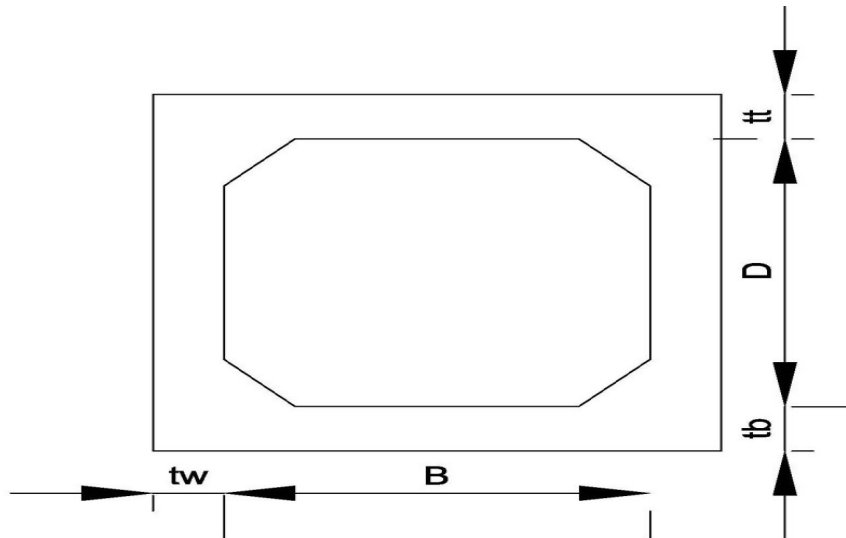
Load combinations as per IRC 6: 2014 have been considered in staad load combination.

1.6 Material properties

- 1 Grade of Concrete M30
- 2 Grade of Steel Fe 500.

	Project		0	Designed by:	KB
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BOX (1 Cell 3m wide x 3m height)



2.1 Dimensions of Box

No. of Cell	=	1	Clear Width of cell	=	3.00 m
Top Slab Thick. (tt)	=	0.420 m	Clear Height of Cell	=	3.00 m
Bot. Slab Thick. (tb)	=	0.420 m	C/C Width of structure	=	3.420 m
Side Wall Thick. (tw)	=	0.420 m	C/C Height of structure	=	3.420 m
Int. wall Thickness (ti)	=	0.000 m	Total length of Structure at top =	=	3.840 m
Total Deck width	=	12.00 m	Total length of Structure at bottom =	=	3.840 m
Carriageway Width	=	11.00 m	Total Height of Structure	=	3.84 m
water above bott. Slab	=	2.495 m	Footpath Dimensions	=	0.00 m
			Crash barrier width	=	0.50 m
Wearing coat for SIDL	=	75mm	Height of fill =	=	0.00 m
Haunch size	=	150mm x150mm			

SIDL (Top Slab)

Crash barrier	=		10	kN/m ²
Due to earth fill	=	0 x20 =	0	kN/m ²
			10	kN/m ²
Due to wearing coat	=	0.075 x 22 =	1.65	kN/m ²

2.2 Basic Parameters

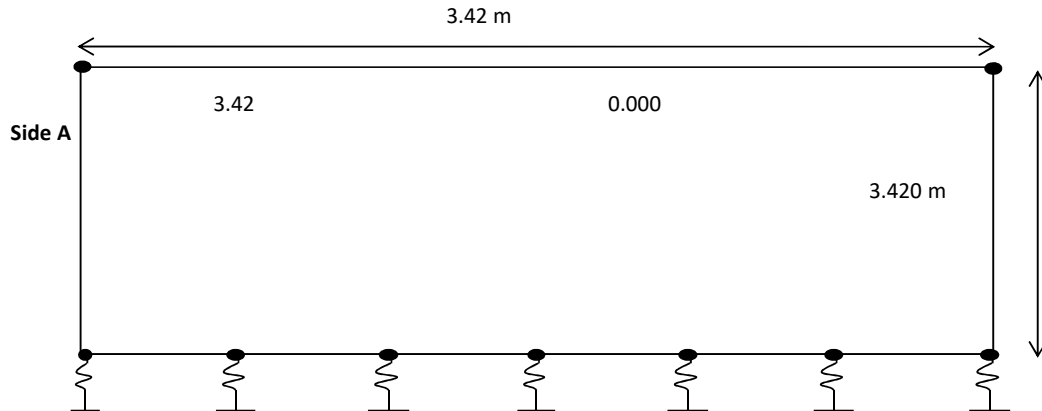
Coefficient of Active Earth Pressure	=	0.279
Earth Pressure at rest $K_0 = (1 - \sin\phi)$	=	0.5
Factor of Earthpressure/Active earthpres:	=	1.793
Saturated Density of fill	=	20 kN/m ³
Submerged Density of fill	=	10 kN/m ³
Dry Density of fill	=	20 kN/m ³
Density of Concrete	=	25 kN/m ³
Live Load Surcharge	=	1.2 m

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Safe Bearing Pressure = 100 kN/m²
 Fluid Pressure as per cl. 214.1 of IRC 6 2010 = 4.71 kN/m²

2.3 Idealised Structure for Staad Analysis

(Analysis is done for 1m Strip)



Nos. of beam for one span at bottom = 10
 Spacing between Springs = 0.342 m
 Modulus of Subgrade Reaction (Assumed) = 2500 kN/m³
 Spring Constant at End Support = 428 kN/m
 Spring Constant at intermediate Support = 855 kN/m

3.1 Earth Pressure and Live Load Calculation

1) a Earth Pressure (Normal Condition)

Earth Pressure	Height
1.17 kN/m ²	0.210 m
20.26 kN/m ²	3.630 m

1) b Fluid Pressure

Fluid Pressure	Height
0.99 kN/m ²	0.210 m
17.09 kN/m ²	3.630 m

1) c Earth Pressure (Normal Condition+Full hydrostatic pressure)

Earth Pressure	Height
2.69	0.21
46.43	3.630 m

1) d Earth Pressure at rest $K_0 = (1 - \sin \phi) = 0.5$

LWL	HFL	Earth Pressure	Height
		2.10	0.210 m
		36.30	3.630 m
		3.15	
		54.45	

2) a Live Load Surcharge (Normal Condition)

Live Load Surcharge = 6.696 kN/m

2) b Live Load Surcharge (Fluid Pressure) as per cl. 214.1 of IRC 6 2014

Live Load Surcharge = 5.651 kN/m

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

2) c Live Load Surcharge (Normal Condition+Full hydrostatic pressure)

Live Load Surcharge = 15.348 kN/m

2) d Live Load Surcharge at rest

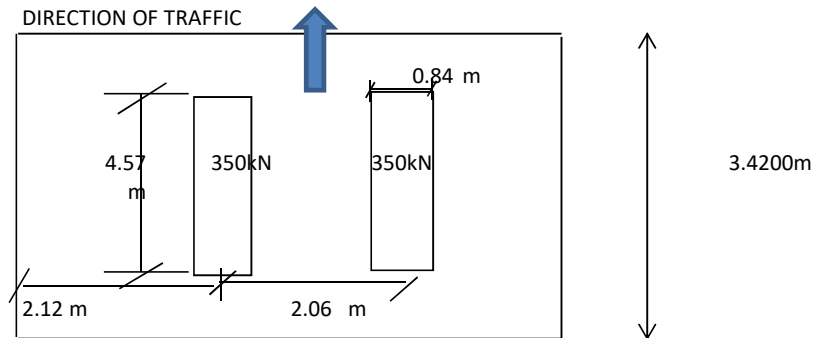
Live Load Surcharge = 12.000 kN/m

2) e Load due to water on Bottom Slab

Uniform Load = 24.95 kN/m²

3) Live Load on Top Slab

A) 70R Track at Mid Span



Total Load = 700kN
 153.17 kN/m
 523.9 kN

4.57 3.4200m

Effective width of Loading

a = 1.71 m
 b1 = 0.99 m
 b/lo = 3.51
 a = 2.60
 beff = 3.21 m

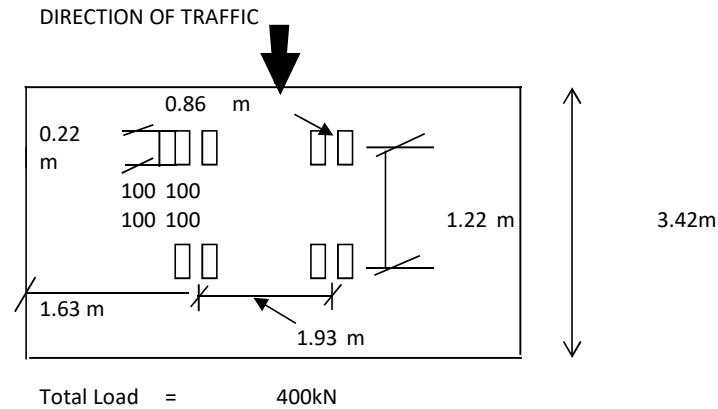
2.06 < 3.21

Therefore overlapping due to load dispersion occurs

Effective width = 5.27 m
 Width along span = 3.42 m
 Load Intensity = 29.07 kN/m²
 Increase due to impact = 36.34 kN/m²
 Say **36.40 kN/m²**

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

B) 40T Boggie Load at Mid Span



Effective width of Loading

a	=	1.71 m
b1	=	1.01 m
b/lo	=	3.51
a	=	2.60
beff	=	3.23 m

1.93 < 3.23 *Therefore overlapping due to load dispersion occurs*

Effective width	=	5.16 m
Width along span	=	2.43 m
Load Intensity	=	31.90 kN/m ²
Increase due to impact	=	39.88 kN/m ²
Say	=	39.90 kN/m²

C) 40T Boggie Load at Support

Effective width of Loading

a	=	0.61 m
b1	=	1.01 m
b/lo	=	3.51
a	=	2.60
beff	=	2.31 m

1.93 < 3.31 *Therefore overlapping due to load dispersion occurs*

Effective width	=	4.24 m
Width along span	=	1.935 m
Load Intensity	=	48.75 kN/m ²
Increase due to impact	=	60.94 kN/m ²
Say	=	61.00 kN/m²

D) 70R Track at Support

Effective width of Loading

a	=	1.71 m
b1	=	0.99 m
b/lo	=	3.51
a	=	2.60
beff	=	3.21 m

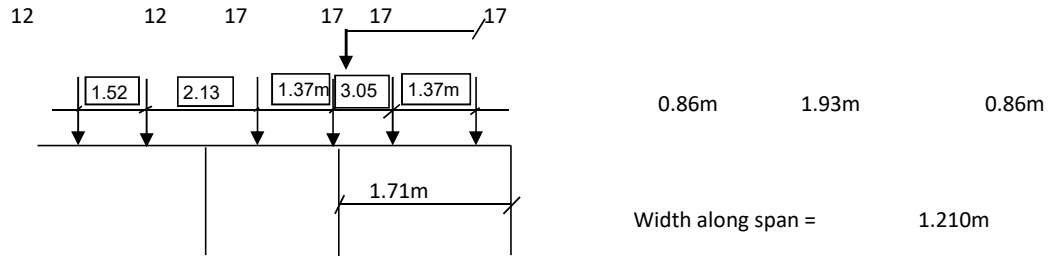
2.06 < 3.21 *Therefore overlapping due to load dispersion occurs*

Effective width	=	5.27 m
Width along span	=	3.420 m
Load Intensity	=	29.07 kN/m ²

	Project		0	Designed by:	KB
	Client		0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3		Date & Rev.	0

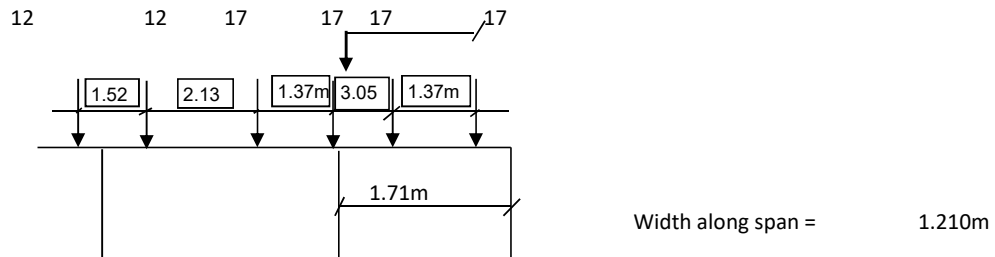
Increase due to impact = 36.34 kN/m²
 Say 36.40 kN/m²

F) 70R Wheel Case 1



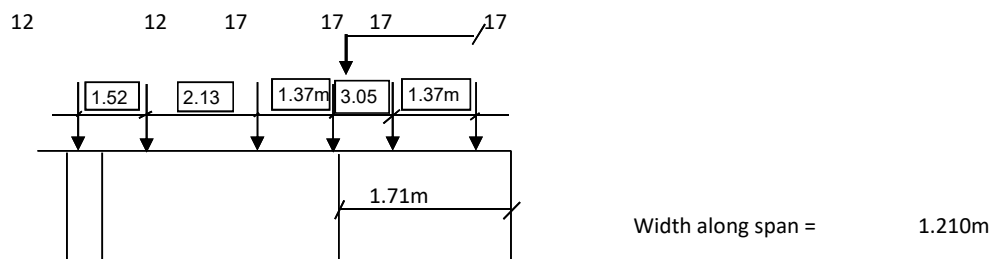
S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	0.61m	2.60	2.30m	Yes	4.23m	32.5 kN/sqm	41 kN/sqm
2	166.77	1.45m	2.60	3.18m	Yes	5.11m	27.0 kN/sqm	34 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

F) 70R Wheel Case 2



S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	1.025	2.60	2.88m	Yes	4.81m	28.7 kN/sqm	36 kN/sqm
2	166.77	1.025	2.60	2.88m	Yes	4.81m	28.7 kN/sqm	36 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

G) 70R Wheel Case 3

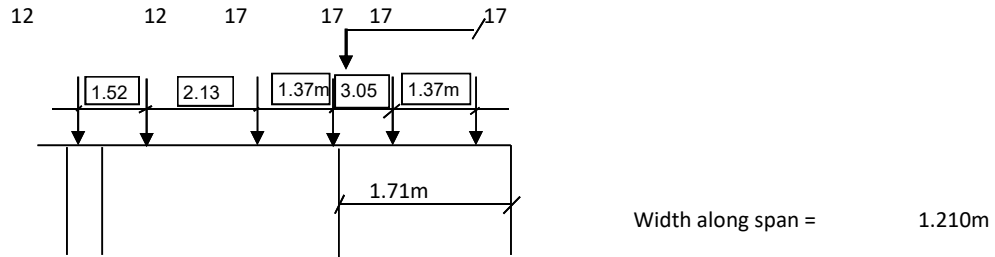


S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	0.605	2.60	2.30m	Yes	4.23m	32.5 kN/sqm	41 kN/sqm
2	166.77	1.445	2.60	3.18m	Yes	5.11m	27.0 kN/sqm	34 kN/sqm

	Project		0	Designed by:	KB
	Client		0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3		Date & Rev.	0

0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

H) 70R Wheel Case 4



S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	0.685	2.60	2.43m	Yes	4.36m	31.6 kN/sqm	39 kN/sqm
2	166.77	1.365	2.60	3.14m	Yes	5.07m	27.2 kN/sqm	34 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

G) Braking load		20%	Av. Eff. Width	Load per meter
Load on the span 70R Wheel	334 kN	67 kN	4.67m	14 kN/m
Load on the span 70R Track	524 kN	105 kN	5.27m	20 kN/m
Max. force				20 kN/m

Project	0	Designed by:	KB
Client	0	Checked by:	0
Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

3.2 Temperature load calculation

Effective Bridge Temperature

Maximum Air Shade temperature	=	47.9	/oC (as per Annexure F of IRC:6-2014)
Minimum Air Shade temperature	=	0.2	/oC (as per Annexure F of IRC:6-2014)
Mean of max and min temperature	=	23.85	/oC (as per clause 215.2 of IRC:6-2014)
Bridge temperature to be assumed	=	33.85	
TEMPERATURE RISE		33.85	
TEMPERATURE FALL		-34.05	

Effect of temperature gradient

The box has been checked for temperature differential.

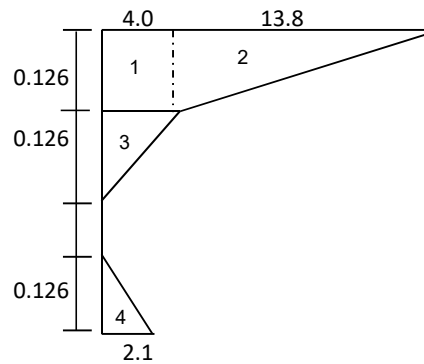
$$F = E_c aDt A$$

E_c = Modulus of Elasticity of Concrete	=	3.21E+06	t/m ²
a = Coefficient of Thermal expansion	=	1.20E-05	/oC (as per IRC:6)
Dt = Temperature differential			
A = X sectional Area of section where temperature differential is Dt			

Average thickness of Deck slab =

420 mm

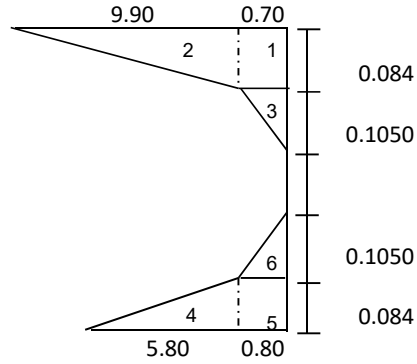
EFFECT OF TEMPERATURE RISE



Sr. No.	Dt	b	t	A = b x t	F (force)	Acting at	Eccentricity e*
1	4.0	1.0	0.126	0.126	19.43	0.063 m from top	0.147
2	$\frac{13.8}{2}$	1.0	0.126	0.126	33.52	0.042 m from top	0.168
3	$\frac{4.0}{2}$	1.0	0.126	0.126	9.72	0.168 m from top	0.042
4	$\frac{2.1}{2}$	1.0	0.126	0.126	5.10	0.042m from bottom	-0.168
					SF = 67.77	M = 8.039	

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

EFFECT OF TEMPERATURE FALL



Sr. No.	Dt	b	t	A = b x t	F (force)	Acting at	Eccentricity e*
1	0.70	1.0	0.084	0.084	2.27	0.042m from top	0.168
2	$\frac{9.90}{2}$	1.0	0.084	0.084	16.03	0.028 m from top	0.182
3	$\frac{0.70}{2}$	1.0	0.1050	0.1050	1.42	0.119 m from top	0.091
4	$\frac{5.80}{2}$	1.0	0.084	0.084	9.39	0.028 m from bottom	-0.182
5	0.80	1.0	0.084	0.084	2.59	0.042m from bottom	-0.168
6	$\frac{0.80}{2}$	1.0	0.1050	0.1050	1.62	0.119 m from bottom	-0.091
					SF = 33.32	M = 1.136	

Project	0
Client	0
Job Name	RCC BOX OF SIZE 1 x 3 x 3

3.3 Summary of factored moments

Grade of Concrete = M30
Grade of Steel = Fe500

Summary of factored moments

Load Case	Top slab			Bottom slab			Outer wall			
	Moment in Mid-Span	Moment at End Support	Top slab shear at	Moment in Mid-Span	Moment at End Support	Bottom slab shear	Min. Axial force	Moment at top	Moment at bottom	Wall shear at deff
	kN-m	kN-m	kN	kN-m	kN-m	kN	kN	kN-m	kN-m	kN
Basic Combination (33 - 62)	70	80	44	-	-	-	31	83	132	149
Rare Combination (63 -122)	53	68	206	77	91		31	68	91	118
Frequent Combination (123 - 182)	-	-	-	-	-	-	-	-	-	-
Quasi Static (183 - 186)	14	26		24	28			26	20	
Combination 1	-	-	-	111	130	187	-	-	-	-
Combination 2	-	-	-	93	107	162	-	-	-	-
	-	-	-	93	107	162	-	-	-	-

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.:	0

4.0 Partial Safety Factors

Material Parameters

Concrete

Refer Table 6.5, IRC:112-2011

Grade		=	M30
Cube strength of concrete at 28 days	f_{ck}	=	30 MPa
Design value of concrete compressive strength	f_{cd}	=	$\alpha f_{ck} / \gamma_m$
			a = 0.67
			Refer cl. 6.4.2.8 of IRC:112-2011
		f_{ctm}	= 2.5 MPa
For Basic Combination	f_{cd}	=	13.40 MPa
For Accidental Combination	f_{cd}	=	16.75 MPa
For Seismic Combination	f_{cd}	=	13.40 MPa
Modulus of Elasticity	E_c	=	31000 MPa
Mean value of axial tensile strength of concrete	f_{ctm}	=	2.5 MPa
Density		=	2.50 t/m ³
Grade		=	Fe500
Characteristics yield strength	f_{yk}	=	500 MPa
Design yield strength	f_{yd}	=	f_{yk} / γ_m
For Basic Combination	f_{yd}	=	434.78 MPa
For Accidental Combination	f_{yd}	=	500 MPa
For Seismic Combination	f_{yd}	=	434.78 MPa
Modulus of Elasticity	E_s	=	2.0E+05 MPa
Density		=	7.85 t/m ³

Partial Safety Factor for Materials

Material	Partial Safety Factor g_m			
	Basic Combination	Accidental Combination	Seismic Combination	
Concrete	1.5	1.2	1.5	Cl 6.4.2.8, IRC:112-2011
Steel	1.15	1	1.15	Cl 6.2.2, IRC:112-2011

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

Partial Safety Factor for Loads

Ultimate Limit State

Partial Safety for Verification of Structural Strength

Table 3.1, Annex B, IRC:6-2014

Also refer IRC Amendment dated 28th July, 2012

Loads	Partial Safety Factor					
	Basic Combination		Accidental Combination		Seismic Combination	
(1)	(2)	(3)	(4)	(5)	(4)	(3)
	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect
Permanent Loads:	1.05	0.95	1.00	1.00	1.05	0.95
Dead Load, SIDL except surfacing, Backfill Weight, Settlement, Creep and shrinkage effect						
Surfacing	1.35	1.00	1.00	1.00	1.35	1.00
Earth Pressure due to Backfill	1.50	0.00	1.00	0.00	1.00	0.00
Variable Loads:						
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:						
a) Leading Load	1.50	0.00	0.75	0.00	0.00	0.00
b) Accompanying Load	1.15	0.00	0.20	0.00	0.20	0.00
c) Construction Live Load	1.35	0.00	1.00	0.00	1.00	0.00
Thermal Loads						
a) As Leading Load	1.50	0.00	0.00	0.00	0.00	0.00
b) As Accompanying Load	0.90	0.00	0.50	0.00	0.50	0.00
Wind						
a) As Leading Load	1.50	0.00	0.00	0.00	0.00	0.00
b) As Accompanying Load	0.90	0.00	0.00	0.00	0.00	0.00
Live Load Surcharge (as accompanying load)	1.20	0.00	0.00	0.00	0.00	0.00
Accidental Effects:						
i) Vehicle Collision						
ii) Barge Impact	0.00	0.00	1.00	0.00	0.00	0.00
iii) Impact due to floating bodies						
Seismic Effect						
a) During Service	0.00	0.00	0.00	0.00	1.50	0.00
b) During Construction	0.00	0.00	0.00	0.00	0.75	0.00
Construction Condition:						
Counter Weights:						
a) When density or self weight is well defined	0.00	0.90	0.00	1.00	0.00	1.00
b) When density or self weight is not well defined	0.00	0.80	0.00	1.00	0.00	1.00
c) Erection effects	1.05	0.95	0.00	0.00	0.00	0.00
Wind						
a) As Leading Load	1.50	0.00	0.00	0.00	0.00	0.00
b) As Accompanying Load	1.20	0.00	0.00	0.00	0.00	0.00
Hydraulic Loads:						
(Accompanying Load):						
Water Current Forces	1.00	0.00	1.00	0.00	1.00	0.00
Wave Pressure	1.00	0.00	1.00	0.00	1.00	0.00
Hydrodynamic Effect	0.00	0.00	0.00	0.00	1.00	0.00
Buoyancy	1.00	0.00	1.00	0.00	1.00	0.00

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.:	0

Partial Safety for Verification of Structural Strength
Also refer IRC Amendment dated 28th July, 2012

Table 3.2, Annex B, IRC:6-2014

Loads	Partial Safety Factor		
	Basic Combination	Accidental Combination	Seismic Combination
(1)	(2)	(3)	(4)
Permanent Loads:			
Dead Load			
SIDL except surfacing			
a) Adding to the effect of variable loads	1.35	1.00	1.35
b) Relieving the effect of variable loads	1.00	1.00	1.00
Surfacing:			
a) Adding to the effect of variable loads	1.75	1.00	1.75
b) Relieving the effect of variable loads	1.00	1.00	1.00
Backfill Weight	1.50	1.00	1.00
Earth Pressure due to Backfill			
a) Leading Load	1.50	0.00	1.00
b) Accompanying Load	1.00	1.00	1.00
Variable Loads:			
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:			
a) Leading Load	1.50	0.75	0.00
b) Accompanying Load	1.15	0.20	0.20
c) Construction Live Load	1.35	1.00	1.00
Wind during service and construction			
a) Leading Load	1.50	0.00	0.00
b) Accompanying Load	0.90	0.00	0.00
Live Load Surcharge (as accompanying load)	1.20	0.20	0.20
Erection effects	1.00	1.00	1.00
Accidental Effects:			
i) Vehicle Collision			
ii) Barge Impact	0.00	1.00	0.00
iii) Impact due to floating bodies			
Seismic Effect			
a) During Service	0.00	0.00	1.50
b) During Construction	0.00	0.00	0.75
Hydraulic Loads (Accompanying Load):			
Water Current Forces	1.00	1.00	1.00
Wave Pressure	1.00	1.00	1.00
Hydrodynamic Effect	0.00	0.00	1.00
Buoyancy	0.15	0.15	0.15

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.:	0

Serviceability Limit State

Partial Safety for Verification of Serviceability Limit State **Table 3.3, Annex B, IRC:6-2014**

Loads	Partial Safety Factor		
	Rare Combination	Frequent Combination	Quasi-permanent
(1)	(2)	(3)	(4)
Permanent Loads:			
Dead Load	1.00	1.00	1.00
SIDL including surfacing	1.00	1.00	1.00
Backfill Weight	1.00	1.00	1.00
Shrinkage and Creep Effects	1.00	1.00	1.00
Earth Pressure due to Backfill	1.00	1.00	1.00
Settlement Effects			
a) Adding to the permanent loads	1.00	1.00	1.00
b) Opposing the permanent loads	0.00	0.00	0.00
Variable Loads:			
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:			
a) Leading Load	1.00	0.75	0.00
b) Accompanying Load	0.75	0.20	0.00
Thermal Loads:			
a) Leading Load	1.00	0.60	0.00
b) Accompanying Load			
Wind			
a) Leading Load	1.00	0.60	0.00
b) Accompanying Load	0.60	0.50	0.00
Live Load Surcharge (Accompanying load)	0.80	0.00	0.00
Hydraulic Loads (Accompanying Load):			
Water Current Forces	1.00	1.00	0.00
Wave Pressure	1.00	1.00	0.00
Buoyancy	0.15	0.15	0.15

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

Combination for Base Pressure and Design of Foundation

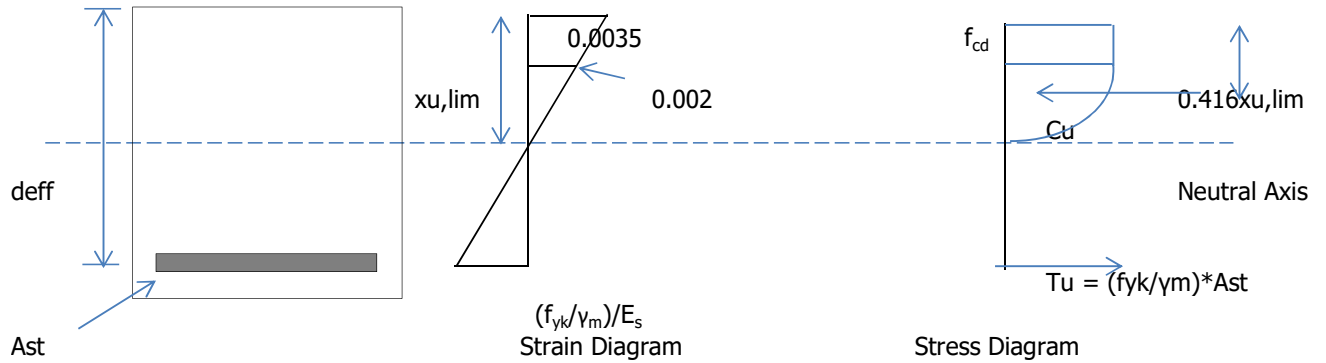
Table 3.4, Annex B, IRC:6-2014

Also refer IRC Amendment dated 28th July, 2012

Loads (1)	Partial Safety Factor			
	Combination (1) (2)	Combination (2) (3)	Seismic Combination (4a)	Accidental Combination (4b)
Permanent Loads:				
Dead Load, SIDL except surfacing, Backfill earth filling	1.35	1.00	1.35	1.00
SIDL Surfacing	1.75	1.00	1.75	1.00
Settlement Effect	1.0 or 0	1.0 or 0	1.0 or 0	1.0 or 0
Earth Pressure due to Backfill				
a) Leading Load	1.50	1.30	0.00	0.00
b) Accompanying Load	1.00	0.85	1.00	1.00
Variable Loads:				
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:				
	1.50	1.30	(0.75 if applicable) or 0	(0.75 if applicable) or 0
a) Leading Load				
b) Accompanying Load	1.15	1.00	0.20	0.20
Thermal Loads as accompanying load	0.90	0.80	0.50	0.50
Wind				
a) Leading Load	1.50	1.30	0.00	0.00
b) Accompanying Load	0.90	0.80	0.00	0.00
Live Load Surcharge (as accompanying load if applicable)	1.20	1.00	0.20	0.20
Accidental Effects or Seismic Effect:				
a) During Service	0.00	0.00	1.50	1.00
b) During Construction	0.00	0.00	0.75	0.50
Erection effects	1.00	1.00	1.00	1.00
Hydraulic Loads:				
Water Current	1.0 or 0	1.0 or 0	1.0 or 0	1.0 or 0
Wave Pressure	1.0 or 0	1.0 or 0	1.0 or 0	1.0 or 0
Hydrodynamic Effect	0.00	0.00	1.0 or 0	1.0 or 0
Buoyancy:				
For Base Pressure	1.00	1.00	1.00	1.00
For Structural Design	0.15	0.15	0.15	0.15

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

5.1.1 Verification of structural strength for top slab



ULTIMATE LIMIT STATE

Grade of Concrete	f_{ck}	=	30	N/mm ²	
As per clause 6.4.2.8, IRC:112-2011					
	f_{cd}	=	13.40	N/mm ²	For Basic Combination
	f_{cd}	=	16.75	N/mm ²	For Accidental Combination
	f_{cd}	=	13.40	N/mm ²	For Seismic Combination
	E_c	=	31000	MPa	
Grade of steel	f_y	=	500	N/mm ²	
	f_{yd}	=	435	N/mm ²	For Basic Combination
	f_{yd}	=	500	N/mm ²	For Accidental Combination
	f_{yd}	=	435	N/mm ²	For Seismic Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement = $\frac{0.87 f_y}{E_s} = \frac{0.87 \times 500}{2.0 \times 10^5} = 2.15 \times 10^{-3}$

$C_u = \frac{f_{cd} \cdot b \cdot (3/7 x_{u,lim} + 2/3 \cdot 4/7 x_{u,lim})}{17/21 \cdot f_{cd} \cdot b \cdot x_u} = 0.8095 \cdot f_{cd} \cdot b \cdot x_u$

cg of compression block from top = $0.416 x_u$

$T_u = f_{yd} \cdot A_{st}$

$R_{lim} = \frac{M_{u,lim}}{bd^2} = 0.8095 f_{cd} \cdot (x_{u,lim}/d) \cdot (1 - 0.416 \cdot x_{u,lim}/d)$

	Basic Comb	Accidental Comb	Seismic Comb
$x_{u,lim}/d$	0.62	0.58	0.62
$R_{lim} = M_{u,lim}/bd^2$	4.97	5.99	4.97

Here R_{lim} is in MPa

Calculation of Reinforcement

Width of section b	=	1000 mm
Depth of section D	=	420 mm
Clear cover	=	50

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

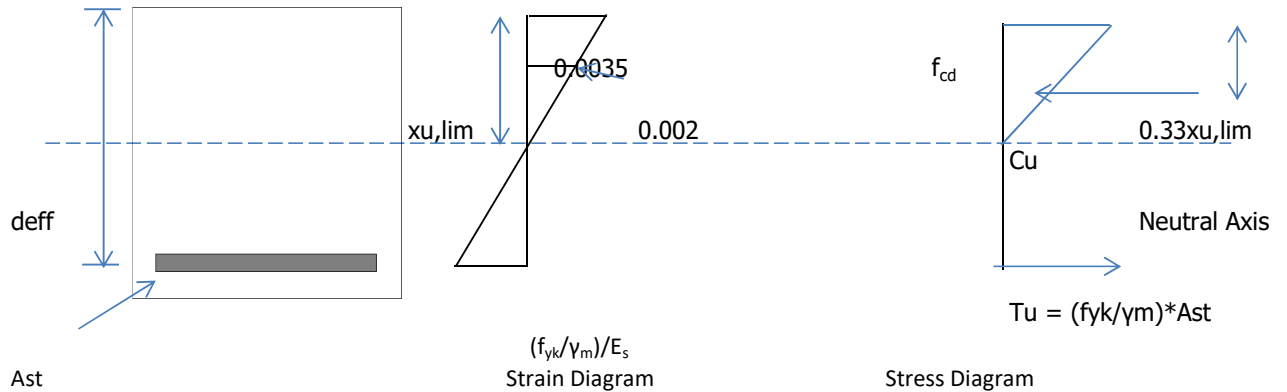
Moment on the section	Top slab Top End support			Top slab Bottom Mid Span		
	Basic Comb			Basic Comb		
Actual moment (KNm)	80.0			70.0		
b	1000			1000		
D	420			420		
c	50			50		
d	352.0			353.0		
f_{cd}	13.40			13.40		
f_{yd}	435			435		
$x_{u,lim}/d$	0.62			0.62		
$R_{sls} = M_{u,sls}/bd^2$	4.97			4.97		
$M_{u,Lim}$ (KNm)	616			620		
	OK			OK		
Ast Req.	536			466		
Dia of bar (main tension) (mm)	12			10		
Spacing (mm)	150			150		
+ dia of bar (main tension) (mm)	12			10		
Spacing (mm)	150			150		
Ast provided (sq mm)	1508			1047		
Dia of bar (main compression) (mm)	10			12		
Spacing (mm)	150			150		
Area of main compression (mm ²)	524			754		
f_{ctm}	2.5			2.5		
f_{yk}	435			435		
cl. 16.6.1 (2) of IRC :112-2011						
$A_{s,min} = 0.26 f_{ctm} b_t d / f_{yk} \geq 0.0013 b_t d$	526			528		
A_{ct}	359558			378026		
$f_{ct,eff}$	2.9			2.9		
$k_c = 0.4 \{ 1 - s_c / (k_1 f_{ct,eff} h/h^*) \} \leq 1$	0.4			0.4		
For Bending or bending combined with axial force						
k	0.9160			0.9160		
s_s	435			435		
$A_{s,max} = 0.025 A_c$ (main tension)	10500			10500		
cl. 16.5.1.1 (2) of IRC :112-2011	OK			OK		
$A_{s,max} = 0.04 A_c$ (tension + compression)	16800			16800		
x (mm)	60			42		
x/d	0.172			0.119		
	OK			OK		
z (mm)	327			336		
MR (KNm)	214			153		
	OK			OK		

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

Shear on the section	Top slab Top End support		
Actual shear V_{Ed} (KN)	44.0		
Actual shear stress (N/mm ²)	0.139		
Max shear capacity, $0.135 f_{ck}(1-f_{ck}/310)$	3.7		
	OK.		
Min shear capacity, $0.0924 f_{ck}(1-f_{ck}/310)$	2.5		
$\Theta = 0.5 \times \sin^{-1}$ (Applied shear stress / $0.135/f_{ck}/(1-f_{ck}/310)$)			
Min angle of inclination, Θ (deg)	21.8		
cl. 10.3.2(2) Eq. 10.2 of IRC :112-2010			
$K = 1 + \sqrt{200/d} \leq 2.0$	1.754		
cl. 10.3.2(2) Eq. 10.3 of IRC :112-2010			
$\eta_{min} = 0.031 K^{3/2} f_{ck}^{1/2}$	0.394		
cl. 10.3.1 of IRC :112-2011			
$r_1 = A_{sl}/(b_w d) \leq 0.02$	0.004		
	OK		
$0.12 K (80 r_1 f_{ck})^{0.33}$	0.454		
Axial compressive force N_{Ed} (KN)	0		
$s_{cp} = N_{Ed} / A_c \leq 0.2 f_{cd}$	0.0		
cl. 10.3.2(2) Eq. 10.1 of IRC :112-2010			
$V_{Rd,c} = [0.12K(80\rho_1 f_{ck})^{0.33} + 0.15\sigma_{cp}]b_w d \leq (\eta_{min} + 0.15 s_{cp}) b_w d$ (KN)	139		
	OK.		
Min shear stress	0.394		
Min shear force for providing reinf., V_E (N)	124930.8		
No. of link for shear reinf.	4		
Dia. of bar for shear reinf.	12		
$S = A_{sw} \times 0.9 \times d \times \cot \Theta \times f_y / V_E$	1247		
A_{sw}	452		
cl. 16.5.2(7) Eq. 16.6 of IRC :112-2011			
$S_{l,max} = 0.75 d$	264		
Spacing provided in Long. Direction (mm)	264.0		
cl. 16.5.2(9) Eq. 16.8 of IRC :112-2011			
$S_{t,max} = 0.75 d \leq 600\text{mm}$	264		
Spacing provided in Trans. Direction, S_t mm	150		
	OK		

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

5.1.2 Verification for serviceability limit state for top slab



SERVICEABILITY LIMIT STATE

Grade of Concrete
As per clause 12.2.1, IRC:112-2011

$$f_{ck} = 30 \text{ N/mm}^2$$

$$f_{cd} = 14.40 \text{ N/mm}^2 \text{ For Rare Combination}$$

$$f_{cd} = 14.40 \text{ N/mm}^2 \text{ For Frequent Combination}$$

$$f_{cd} = 10.80 \text{ N/mm}^2 \text{ For Quasi-Perma. Combination}$$

As per clause 12.2.2, IRC:112-2011

Grade of steel

$$f_y = 500 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2 \text{ For Rare Combination}$$

$$f_{yd} = 300 \text{ N/mm}^2 \text{ For Frequent Combination}$$

$$f_{yd} = 300 \text{ N/mm}^2 \text{ For Quasi-Perma. Combination}$$

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

$$\text{Minimum strain in steel reinforcement} = 0.87 f_y / E_s$$

$$E_s = 2.0E+05 \text{ MPa}$$

$$E_c = 31000 \text{ MPa}$$

$$C_u = 1/2 \cdot f_{cd} \cdot b \cdot x_{u,lim}$$

$$= 0.5 \cdot f_{cd} \cdot b \cdot x_{u,lim}$$

cg of compression block from top

$$= 0.33 x_{u,lim}$$

$$T_u = f_{yd} \cdot A_{st}$$

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

$$R_{s_{ls}} = M_{u,s_{ls}} / b d^2 = 0.5 f_{cd} \cdot (x_{u,lim} / d) \cdot (1 - 0.33 \cdot x_{u,lim} / d)$$

	Rare Comb	Frequent Comb	Quasi-Perma. Comb
$x_{u,s_{ls}} / d$	0.70	0.70	0.70
$R_{s_{ls}} = M_{u,s_{ls}} / b d^2$	3.88	3.88	2.91

Here $R_{s_{ls}}$ is in MPa

Calculation of Reinforcement

$$\text{Width of section } b = 1000 \text{ mm}$$

$$\text{Depth of section } d = 420 \text{ mm}$$

$$\text{Clear cover} = 40$$

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

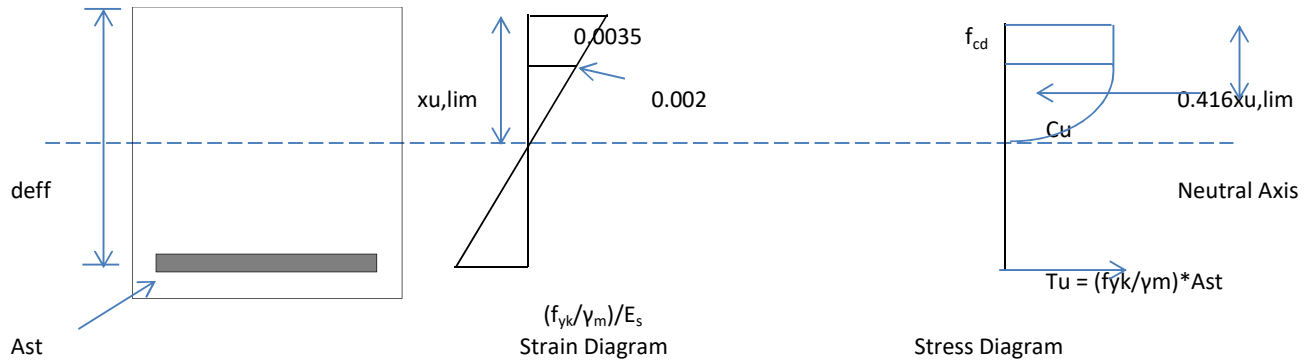
Moment on the section	Top slab Top End support			Top slab Bottom Mid Span		
	Rare Comb		Quasi-Perma. Comb	Rare Comb		Quasi-Perma. Comb
Actual moment (KNm)	68.0		26.0	53		14
b	1000		1000	1000		1000
D	420		420	420		420
c	40		40	40		40
d	362.0		362.0	363.0		363.0
f_{cd}	14.40		10.80	14.40		10.80
f_{yd}	300		300	300		300
$x_{u,sls}/d$	0.70		0.70	0.70		0.70
$R_{sls} = M_{u,sls}/bd^2$	3.88		2.91	3.88		2.91
$M_{u,sls}$ (KNm)	508		381	511		383
	OK		OK	OK		OK
Ast Req.	642		242	496		129
Dia of bar (main tension) (mm)	12		12	10		10
Spacing (mm)	150		150	150		150
+ dia of bar (main tension) (mm)	12		12	10		10
Spacing (mm)	150		150	150		150
Ast provided (sq mm)	1508		1508	1047		1047
Dia of bar (main compression) (mm)	10		10	12		12
Spacing (mm)	150		150	150		150
Area of main compression (mm ²)	524		524	754		754
f_{ctm}	2.5		2.5	2.5		2.5
x (mm)	62.8		83.8	43.6		58.2
x/d	0.174		0.231	0.120		0.160
	OK		OK	OK		OK
z (mm)	341		334	349		344
MR_{sls} (KNm)	154		151	110		108
	OK		OK	OK		OK
$s_{sc} = M/(A_s z)$	132		52	145		39
	OK		OK	OK		OK
$s_{ca} = M/(0.8095 z b x_u)$	6.34		1.86	6.97		1.40
	OK		OK	OK		OK

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

Calculation of crack width	Top slab Top End support		Top slab Bottom Mid Span	
n_1		7		7
n_2		7		7
$f_{eq} = (n_1 f_1^2 + n_2 f_2^2) / (n_1 f_1 + n_2 f_2)$		12		10
cl. 12.3.4 (3) of IRC :112-2011				
c		40		40
k_1		0.8		0.8
k_2		0.50		0.50
For skew slab refer eq. 12.10 of IRC :112-2011				
$r_{p,eff} = A_s / A_{c,eff}$		0.013		0.009
$S_{r,max} = \{ 3.4 c + (0.425 k_1 k_2 f) / r_{p,eff} \}$		292		319
cl. 12.3.4 (3) of IRC :112-2011				
k_t		0.5		0.5
$f_{ct,eff}$		2.90		2.90
E_s		200000		200000
E_{cm}		31000		31000
$a_e = E_s / E_{cm}$		6.45		6.45
$(e_{sm} - e_{cm}) = (s_{sc} - k_t f_{ct,eff} (1 + a_e r_{p,eff}) / r_{p,eff}) / E_s$ $\geq 0.6 s_{sc} / E_s$		0.0002		0.0001
cl. 12.3.4 (2) of IRC :112-2011				
$W_k = S_{r,max} (e_{sm} - e_{cm})$		0.045		0.04
cl. 12.3.4 (1) of IRC :112-2011				
		OK	OK	OK
Calculation of deflection				
Span (mm)				3420
span/800				4.3
cl. 12.4.1 (2) of IRC :112-2011				
Short term elastic deflection from STAAD				0.2
				OK

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

5.2.1 Verification of structural strength for bottom slab



ULTIMATE LIMIT STATE

Grade of Concrete	f_{ck}	=	30	N/mm ²	
As per clause 6.4.2.8, IRC:112-2011					
	f_{cd}	=	13.40	N/mm ²	Combination (1)
	f_{cd}	=	16.75	N/mm ²	Accidental Combi.
	f_{cd}	=	13.40	N/mm ²	Combination (2)
	E_c	=	31000	MPa	
Grade of steel	f_y	=	500	N/mm ²	
	f_{yd}	=	435	N/mm ²	Combination (1)
	f_{yd}	=	500	N/mm ²	Accidental Combi.
	f_{yd}	=	435	N/mm ²	Combination (2)

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement = $0.87 f_y / E_s$
 $E_s = 2.0E+05$ MPa

$E_c = 31000$ MPa

$$C_u = \frac{f_{cd} * b * (3/7 x_{u,lim} + 2/3 * 4/7 x_{u,lim})}{17/21 * f_{cd} * b * x_u} = 0.8095 * f_{cd} * b * x_u$$

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

cg of compression block from top = $0.416 x_u$

$T_u = f_{yd} * A_{st}$

$$R_{lim} = M_{u,lim} / b d^2 = 0.8095 f_{cd} * (x_{u,lim} / d) * (1 - 0.416 * x_{u,lim} / d)$$

	Basic Comb	Accidental Comb	Seismic Comb
$x_{u,lim} / d$	0.62	0.58	0.62
$R_{lim} = M_{u,lim} / b d^2$	4.97	5.99	4.97

Here R_{lim} is in MPa

Calculation of Reinforcement

Width of section b	=	1000	mm
Depth of section D	=	420	mm
Clear cover at bott.	=	75	
Clear cover at top	=		40

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

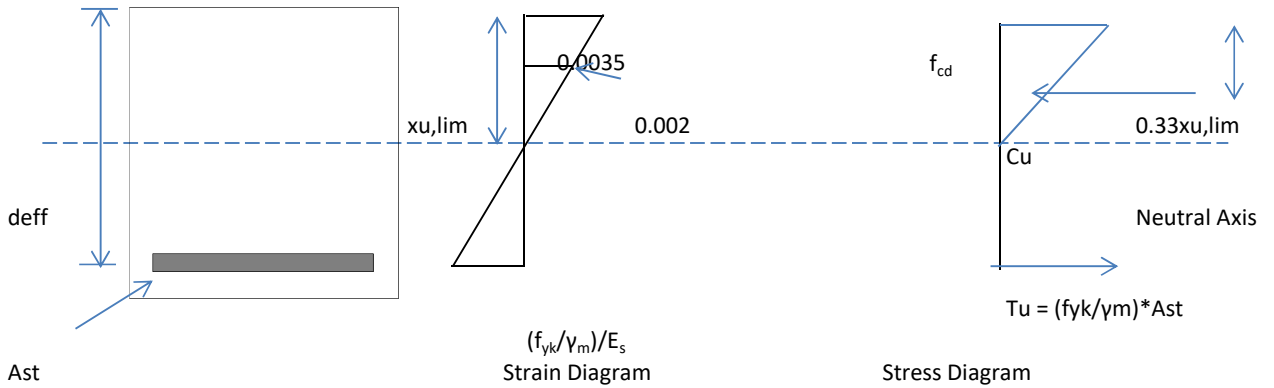
Moment on the section	Bottom End support		Top Mid Span		
	Combinatio n (1)		Combinatio n (2)	Combinatio n (1)	Combinatio n (2)
Actual moment (KNm)	130.0		107.0	111.0	93.0
b	1000		1000	1000	1000
D	420		420	420	420
c	75		75	40	40
d	327.0		327.0	363.0	363.0
f _{cd}	13.40		13.40	13.40	13.40
f _{yd}	435		435	435	435
x _{u,lim} /d	0.62		0.62	0.62	0.62
$R_{sls} = M_{u,sls}/bd^2$	4.97		4.97	4.97	4.97
M _{u,lim} (KNm)	532		532	655	655
	OK		OK	OK	OK
Ast Req.	962		784	728	606
Dia of bar (main tension) (mm)	12		12	10	10
Spacing (mm)	150		150	150	150
+ dia of bar (main tension) (mm)	12		12	10	10
Spacing (mm)	150		150	150	150
Ast provided (sq mm)	1508		1508	1047	1047
Dia of bar (main compression) (mm)	10		10	12	12
Spacing (mm)	150		150	150	150
Area of main compression (mm ²)	524		524	754	754
f _{ctm}	2.5		2.5	2.5	2.5
f _{yk}	435		435	435	435
cl. 16.6.1 (2) of IRC :112-2011					
$A_{s,min} = 0.26 f_{ctm} b_t d / f_{yk} \geq 0.0013 b_t d$	489		489	543	543
A _{ct}	359558		359558	378026	378026
f _{ct,eff}	2.9		2.9	2.9	2.9
$k_c = 0.4 \{ 1 - s_c / (k_1 f_{ct,eff} h/h^*) \} \leq 1$	0.4		0.4	0.4	0.4
For Bending or bending combined with axial force					
k	0.9160		0.9160	0.9160	0.9160
s _s	435		435	435	435
As.max = 0.025 Ac (main tension)	10500		10500	10500	10500
cl. 16.5.1.1 (2) of IRC :112-2011	OK		OK	OK	OK
As.max = 0.04 Ac (tension + compression)	16800		16800	16800	16800
x (mm)	60		60	42	42
x/d	0.185		0.185	0.116	0.116
	OK		OK	OK	OK
z (mm)	302		302	346	346
MR (KNm)	198		198	157	157
	OK		OK	OK	OK

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

Shear on the section	Bottom End support		
Actual shear V_{Ed} (KN)	187.0		162.0
Actual shear stress (N/mm ²)	0.635		0.550
Max shear capacity, $0.135 f_{ck}(1-f_{ck}/310)$	3.7		3.7
	OK.		OK.
Min shear capacity, $0.0924 f_{ck}(1-f_{ck}/310)$	2.5		2.5
$\Theta = 0.5 \times \sin^{-1}$ (Applied shear stress / $0.135/f_{ck}/(1-f_{ck}/310)$)			
Min angle of inclination, Θ (deg)	21.8		21.8
cl. 10.3.2(2) Eq. 10.2 of IRC :112-2010			
$K = 1 + \sqrt{200/d} \leq 2.0$	1.782		1.782
cl. 10.3.2(2) Eq. 10.3 of IRC :112-2010			
$n_{min} = 0.031 K^{3/2} f_{ck}^{1/2}$	0.404		0.404
cl. 10.3.1 of IRC :112-2011			
$r_1 = A_{sl}/(b_w d) \leq 0.02$	0.005		0.005
	OK		OK
$0.12 K (80 r_1 f_{ck})^{0.33}$	0.473		0.5
Axial compressive force N_{Ed} (KN)	0		0
$s_{cp} = N_{Ed} / A_c \leq 0.2 f_{cd}$	0.0		0.0
cl. 10.3.2(2) Eq. 10.1 of IRC :112-2010			
$V_{Rd,c} = [0.12K(80\rho_1 f_{ck})^{0.33} + 0.15\sigma_{cp}]b_w d \leq (n_{min} + 0.15 s_{cp}) b_w d$ (KN)	132		132
	Provide Shear Reinf.		Provide Shear Reinf.

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

5.2.2 Verification for serviceability limit state for bottom slab



SERVICEABILITY LIMIT STATE

Grade of Concrete
As per clause 12.2.1, IRC:112-2011

f_{ck}	=	30	N/mm ²	
f_{cd}	=	14.40	N/mm ²	For Rare Combination
f_{cd}	=	14.40	N/mm ²	For Frequent Combination
f_{cd}	=	10.80	N/mm ²	For Quasi-Perma. Combination

As per clause 12.2.2, IRC:112-2011
Grade of steel

f_y	=	500	N/mm ²	
f_{yd}	=	300	N/mm ²	For Rare Combination
f_{yd}	=	300	N/mm ²	For Frequent Combination
f_{yd}	=	300	N/mm ²	For Quasi-Perma. Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement	=	0.87 f_y / E_s	
E_s	=	2.0E+05 MPa	$E_c = 31000$ MPa

$$C_u = \frac{1}{2} * f_{cd} * b * x_u$$

$$= 0.5 * f_{cd} * b * x_u$$

cg of compression block from top = 0.33 x_u

$$T_u = f_{yd} * A_{st}$$

$$R_{s_{sls}} = M_{u,sls} / b d^2 = 0.5 f_{cd} * (x_u / d) * (1 - 0.33 * x_u / d)$$

	Rare Comb	Frequent Comb	Quasi-Perma. Comb
$x_{u,sls} / d$	0.70	0.70	0.70
$R_{s_{sls}} = M_{u,sls} / b d^2$	3.88	3.88	2.91

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

Here $R_{s_{sls}}$ is in MPa

Calculation of Reinforcement

Width of section b	=	1000 mm	
Depth of section d	=	420 mm	
Clear cover at bott.	=	75	Clear cover at top = 40

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

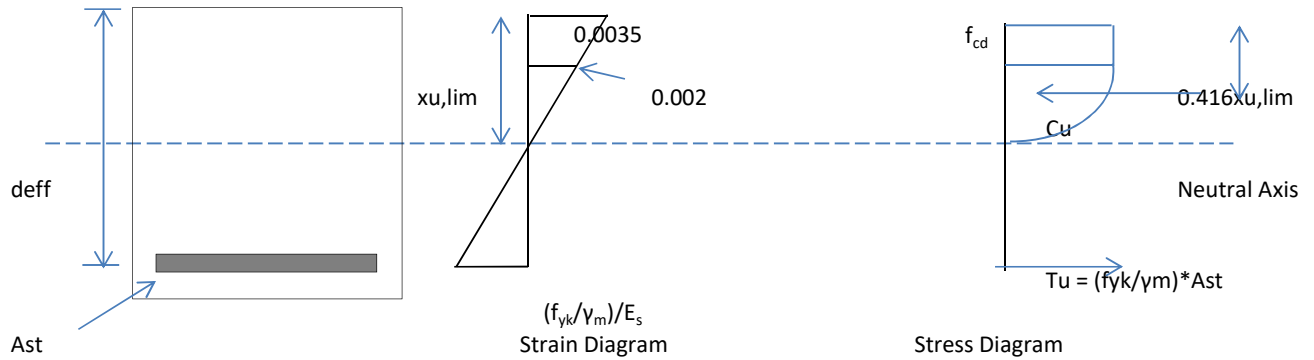
Moment on the section	Bottom End support		Top Mid Span		
	For Rare Combination		For Quasi-Perma. Combination	For Rare Combination	For Quasi-Perma. Combination
Actual moment (KNm)	91.0		28.0	77	24
b	1000		1000	1000	1000
D	420		420	420	420
c	75		75	40	40
d	327.0		327.0	363.0	363.0
f_{cd}	14.40		10.80	14.40	10.80
f_{yd}	300		300	300	300
$x_{u,sls}/d$	0.70		0.70	0.70	0.70
$R_{sls} = M_{u,sls}/bd^2$	3.88		2.91	3.88	2.91
$M_{u,sls}$ (KNm)	414		311	511	383
	OK		OK	OK	OK
Ast Req.	967		290	727	223
Dia of bar (main tension) (mm)	12		12	10	10
Spacing (mm)	150		150	150	150
+ dia of bar (main tension) (mm)	12		12	10	10
Spacing (mm)	150		150	150	150
Ast provided (sq mm)	1508		1508	1047	1047
Dia of bar (main compression) (mm)	10		10	12	12
Spacing (mm)	150		150	150	150
Area of main compression (mm ²)	524		524	754	754
f_{ctm}	2.5		2.5	2.5	2.5
x (mm)	62.8		83.8	43.6	58.2
x/d	0.192		0.256	0.120	0.160
	OK		OK	OK	OK
z (mm)	306		299	349	344
MR_{sls} (KNm)	139		135	110	108
	OK		OK	OK	OK
$s_{sc} = M/(A_s z)$	197		62	211	67
	OK		OK	OK	OK
$s_{ca} = M/(0.8095 z b x_u)$	9.46		2.23	10.12	2.40
	OK		OK	OK	OK

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

Calculation of crack width	Bottom End support		Top Mid Span	
n_1			7	7
n_2			7	7
$f_{eq} = (n_1 f_1^2 + n_2 f_2^2) / (n_1 f_1 + n_2 f_2)$			12	10
cl. 12.3.4 (3) of IRC :112-2011				
c			75	40
k1			0.8	0.8
k2			0.50	0.50
For skew slab refer				
$r_{p,eff} = A_s / A_{c,eff}$			0.007	0.009
$S_{r,max} = \{ 3.4 c + (0.425 k_1 k_2 f) / r_{p,eff} \}$			529	319
cl. 12.3.4 (3) of IRC :112-2011				
k_t			0.5	0.5
$f_{ct,eff}$			2.90	2.90
E_s			200000	200000
E_{cm}			31000	31000
$a_e = E_s / E_{cm}$			6.45	6.45
$(e_{sm} - e_{cm}) = (s_{sc} - k_t f_{ct,eff} (1 + a_e r_{p,eff}) / r_{p,eff}) / E_s$ $\geq 0.6 s_{sc} / E_s$			0.0002	0.0002
cl. 12.3.4 (2) of IRC :112-2011				
$W_k = S_{r,max} (e_{sm} - e_{cm})$			0.10	0.06
cl. 12.3.4 (1) of IRC :112-2011				
			OK	OK

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

5.3.1 Verification of structural strength for outer wall



ULTIMATE LIMIT STATE

Grade of Concrete	f_{ck}	=	30	N/mm ²	
As per clause 6.4.2.8, IRC:112-2011					
	f_{cd}	=	13.40	N/mm ²	For Basic Combination
	f_{cd}	=	16.75	N/mm ²	For Accidental Combination
	f_{cd}	=	13.40	N/mm ²	For Seismic Combination
	E_c	=	31000	MPa	
Grade of steel	f_y	=	500	N/mm ²	
	f_{yd}	=	435	N/mm ²	For Basic Combination
	f_{yd}	=	500	N/mm ²	For Accidental Combination
	f_{yd}	=	435	N/mm ²	For Seismic Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement = $0.87 f_y / E_s$
 $E_s = 2.0E+05$ MPa

$E_c = 31000$ MPa

$$C_u = \frac{f_{cd} \cdot b \cdot (3/7 x_{u,lim} + 2/3 \cdot 4/7 x_{u,lim})}{17/21 \cdot f_{cd} \cdot b \cdot x_u} = 0.8095 \cdot f_{cd} \cdot b \cdot x_u$$

Refer Chaper 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

cg of compression block from top = $0.416 x_u$

$T_u = f_{yd} \cdot A_{st}$

$$R_{lim} = M_{u,lim} / b d^2 = 0.8095 f_{cd} \cdot (x_{u,lim} / d) \cdot (1 - 0.416 \cdot x_{u,lim} / d)$$

	Basic Comb	Accidental Comb	Seismic Comb
$x_{u,lim} / d$	0.62	0.58	0.62
$R_{lim} = M_{u,lim} / b d^2$	4.97	5.99	4.97

Here R_{lim} is in MPa

Calculation of Reinforcement

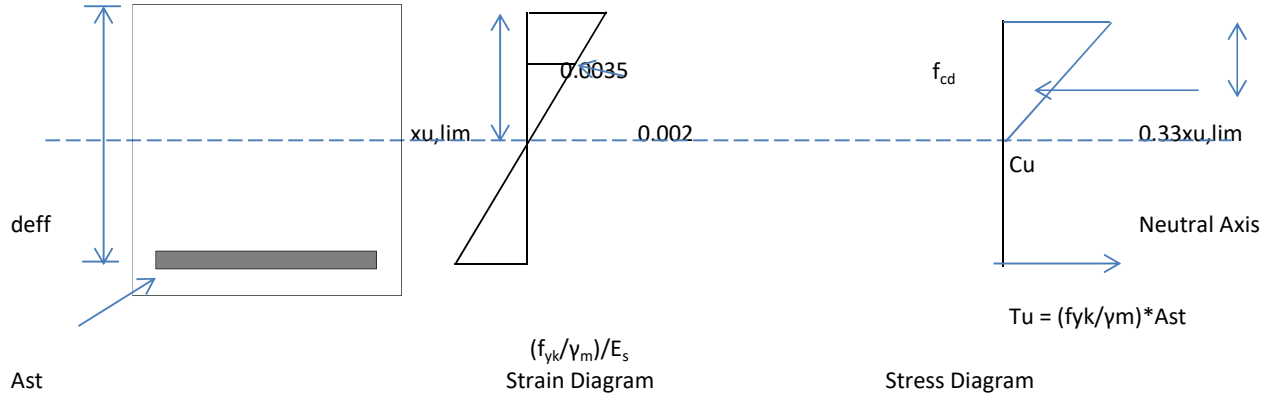
Width of section b	=	1000 mm
Depth of section D	=	420 mm
Clear cover	=	75

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

Moment on the section	Bottom End support			Top End support		
	Basic Comb			Basic Comb		
Actual moment (KNm)	132.0			83.0		
b	1000			1000		
D	420			420		
c	75			75		
d	327.0			327.0		
f_{cd}	13.40			13.40		
f_{yd}	435			435		
xu_{lim}/d	0.62			0.62		
$R_{sls} = M_{u,sls}/bd^2$	4.97			4.97		
$M_{u,Lim}$ (KNm)	532			532		
	OK			OK		
Ast Req.	977			602		
Dia of bar (main tension) (mm)	12			12		
Spacing (mm)	150			150		
+ dia of bar (main tension) (mm)	12			12		
Spacing (mm)	150			150		
Ast provided (sq mm)	1508			1508		
Dia of bar (main compression) (mm)	10			10		
Spacing (mm)	150			150		
Area of main compression (mm ²)	524			524		
f_{ctm}	2.5			2.5		
f_{yk}	435			435		
cl. 16.6.1 (2) of IRC :112-2011						
$A_{s,min} = 0.26 f_{ctm} b_t d / f_{yk} \geq 0.0013 b_t d$	489			489		
A_{ct}	359558			359558		
$f_{ct,eff}$	2.9			2.9		
$k_c = 0.4 \{ 1 - s_c / (k_1 f_{ct,eff} h/h^*) \} \leq 1$	0.4			0.4		
For Bending or bending combined with axial force						
k	0.9160			0.9160		
s_s	435			435		
$A_{s,max} = 0.025 A_c$ (main tension)	10500			10500		
cl. 16.5.1.1 (2) of IRC :112-2011	OK			OK		
$A_{s,max} = 0.04 A_c$ (tension + compression)	16800			16800		
x (mm)	60			60		
x/d	0.185			0.185		
	OK			OK		
z (mm)	302			302		
MR (KNm)	198			198		
	OK			OK		

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

5.3.2 Verification for serviceability limit state for outer wall



SERVICEABILITY LIMIT STATE

Grade of Concrete
As per clause 12.2.1, IRC:112-2011

$$f_{ck} = 30 \text{ N/mm}^2$$

$$f_{cd} = 14.40 \text{ N/mm}^2$$

$$f_{cd} = 14.40 \text{ N/mm}^2$$

$$f_{cd} = 10.80 \text{ N/mm}^2$$

For Rare Combination
For Frequent Combination
For Quasi-Perma. Combination

As per clause 12.2.2, IRC:112-2011

Grade of steel

$$f_y = 500 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

For Rare Combination
For Frequent Combination
For Quasi-Perma. Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

$$\text{Minimum strain in steel reinforcement} = 0.87 f_y / E_s$$

$$E_s = 2.0E+05 \text{ MPa}$$

$$E_c = 31000 \text{ MPa}$$

$$C_u = 1/2 * f_{cd} * b * x_u$$

$$= 0.5 * f_{cd} * b * x_u$$

cg of compression block from top

$$= 0.33 x_u$$

$$T_u = f_{yd} * A_{st}$$

Refer Chapter 5 of Reinforced Concrete
Limit State Design by Ashok K. Jain

$$R_{sls} = M_{u,sls} / b d^2 = 0.5 f_{cd} * (x_u/d) * (1 - 0.33 * x_u/d)$$

	Rare Comb	Frequent Comb	Quasi-Perma. Comb
$x_{u,sls}/d$	0.70	0.70	0.70
$R_{sls} = M_{u,sls} / b d^2$	3.88	3.88	2.91

Here R_{sls} is in MPa

Calculation of Reinforcement

$$\text{Width of section } b = 1000 \text{ mm}$$

$$\text{Depth of section } d = 420 \text{ mm}$$

$$\text{Clear cover} = 75$$

	Project	0	Designed by	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

Moment on the section	Bottom End support			Top End support		
	Rare Comb		Quasi-Perma. Comb	Rare Comb		Quasi-Perma. Comb
Actual moment (KNm)	91.0		20.0	68		26
b	1000		1000	1000		1000
D	420		420	420		420
c	75		75	75		75
d	327.0		327.0	327.0		327.0
f_{cd}	14.40		10.80	14.40		10.80
f_{yd}	300		300	300		300
$x_{u,sls}/d$	0.70		0.70	0.70		0.70
$R_{sls} = M_{u,sls}/bd^2$	3.88		2.91	3.88		2.91
$M_{u,sls}$ (KNm)	414		311	414		311
	OK		OK	OK		OK
Ast Req.	967		206	715		269
Dia of bar (main tension) (mm)	12		12	12		12
Spacing (mm)	150		150	150		150
+ dia of bar (main tension) (mm)	12		12	12		12
Spacing (mm)	150		150	150		150
Ast provided (sq mm)	1508		1508	1508		1508
Dia of bar (main compression) (mm)	10		10	10		10
Spacing (mm)	150		150	150		150
Area of main compression (mm ²)	524		524	524		524
f_{ctm}	2.5		2.5	2.5		2.5
x (mm)	62.8		83.8	62.8		83.8
x/d	0.192		0.256	0.192		0.256
	OK		OK	OK		OK
z (mm)	306		299	306		299
MR_{sls} (KNm)	139		135	139		135
	OK		OK	OK		OK
$s_{sc} = M/(A_s z)$	197		44	147		58
	OK		OK	OK		OK
$s_{ca} = M/(0.8095 z b x_u)$	9.46		1.59	7.07		2.07
	OK		OK	OK		OK

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

Calculation of crack width	Bottom End support		Top End support	
n_1			7	7
n_2			7	7
$f_{eq} = (n_1 f_1^2 + n_2 f_2^2) / (n_1 f_1 + n_2 f_2)$			12	12
cl. 12.3.4 (3) of IRC :112-2011				
c			75	75
k1			0.8	0.8
k2			0.50	0.50
For skew slab refer eq. 12.10 of IRC :112-2011				
$r_{p,eff} = A_s / A_{c,eff}$			0.007	0.007
$S_{r,max} = \{ 3.4 c + (0.425 k_1 k_2 f) / r_{p,eff} \}$			529	529
cl. 12.3.4 (3) of IRC :112-2011				
k_t			0.5	0.5
$f_{ct,eff}$			2.90	2.90
E_s			200000	200000
E_{cm}			31000	29626
$a_e = E_s / E_{cm}$			6.45	6.75
$(e_{sm} - e_{cm}) = (s_{sc} - k_t f_{ct,eff} (1 + a_e r_{p,eff}) / r_{p,eff}) / E_s$ $>= 0.6 s_{sc} / E_s$			0.0001	0.0002
cl. 12.3.4 (2) of IRC :112-2011				
$W_k = S_{r,max} (e_{sm} - e_{cm})$			0.07	0.09
cl. 12.3.4 (1) of IRC :112-2011				
			OK	OK

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

6.0 Summary of provided Reinforcement

Provided Reinforcement

Top Slab

<u>At top of Mid Span</u>			Required
Area of Steel Provided	=	754.0 mm ² /m	526
12mm dia @		150mmc/c Top slab (Top main reinforcement)	
<u>At bottom of Mid Span</u>			
Area of Steel Provided	=	1047.2 mm ² /m	
10mm dia @		150mmc/c Top slab (Bottom main reinforcement)	
10mm dia @		150mmc/c Top slab (Bottom extra reinforcement)	OK
<u>At top of End Support</u>			
Area of Steel Provided	=	1508.0 mm ² /m	
12mm dia @		150mmc/c Top slab (Top main reinforcement)	
12mm dia @		150mmc/c Outer wall (Outer main reinforcement)	OK
0mm dia @		150mmc/c Top corner extra reinforcement	
<u>At bottom of End Support</u>			
Area of Steel Provided	=	523.6 mm ² /m	
10mm dia @		150mmc/c Top slab (Bottom main reinforcement)	OK
0mm dia @		150mmc/c	

Bottom Slab

<u>At top of Mid Span</u>			
Area of Steel Provided	=	1047.2 mm ² /m	
10mm dia @		150mmc/c Bottom slab (Top main reinforcement)	
10mm dia @		150mmc/c Bottom slab (Top extra reinforcement)	OK
<u>At bottom of Mid Span</u>			
Area of Steel Provided	=	754.0 mm ² /m	
12mm dia @		150mmc/c Bottom slab (Bottom main reinforcement)	
0mm dia @		150mmc/c Bottom slab (Bottom extra reinforcement)	
<u>At top of End Support</u>			
Area of Steel Provided	=	523.6 mm ² /m	
10mm dia @		150mmc/c Bottom slab (Top main reinforcement)	OK
0mm dia @		150mmc/c	
<u>At bottom of End Support</u>			
Area of Steel Provided	=	1508.0 mm ² /m	
12mm dia @		150mmc/c Bottom slab (Bottom main reinforcement)	
12mm dia @		150mmc/c Outer wall (Outer main reinforcement)	OK
0mm dia @		150mmc/c Bottom corner extra reinforcement	

	Project	0	Designed by:	KB
	Client	0	Checked by:	0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3	Date & Rev.	0

Outer Wall

At outer face of top end

Area of Steel Provided	=	1508.0 mm ² /m	
12mm dia @ 150mmc/c		Outer wall (Outer main reinforcement)	
12mm dia @ 150mmc/c		Top slab (Top main reinforcement)	OK
0mm dia @ 150mmc/c		Top corner extra reinforcement	

At inner face of top end

Area of Steel Required	=	488.9 mm ² /m	
Area of Steel Provided	=	523.6 mm ² /m	
10mm dia @ 150mmc/c		Outer wall (Inner main reinforcement)	OK

At outer face of bottom end

Area of Steel Provided	=	1508.0 mm ² /m	
12mm dia @ 150mmc/c		Bottom slab (Bottom main reinforcement)	
12mm dia @ 150mmc/c		Outer wall (Outer main reinforcement)	OK
0mm dia @ 150mmc/c		Bottom corner extra reinforcement	

At inner face of bottom end

Area of Steel Provided	=	523.6 mm ² /m	
10mm dia @ 150mmc/c		Outer wall (Inner main reinforcement)	

Shear Reinforcement

Bottom Slab

12mm dia	225mmc/c (Long. Direc	0	185.295 kN
12mm dia	150mmc/c (Trans. Direction)		

Distribution Reinforcement

As per cl. 16.6.1.1 (3) of IRC :112-2011

Top Slab

Req. Reinforcement	=	264 mm ² /m	
Provided Reinforcement	=		
12mm dia @ 225mmc/c		502.7 mm ² /m	OK

Bottom Slab

Req. Reinforcement	=	271.3 mm ² /m	
Provided Reinforcement	=		
12mm dia @ 225mmc/c		502.7 mm ² /m	OK

Outer Wall

Req. Reinforcement	=	244.4 mm ² /m	
Provided Reinforcement	=		
12mm dia @ 225mmc/c		502.7 mm ² /m	OK

	Project	0		KB
	Client	0		0
	Job Name	RCC BOX OF SIZE 1 x 3 x 3		0

7.0 Base Pressure

L/C	Node											Total Wt (KN/m)	Base Pressure (KN/m ²)
	1	2	5	6	7	8	9	10	11	12	13		
299	12	12	24	24	24	24	24	24	24	25	25	242	63
300	15	15	30	30	30	30	30	30	30	31	31	302	79

Max	79
Min.	63
	OK

Bearing capacity = 100 KN/sqm

**Design note
for
RCC BOX OF SIZE 2 x 2 x 2**

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

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	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

1.0 Design Report

The following report represents the design note of RCC BOX of clear span 2 x 2 x 2

1.1 Introduction:-

Design is presented consistently in SI units; the following apply unless mentioned specifically otherwise:

Length	m
Force	kN
Stress	MPa
Bearing Pressure	kN/m ²
Hog Mom/Com Str	-ve
Sag Mom/Ten Str	+ve

1.2 Reference documents :-

- 1 IRC codes /guidelines/special publications
- 2 MORTH specification
- 3 Specialised literature as relevant

1.3 Assumptions:-

The following assumptions have been taken while designing the Box.

- 1 Structure is designed for per metre width.
- 2 On top slab 50mm thick wearing coat is considered for SIDL.
- 3 Deck width taken 12 m
- 4 Carriageway width- 11 m
- 5 Modulus of subgrade reaction (Assumed) - 2500 KN/m³
- 6 Shear value is taken at dist. 0.15m from the face of the slab.
- 7 In case of load dispersion wearing coat thickness, fill thickness and top slab thickness is considered wherever applicable.
- 8 In case of design sheet under summary of moments, only magnitude of force has been considered.
- 9 In case of earth pressure and LL surcharge governing case out of Normal earth pressure, Fluid pressure and Normal earth pressure + hydrostatic fluid pressure is taken.
- 10 Structure is designed for standard earth pressure without weep holes.

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

1.4 Loads:-

The different types of loads used as per IRC 6 : 2017 are.

- 1 Dead load.
- 2 In SIDL fill, crash barrier, and wearing coat load is considered.
- 3 Normal Earth pressure with hydrostatic pressure.
- 4 Live load -70R Track, 40 T Boggie, 70R Wheel load in case of top slab.
- 5 Live load surcharge.
- 6 Braking load is taken as 20% of the live load on top slab.
- 7 1.25 of Impact factor is considered.
- 8 Temperature loading for uniform rise and temperature gradient is considered.
- 9 The Earth pressure coefficient at rest 0.5 is considered.

1.5 Load combinations

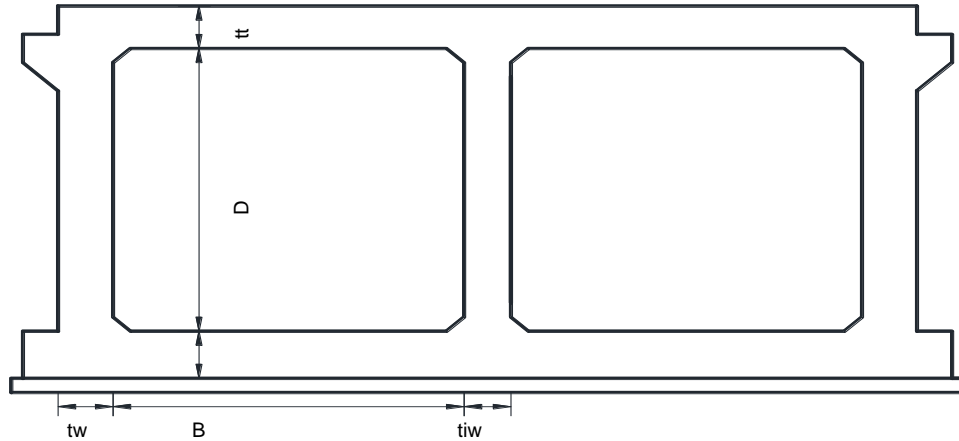
Load combinations as per IRC 6: 2017 have been considered in staad load combination.

1.6 Material properties

- 1 Grade of Concrete M30
- 2 Grade of Steel Fe 500.

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

BOX (2 Cell 2m wide x 2m height)



2.1 Dimensions of Box

No. of Cell	=	2	Clear Width of cell	=	2.00 m
Top Slab Thick. (tt)	=	0.300 m	Clear Height of Cell	=	2.00 m
Bot. Slab Thick. (tb)	=	0.325 m	C/C Width of structure	=	4.600 m
Side Wall Thick. (tw)	=	0.300 m	C/C Height of structure	=	2.313 m
Int. wall Thickness (ti)	=	0.300 m	Total length of Structure at top =	=	4.900 m
Total Deck width	=	12.00 m	Total length of Structure at bottom =	=	4.900 m
Carriageway Width	=	11.00 m	Total Height of Structure	=	2.63 m
water above bott. Slab	=	0.375 m	Footpath Dimensions	=	0.00 m
			Crash barrier width	=	0.50 m
Wearing coat for SIDL	=	75mm	Height of fill =	=	0.00 m
Haunch size	=	150mm			x150mm

SIDL (Top Slab)

Crash barrier	=		10	kN/m ²
Due to earth fill	=	0 x 20 =	0	kN/m ²
			10	kN/m ²
Due to wearing coat	=	0.075 x 22 =	1.65	kN/m ²

2.2 Basic Parameters

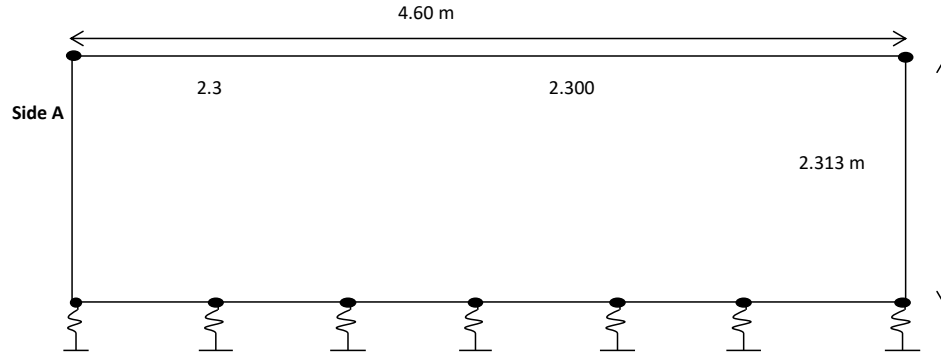
Coefficient of Active Earth Pressure	=	0.279
Earth Pressure at rest $K_0 = (1 - \sin\phi)$	=	0.5
Factor of Earthpressure/Active earthpressi	=	1.793
Saturated Density of fill	=	20 kN/m ³
Submerged Density of fill	=	10 kN/m ³
Dry Density of fill	=	20 kN/m ³
Density of Concrete	=	25 kN/m ³
Live Load Surcharge	=	1.2 m

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Safe Bearing Pressure = 100 kN/m²
 Fluid Pressure as per cl. 214.1 of IRC 6 2010 = 4.71 kN/m²

2.3 Idealised Structure for Staad Analysis

(Analysis is done for 1m Strip)



Nos. of beam for one span at bottom = 10
 Spacing between Springs = 0.230 m
 Modulus of Subgrade Reaction (Assumed) = 2500 kN/m³
 Spring Constant at End Support = 288 kN/m
 Spring Constant at intermediate Support = 575 kN/m

3.1 Earth Pressure and Live Load Calculation

1) a Earth Pressure (Normal Condition)

Earth Pressure	Height
0.84 kN/m ²	0.150 m
13.74 kN/m ²	2.463 m

1) b Fluid Pressure

Fluid Pressure	Height
0.71 kN/m ²	0.150 m
11.60 kN/m ²	2.463 m

1) c Earth Pressure (Normal Condition+Full hydrostatic pressure)

Earth Pressure	Height
1.92	0.15
31.50	2.463 m

1) d Earth Pressure at rest K₀ = (1-sinf) =

LWL		HFL		Height
Earth Pressure	Earth Pressure	Earth Pressure	Earth Pressure	
1.50	2.25	2.25	2.25	0.150 m
24.63	36.94	36.94	36.94	2.463 m

2) a Live Load Surcharge (Normal Condition)

Live Load Surcharge = 6.696 kN/m

2) b Live Load Surcharge (Fluid Pressure) as per cl. 214.1 of IRC 6 2014

Live Load Surcharge = 5.651 kN/m

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

2) c Live Load Surcharge (Normal Condition+Full hydrostatic pressure)

Live Load Surcharge = 15.348 kN/m

2) d Live Load Surcharge at rest

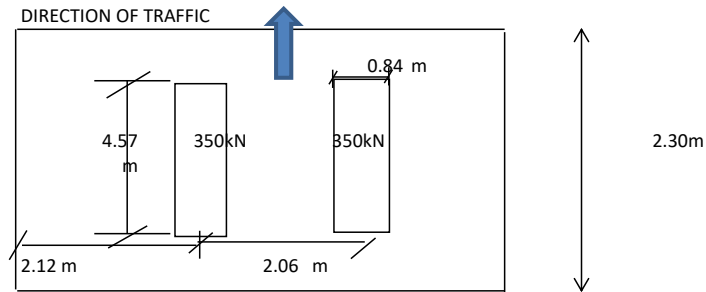
Live Load Surcharge = 12.000 kN/m

2) Load due to water on Bottom Slab

Uniform Load = 3.75 kN/m²

3) Live Load on Top Slab

A) 70R Track at Mid Span



Total Load = **700kN** 4.57 2.3000m
153.17 kN/m
352.3 kN

Effective width of Loading

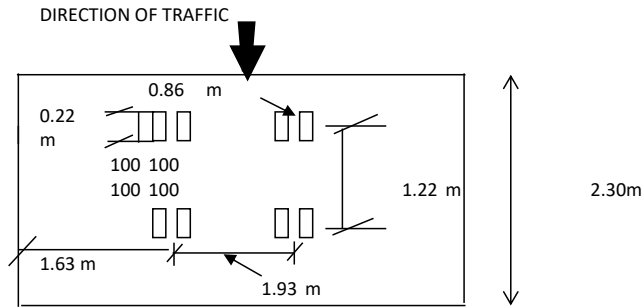
a = 1.15 m
b1 = 0.99 m
b/lo = 5.22
a = 2.60
beff = 2.49 m

2.06 < 2.49 *Therefore overlapping due to load dispersion occurs*

Effective width = 4.55 m
Width along span = 2.3 m
Load Intensity = 33.66 kN/m²
Increase due to impact = 42.08 kN/m²
Say **42.10 kN/m²**

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

B) 40T Boggie Load at Mid Span



Total Load = 400kN

Effective width of Loading

a	=	1.15 m
b1	=	1.01 m
b/lo	=	5.22
a	=	2.60
beff	=	2.51 m
1.93 < 2.51		Therefore overlapping due to load dispersion occurs

Effective width	=	4.44 m
Width along span	=	2.19 m
Load Intensity	=	41.14 kN/m ²
Increase due to impact	=	51.43 kN/m ²
Say		51.50 kN/m²

C) 40T Boggie Load at Support

Effective width of Loading

a	=	0.61 m
b1	=	1.01 m
b/lo	=	5.22
a	=	2.60
beff	=	2.18 m
1.93 < 2.18		Therefore overlapping due to load dispersion occurs

Effective width	=	4.11 m
Width along span	=	1.815 m
Load Intensity	=	53.62 kN/m ²
Increase due to impact	=	67.03 kN/m ²
Say		67.10 kN/m²

D) 70R Track at Support

Effective width of Loading

a	=	1.15 m
b1	=	0.99 m
b/lo	=	5.22
a	=	2.60
beff	=	2.49 m
2.06 < 2.49		Therefore overlapping due to load dispersion occurs

Effective width	=	4.55 m
Width along span	=	2.300 m
Load Intensity	=	33.66 kN/m ²
Increase due to impact	=	42.08 kN/m ²
Say		42.10 kN/m²

E) 70R Track at int side wall

Effective width of Loading

a	=	1.14 m
b1	=	0.99 m
b/lo	=	5.22
a	=	2.60
beff	=	2.48 m

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

2.06 < 2.48

Therefore overlapping due to load dispersion occurs

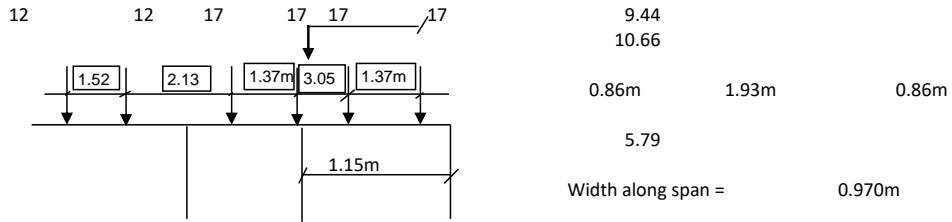
Effective width	4.54 m
Width along span	2.3 m
Load Intensity	33.74 kN/m ²
Increase due to impact	42.18 kN/m ²
Say	42.20 kN/m²

E) Live Load Case for Bottom Slab

Uniform Load = **42.10 kN/m²**

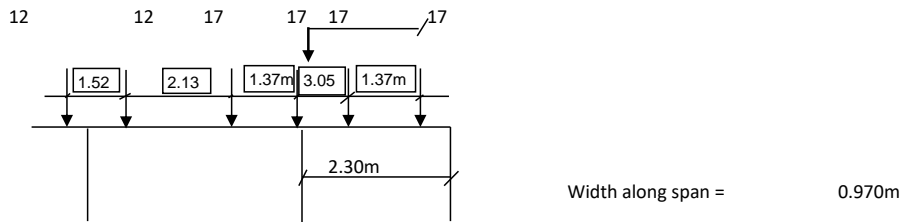
	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

F) 70R Wheel Case 1 (at support)



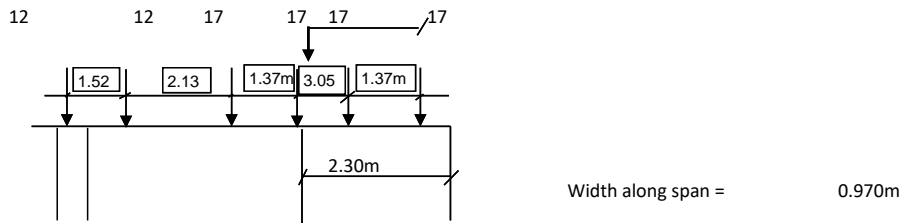
S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	0.49m	2.60	2.01m	Yes	3.94m	43.7 kN/sqm	55 kN/sqm
2	166.77	0.45m	2.60	1.94m	Yes	3.87m	44.4 kN/sqm	55 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.00m	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

F) 70R Wheel Case 2 (at mid)



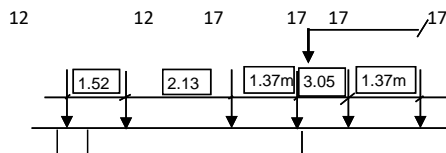
S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	0.485	2.60	2.01m	Yes	3.94m	43.7 kN/sqm	55 kN/sqm
2	166.77	0.445	2.60	1.94m	Yes	3.87m	44.4 kN/sqm	55 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

G) 70R Wheel Case 3 (outerwall)

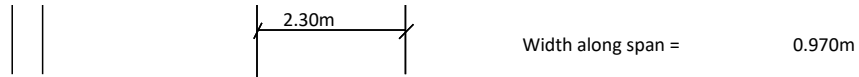


S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	0.485	2.60	2.01m	Yes	3.94m	43.7 kN/sqm	55 kN/sqm
2	166.77	0.445	2.60	1.94m	Yes	3.87m	44.4 kN/sqm	55 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

H) 70R Wheel Case 4 (inner wall)



	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-



S.No.	Load	a	a	beff	Overlap	Eff. Width	Load Int.	With Imp.
1	166.77	0.685	2.60	2.26m	Yes	4.19m	41.0 kN/sqm	51 kN/sqm
2	166.77	0.245	2.60	1.58m	No	1.58m	54.4 kN/sqm	68 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm
0	0	0.000	0.00	0.00m	No	0.00m	0.0 kN/sqm	0 kN/sqm

G) Braking load		20%		Av. Eff. Width	Load per meter
Load on the span 70R Wheel	334 kN	67 kN		3.90m	17 kN/m
Load on the span 70R Track	352 kN	70 kN		4.55m	15 kN/m
Max. force					17 kN/m

A) 70R Track at Inner Wall

a	=	1.14 m
b1	=	0.99 m
b/lo	=	5.22
a	=	2.60
beff	=	2.48 m
2.06 < 2.48	<i>Therefore overlapping due to load dispersion occurs</i>	
Effective width	=	4.54 m
Width along span	=	2.3 m
Load Intensity	=	33.74 kN/m ²
Increase due to impact	=	42.18 kN/m ²
	Say	42.20 kN/m²

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

4) COLLISION LOAD

Nominal Vehicle collision load as per cl. 222.3 table 9 of IRC 6 2010

Point of application above Carriageway level	Direction of load	Load	Av. Eff. Width	Load per meter
At crash barrier due to live load moving on bottom slab				
Main + Residual Load	1.0m Normal to the carriageway	0 kN	1.00m	0 kN/m/m
Main + Residual Load	1.0m Parallel to the carriageway	0 kN	1.00m	0 kN/m/m

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

3.2 Temperature load calculation

Effective Bridge Temperature

Maximum Air Shade temperature	=	47.9	/oC (as per Annexure F of IRC:6-2017)
Minimum Air Shade temperature	=	0.2	/oC (as per Annexure F of IRC:6-2017)
Mean of max and min temperature	=	23.85	/oC (as per clause 215.2 of IRC:6-2017)
Bridge temperature to be assumed	=	33.85	
TEMPERATURE RISE		33.85	
TEMPERATURE FALL		-34.05	

Effect of temperature gradient

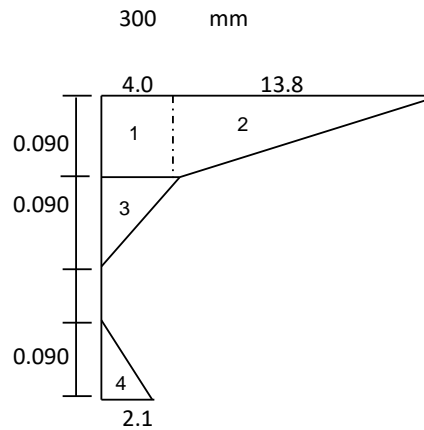
The box has been checked for temperature differential.

$$F = E_c aDt A$$

E_c = Modulus of Elasticity of Concrete	=	3.20E+06	t/m ²
a = Coefficient of Thermal expansion	=	1.20E-05	/oC (as per IRC:6)
Dt = Temperature differential			
A = X sectional Area of section where temperature differential is Dt			

Average thickness of Deck slab =

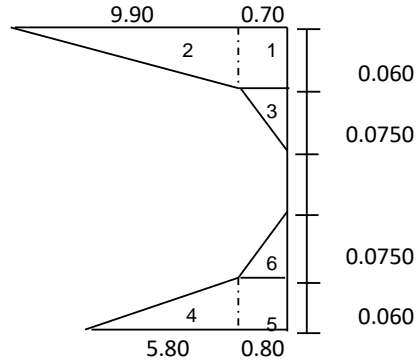
EFFECT OF TEMPERATURE RISE



Sr. No.	Dt	b	t	A = b x t	F (force)	Acting at	Eccentricity e*
1	4.0	1.0	0.090	0.090	13.82	0.045 m from top	0.105
2	$\frac{13.8}{2}$	1.0	0.100	0.100	26.50	0.033 m from top	0.117
3	$\frac{4.0}{2}$	1.0	0.090	0.090	6.91	0.120 m from top	0.030
4	$\frac{2.1}{2}$	1.0	0.090	0.090	3.63	0.030m from bottom	-0.120
					SF = 50.86	M = 4.315	

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

EFFECT OF TEMPERATURE FALL



Sr. No.	Dt	b	t	A = b x t	F (force)	Acting at	Eccentricity e*
1	0.70	1.0	0.060	0.060	1.61	0.03 m from top	0.120
2	$\frac{9.90}{2}$	1.0	0.060	0.060	11.40	0.020 m from top	0.130
3	$\frac{0.70}{2}$	1.0	0.0750	0.0750	1.01	0.085 m from top	0.065
4	$\frac{5.80}{2}$	1.0	0.060	0.060	6.68	0.020 m from bottom	-0.130
5	0.80	1.0	0.060	0.060	1.84	0.030 m from bottom	-0.120
6	$\frac{0.80}{2}$	1.0	0.0750	0.0750	1.15	0.085 m from bottom	-0.065
					SF = 23.70	M = 0.577	

Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

3.3 Summary of factored moments

Grade of Concrete = M25

Grade of Steel = Fe500

Summary of factored moments

Load Case	Top slab			Bottom slab			Outer wall				Inner wall			
	Moment in Mid-Span	Moment at End Support	Top slab shear at	Moment in Mid-Span	Moment at End Support	Bottom slab shear	Min. Axial force	Moment at top	Moment at bottom	Wall shear at deff	Min. Axial force	Moment at top	Moment at bottom	Wall shear at deff
	kN-m	kN-m	kN	kN-m	kN-m	kN	KN	kN-m	kN-m	kN	KN	kN-m	kN-m	kN
Basic Combination (35 - 72)	48.3	57	30	-	-	-	17	55	80	93	18	26	37	17
Rare Combination (73 -148)	33	42	26	43	65		14	39	62	70	16	20	31	18
Frequent Combinatio (149 - 225)	-	-	-	-	-	-	-	-	-	-		-	-	-
Quasi Static (226 - 229)	10	15		6	15			14	13			1	1	
Combination 1 (230 -301)	-	-	-	65	86	123	-	-	-	-		-	-	-
Combination 2 (302 - 373)	-	-	-	58	80	122	-	-	-	-		-	-	-
	-	-	-	58	80	122	-	-	-	-		-	-	-

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

4.0 Partial Safety Factors

Material Parameters

Concrete

Refer Table 6.5, IRC:112-2011

Grade		=	M35
Cube strength of concrete at 28 days	f_{ck}	=	35 MPa
Design value of concrete compressive strength	f_{cd}	=	$\alpha f_{ck} / \gamma_m$
			a = 0.67
			Refer cl. 6.4.2.8 of IRC:112-2011
	f_{ctm}	=	2.8 MPa
For Basic Combination	f_{cd}	=	15.63 MPa
For Accidental Combination	f_{cd}	=	19.54 MPa
For Seismic Combination	f_{cd}	=	15.63 MPa
Modulus of Elasticity	E_c	=	32000 MPa
Mean value of axial tensile strength of concrete	f_{ctm}	=	2.8 MPa
Density		=	2.50 t/m³
Grade		=	Fe500
Characteristics yield strength	f_{yk}	=	500 MPa
Design yield strength	f_{yd}	=	f_{yk} / γ_m
For Basic Combination	f_{yd}	=	434.78 MPa
For Accidental Combination	f_{yd}	=	500 MPa
For Seismic Combination	f_{yd}	=	434.78 MPa
Modulus of Elasticity	E_s	=	2.0E+05 MPa
Density		=	7.85 t/m³

Partial Safety Factor for Materials

Material	Partial Safety Factor g_m			
	Basic Combination	Accidental Combination	Seismic Combination	
Concrete	1.5	1.2	1.5	Cl 6.4.2.8, IRC:112-2011
Steel	1.15	1	1.15	Cl 6.2.2, IRC:112-2011

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Partial Safety Factor for Loads

Ultimate Limit State

Partial Safety for Verification of Structural Strength
Also refer IRC Amendment dated 28th July, 2012

Table 3.1, Annex B, IRC:6-2014

Loads	Partial Safety Factor					
	Basic Combination		Accidental Combination		Seismic Combination	
(1)	(2)	(3)	(4)	(5)	(4)	(3)
	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect	Overturning or Sliding or Uplift Effect	Restoring or Resisting Effect
Permanent Loads:	1.05	0.95	1.00	1.00	1.05	0.95
Dead Load, SIDL except surfacing, Backfill Weight, Settlement, Creep and shrinkage effect						
Surfacing	1.35	1.00	1.00	1.00	1.35	1.00
Earth Pressure due to Backfill	1.50	0.00	1.00	0.00	1.00	0.00
Variable Loads:						
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:						
a) Leading Load	1.50	0.00	0.75	0.00	0.00	0.00
b) Accompanying Load	1.15	0.00	0.20	0.00	0.20	0.00
c) Construction Live Load	1.35	0.00	1.00	0.00	1.00	0.00
Thermal Loads						
a) As Leading Load	1.50	0.00	0.00	0.00	0.00	0.00
b) As Accompanying Load	0.90	0.00	0.50	0.00	0.50	0.00
Wind						
a) As Leading Load	1.50	0.00	0.00	0.00	0.00	0.00
b) As Accompanying Load	0.90	0.00	0.00	0.00	0.00	0.00
Live Load Surcharge (as accompanying load)	1.20	0.00	0.00	0.00	0.00	0.00
Accidental Effects:						
i) Vehicle Collision						
ii) Barge Impact	0.00	0.00	1.00	0.00	0.00	0.00
iii) Impact due to floating bodies						
Seismic Effect						
a) During Service	0.00	0.00	0.00	0.00	1.50	0.00
b) During Construction	0.00	0.00	0.00	0.00	0.75	0.00
Construction Condition:						
Counter Weights:						
a) When density or self weight is well defined	0.00	0.90	0.00	1.00	0.00	1.00
b) When density or self weight is not well defined	0.00	0.80	0.00	1.00	0.00	1.00
c) Erection effects	1.05	0.95	0.00	0.00	0.00	0.00
Wind						
a) As Leading Load	1.50	0.00	0.00	0.00	0.00	0.00
b) As Accompanying Load	1.20	0.00	0.00	0.00	0.00	0.00
Hydraulic Loads:						
(Accompanying Load):						
Water Current Forces	1.00	0.00	1.00	0.00	1.00	0.00
Wave Pressure	1.00	0.00	1.00	0.00	1.00	0.00
Hydrodynamic Effect	0.00	0.00	0.00	0.00	1.00	0.00
Buoyancy	1.00	0.00	1.00	0.00	1.00	0.00

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Partial Safety for Verification of Structural Strength
Also refer IRC Amendment dated 28th July, 2012

Table 3.2, Annex B, IRC:6-2014

Loads	Partial Safety Factor		
	Basic Combination	Accidental Combination	Seismic Combination
(1)	(2)	(3)	(4)
Permanent Loads:			
Dead Load			
SIDL except surfacing			
a) Adding to the effect of variable loads	1.35	1.00	1.35
b) Relieving the effect of variable loads	1.00	1.00	1.00
Surfacing:			
a) Adding to the effect of variable loads	1.75	1.00	1.75
b) Relieving the effect of variable loads	1.00	1.00	1.00
Backfill Weight	1.50	1.00	1.00
Earth Pressure due to Backfill			
a) Leading Load	1.50	0.00	1.00
b) Accompanying Load	1.00	1.00	1.00
Variable Loads:			
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:			
a) Leading Load	1.50	0.75	0.00
b) Accompanying Load	1.15	0.20	0.20
c) Construction Live Load	1.35	1.00	1.00
Wind during service and construction			
a) Leading Load	1.50	0.00	0.00
b) Accompanying Load	0.90	0.00	0.00
Live Load Surcharge (as accompanying load)	1.20	0.20	0.20
Erection effects	1.00	1.00	1.00
Accidental Effects:			
i) Vehicle Collision			
ii) Barge Impact	0.00	1.00	0.00
iii) Impact due to floating bodies			
Seismic Effect			
a) During Service	0.00	0.00	1.50
b) During Construction	0.00	0.00	0.75
Hydraulic Loads (Accompanying Load):			
Water Current Forces	1.00	1.00	1.00
Wave Pressure	1.00	1.00	1.00
Hydrodynamic Effect	0.00	0.00	1.00
Buoyancy	0.15	0.15	0.15

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Serviceability Limit State

Partial Safety for Verification of Serviceability Limit State

Table 3.3, Annex B, IRC:6-2014

Loads	Partial Safety Factor		
	Rare Combination	Frequent Combination	Quasi-permanent
(1)	(2)	(3)	(4)
Permanent Loads:			
Dead Load	1.00	1.00	1.00
SIDL including surfacing	1.00	1.00	1.00
Backfill Weight	1.00	1.00	1.00
Shrinkage and Creep Effects	1.00	1.00	1.00
Earth Pressure due to Backfill	1.00	1.00	1.00
Settlement Effects			
a) Adding to the permanent loads	1.00	1.00	1.00
b) Opposing the permanent loads	0.00	0.00	0.00
Variable Loads:			
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:			
a) Leading Load	1.00	0.75	0.00
b) Accompanying Load	0.75	0.20	0.00
Thermal Loads:			
a) Leading Load	1.00	0.60	0.00
b) Accompanying Load			
Wind			
a) Leading Load	1.00	0.60	0.00
b) Accompanying Load	0.60	0.50	0.00
Live Load Surcharge (Accompanying load)	0.80	0.00	0.00
Hydraulic Loads (Accompanying Load):			
Water Current Forces	1.00	1.00	0.00
Wave Pressure	1.00	1.00	0.00
Buoyancy	0.15	0.15	0.15

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Combination for Base Pressure and Design of Foundation

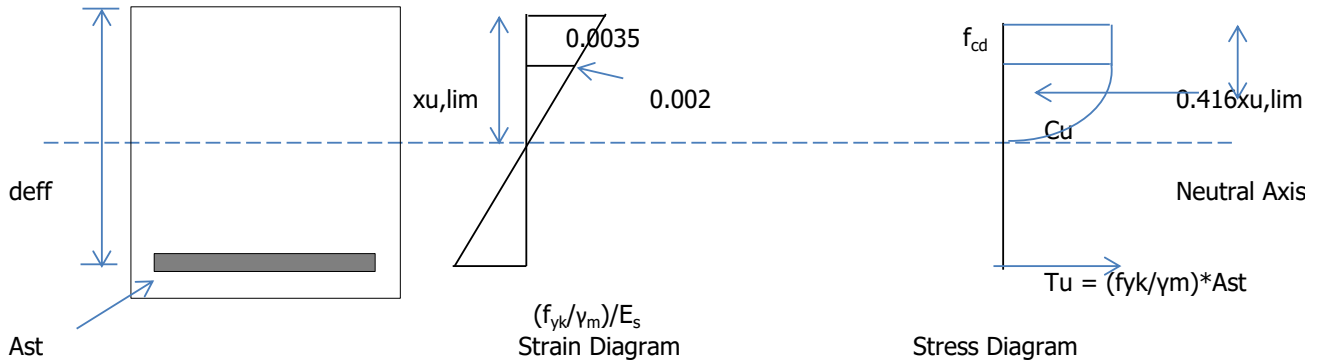
Table 3.4, Annex B, IRC:6-2014

Also refer IRC Amendment dated 28th July, 2012

Loads	Partial Safety Factor			
	Combination (1)	Combination (2)	Seismic Combination	Accidental Combination
(1)	(2)	(3)	(4a)	(4b)
Permanent Loads:				
Dead Load, SIDL except surfacing, Backfill earth filling	1.35	1.00	1.35	1.00
SIDL Surfacing	1.75	1.00	1.75	1.00
Settlement Effect	1.0 or 0	1.0 or 0	1.0 or 0	1.0 or 0
Earth Pressure due to Backfill				
a) Leading Load	1.50	1.30	0.00	0.00
b) Accompanying Load	1.00	0.85	1.00	1.00
Variable Loads:				
Carriageway Live Load and associated loads (braking, tractive and centrifugal forces) and pedestrian live load:			(0.75 if applicable) or	(0.75 if applicable)
a) Leading Load	1.50	1.30	0	or 0
b) Accompanying Load	1.15	1.00	0.20	0.20
Thermal Loads as accompanying load	0.90	0.80	0.50	0.50
Wind				
a) Leading Load	1.50	1.30	0.00	0.00
b) Accompanying Load	0.90	0.80	0.00	0.00
Live Load Surcharge (as accompanying load if applicable)	1.20	1.00	0.20	0.20
Accidental Effects or Seismic Effect:				
a) During Service	0.00	0.00	1.50	1.00
b) During Construction	0.00	0.00	0.75	0.50
Erection effects	1.00	1.00	1.00	1.00
Hydraulic Loads:				
Water Current	1.0 or 0	1.0 or 0	1.0 or 0	1.0 or 0
Wave Pressure	1.0 or 0	1.0 or 0	1.0 or 0	1.0 or 0
Hydrodynamic Effect	0.00	0.00	1.0 or 0	1.0 or 0
Buoyancy:				
For Base Pressure	1.00	1.00	1.00	1.00
For Structural Design	0.15	0.15	0.15	0.15

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.:	-

5.1.1 Verification of structural strength for top slab



ULTIMATE LIMIT STATE

Grade of Concrete
As per clause 6.4.2.8, IRC:112-2011

$$f_{ck} = 35 \text{ N/mm}^2$$

$$f_{cd} = 15.63 \text{ N/mm}^2 \text{ For Basic Combination}$$

$$f_{cd} = 19.54 \text{ N/mm}^2 \text{ For Accidental Combination}$$

$$f_{cd} = 15.63 \text{ N/mm}^2 \text{ For Seismic Combination}$$

$$E_c = 32000 \text{ MPa}$$

Grade of steel

$$f_y = 500 \text{ N/mm}^2$$

$$f_{yd} = 435 \text{ N/mm}^2 \text{ For Basic Combination}$$

$$f_{yd} = 500 \text{ N/mm}^2 \text{ For Accidental Combination}$$

$$f_{yd} = 435 \text{ N/mm}^2 \text{ For Seismic Combination}$$

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

$$\text{Minimum strain in steel reinforcement} = \frac{0.87 f_y}{E_s} = \frac{0.87 \times 500}{2.0 \times 10^5} = 2.1525 \times 10^{-3}$$

$$\begin{aligned} Cu &= f_{cd} \cdot b \cdot \left(\frac{3}{7} x_{u,lim} + \frac{2}{3} \cdot \frac{4}{7} x_{u,lim} \right) \\ &= \frac{17}{21} \cdot f_{cd} \cdot b \cdot x_{u,lim} \\ &= 0.8095 \cdot f_{cd} \cdot b \cdot x_{u,lim} \end{aligned}$$

$E_c = 32000 \text{ MPa}$
Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashc K. Jain

$$\text{cg of compression block from top} = 0.416 x_{u,lim}$$

$$T_u = f_{yd} \cdot A_{st}$$

$$R_{lim} = \frac{M_{u,lim}}{bd^2} = \frac{0.8095 f_{cd} \cdot (x_{u,lim}/d) \cdot (1 - 0.416 \cdot x_{u,lim}/d)}{bd^2}$$

	Basic Comb	Accidental Comb	Seismic Comb
$x_{u,lim}/d$	0.62	0.58	0.62
$R_{lim} = M_{u,lim}/bd^2$	5.80	6.99	5.80

Here R_{lim} is in MPa

Calculation of Reinforcement

Width of section b = 1000 mm

Depth of section D = 300 mm

Clear cover = 50 mm

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.:	-

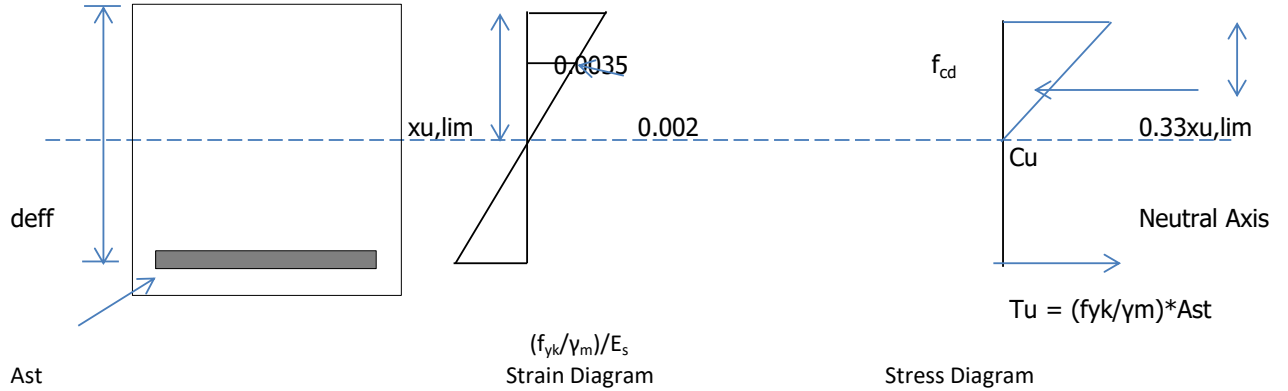
Moment on the section	Top slab Top End support			Top slab Bottom Mid Span		
	Basic Comb			Basic Comb		
Actual moment (KNm)	57.0			48.3		
b	1000			1000		
D	300			300		
c	50			50		
d	232.0			232.0		
f_{cd}	15.63			15.63		
f_{yd}	435			435		
$x_{u,lim}/d$	0.62			0.62		
$R_{sfs} = M_{u,sfs}/bd^2$	5.80			5.80		
$M_{u,Lim}$ (KNm)	312			312		
	OK			OK		
Ast Req.	586			494		
Dia of bar (main tension) (mm)	12			12		
Spacing (mm)	180			180		
+ dia of bar (main tension) (mm)	12			12		
Spacing (mm)	180			180		
Ast provided (sq mm)	1257			1257		
Dia of bar (main compression) (mm)	12			12		
Spacing (mm)	180			180		
Area of main compression (mm ²)	628			628		
f_{ctm}	2.8			2.8		
f_{yk}	435			435		
cl. 16.6.1 (2) of IRC :112-2011						
$A_{s,min} = 0.26 f_{ctm} b_t d / f_{yk} \geq 0.0013 b_t d$	388			388		
A_{ct}	256827			256827		
$f_{ct,eff}$	2.9			2.9		
$k_c = 0.4 \{ 1 - s_c / (k_1 f_{ct,eff} h/h^*) \} \leq 1$	0.4			0.4		
For Bending or bending combined with axial force						
k	1.0000			1.0000		
s_s	435			435		
$A_{s,max} = 0.025 A_c$ (main tension)	7500			7500		
cl. 16.5.1.1 (2) of IRC :112-2011	OK			OK		
$A_{s,max} = 0.04 A_c$ (tension + compression)	12000			12000		
x (mm)	43			43		
x/d	0.186			0.186		
	OK			OK		
z (mm)	214			214		
MR (KNm)	117			117		
	OK			OK		

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Shear on the section	Top slab Top End support		
Actual shear V_{Ed} (KN)	30.0		
Actual shear stress (N/mm ²)	0.144		
Max shear capacity, $0.135 f_{ck}(1-f_{ck}/310)$	4.2		
	OK.		
Min shear capacity, $0.0924 f_{ck}(1-f_{ck}/310)$	2.9		
$\Theta = 0.5 \times \sin^{-1}$ (Applied shear stress / $0.135/f_{ck}/(1-f_{ck}/310)$)			
Min angle of inclination, Θ (deg)	21.8		
cl. 10.3.2(2) Eq. 10.2 of IRC :112-2010			
$K = 1 + \text{Sqrt}(200/d) \leq 2.0$	1.928		
cl. 10.3.2(2) Eq. 10.3 of IRC :112-2010			
$n_{min} = 0.031 K^{3/2} f_{ck}^{1/2}$	0.491		
cl. 10.3.1 of IRC :112-2011			
$r1 = A_{sl}/(b_w d) \leq 0.02$	0.005		
	OK		
$0.12 K (80 r1 f_{ck})^{0.33}$	0.568		
Axial compressive force N_{Ed} (KN)	0		
$s_{cp} = N_{Ed} / A_c \leq 0.2 f_{cd}$	0.0		
cl. 10.3.2(2) Eq. 10.1 of IRC :112-2010			
$V_{Rd,c} = [0.12K(80\rho_1 f_{ck})^{0.33} + 0.15\sigma_{cp}]b_w d \leq (n_{min} + 0.15 s_{cp}) b_w d$ (KN)	114		
	OK.		
Min shear stress	0.491		
Min shear force for providing reinf., V_E (N)	102552.9		
No. of link for shear reinf.	4		
Dia. of bar for shear reinf.	12		
$S = A_{sw} \times 0.9 \times d \times \cot \Theta \times f_y / V_E$	1001		
A_{sw}	452		
cl. 16.5.2(7) Eq. 16.6 of IRC :112-2011			
$S_{l,max} = 0.75 d$	174		
Spacing provided in Long. Direction (mm)	174.0		
cl. 16.5.2(9) Eq. 16.8 of IRC :112-2011			
$S_{t,max} = 0.75 d \leq 600\text{mm}$	174		
Spacing provided in Trans. Direction, S_t mm	150		
	OK		

	Project	-	Designed by	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

5.1.2 Verification for serviceability limit state for top slab



SERVICEABILITY LIMIT STATE

Grade of Concrete
As per clause 12.2.1, IRC:112-2011

$$f_{ck} = 35 \text{ N/mm}^2$$

$$f_{cd} = 16.80 \text{ N/mm}^2$$

$$f_{cd} = 16.80 \text{ N/mm}^2$$

$$f_{cd} = 12.60 \text{ N/mm}^2$$

For Rare Combination

For Frequent Combination

For Quasi-Perma. Combination

As per clause 12.2.2, IRC:112-2011

Grade of steel

$$f_y = 500 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

For Rare Combination

For Frequent Combination

For Quasi-Perma. Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

$$\text{Minimum strain in steel reinforcement} = 0.87 f_y / E_s$$

$$E_s = 2.0E+05 \text{ MPa}$$

$$E_c = 32000 \text{ MPa}$$

$$C_u = 1/2 \cdot f_{cd} \cdot b \cdot x_u$$

$$= 0.5 \cdot f_{cd} \cdot b \cdot x_u$$

cg of compression block from top

$$= 0.33 x_u$$

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

$$T_u = f_{yd} \cdot A_{st}$$

$$R_{sls} = M_{u,sls} / b d^2 = 0.5 f_{cd} \cdot (x_u/d) \cdot (1 - 0.33 \cdot x_u/d)$$

	Rare Comb	Frequent Comb	Quasi-Perma. Comb
$x_{u,sls}/d$	0.70	0.70	0.70
$R_{sls} = M_{u,sls} / b d^2$	4.52	4.52	3.39

Here R_{sls} is in MPa

Calculation of Reinforcement

Width of section b = 1000 mm

Depth of section d = 300 mm

Clear cover = 40

	Project	-	Designed by	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

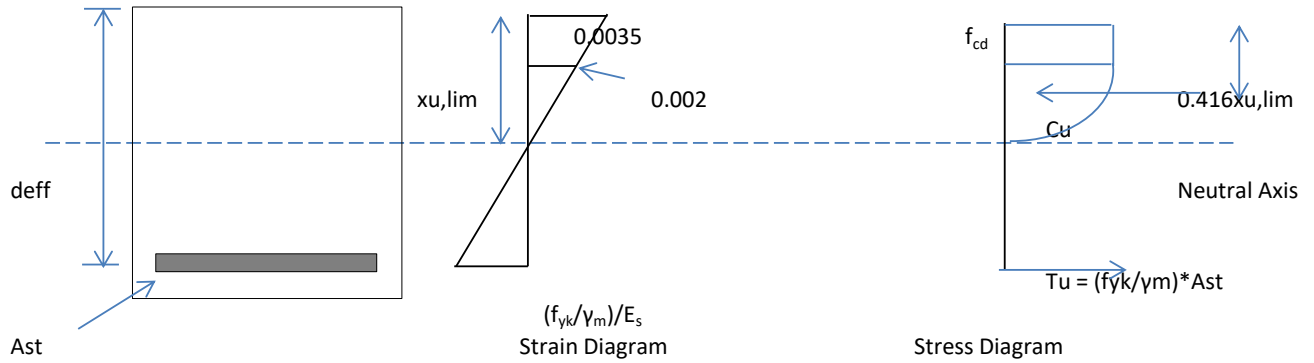
Moment on the section	Top slab Top End support			Top slab Bottom Mid Span		
	Rare Comb		Quasi-Perma. Comb	Rare Comb		Quasi-Perma. Comb
Actual moment (KNm)	42.0		15.0	33		10
b	1000		1000	1000		1000
D	300		300	300		300
c	40		40	40		40
d	242.0		242.0	242.0		242.0
f _{cd}	16.80		12.60	16.80		12.60
f _{Yd}	300		300	300		300
x _{u,sls} /d	0.70		0.70	0.70		0.70
R _{sls} = M _{u,sls} /bd ²	4.52		3.39	4.52		3.39
M _{u,sls} (KNm)	265		199	265		199
	OK		OK	OK		OK
Ast Req.	596		209	465		139
Dia of bar (main tension) (mm)	12		12	12		12
Spacing (mm)	180		180	180		180
+ dia of bar (main tension) (mm)	12		12	12		12
Spacing (mm)	180		180	180		180
Ast provided (sq mm)	1257		1257	1257		1257
Dia of bar (main compression) (mm)	12		12	12		12
Spacing (mm)	180		180	180		180
Area of main compression (mm ²)	628		628	628		628
f _{ctm}	2.8		2.8	2.8		2.8
x (mm)	44.9		59.8	44.9		59.8
x/d	0.185		0.247	0.185		0.247
	OK		OK	OK		OK
z (mm)	227		222	227		222
MR _{sls} (KNm)	86		84	86		84
	OK		OK	OK		OK
s _{sc} = M/(A _s z)	147		54	116		36
	OK		OK	OK		OK
s _{ca} = M/(0.8095 z b x _u)	8.24		2.26	6.47		1.50
	OK		OK	OK		OK

	Project	-	Designed by	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Calculation of crack width	Top slab Top End support		Top slab Bottom Mid Span	
n_1		6		6
n_2		6		6
$f_{eq} = (n_1 f_1^2 + n_2 f_2^2) / (n_1 f_1 + n_2 f_2)$		12		12
cl. 12.3.4 (3) of IRC :112-2011				
c		40		40
k_1		0.8		0.8
k_2		0.50		0.50
For skew slab refer eq. 12.10 of IRC :112-2011				
$r_{p,eff} = A_s / A_{c,eff}$		0.011		0.011
$S_{r,max} = \{ 3.4 c + (0.425 k_1 k_2 f) / r_{p,eff} \}$		323		323
cl. 12.3.4 (3) of IRC :112-2011				
k_t		0.5		0.5
$f_{ct,eff}$		2.90		2.90
E_s		200000		200000
E_{cm}		32000		32000
$a_e = E_s / E_{cm}$		6.25		6.25
$(e_{sm} - e_{cm}) = (s_{sc} - k_t f_{ct,eff} (1 + a_e r_{p,eff}) / r_{p,eff}) / E_s$ $\geq 0.6 s_{sc} / E_s$		0.0002		0.0001
cl. 12.3.4 (2) of IRC :112-2011				
$W_k = S_{r,max} (e_{sm} - e_{cm})$		0.052		0.03
cl. 12.3.4 (1) of IRC :112-2011				
		OK	OK	OK
Calculation of deflection				
Span (mm)				4600
span/800				5.8
cl. 12.4.1 (2) of IRC :112-2011				
Short term elastic deflection from STAAD				0.2
				OK

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

5.2.1 Verification of structural strength for bottom slab



ULTIMATE LIMIT STATE

Grade of Concrete	f_{ck}	=	35	N/mm ²	
As per clause 6.4.2.8, IRC:112-2011					
	f_{cd}	=	15.63	N/mm ²	Combination (1)
	f_{cd}	=	19.54	N/mm ²	Accidental Combi.
	f_{cd}	=	15.63	N/mm ²	Combination (2)
	E_c	=	32000	MPa	
Grade of steel	f_y	=	500	N/mm ²	
	f_{yd}	=	435	N/mm ²	Combination (1)
	f_{yd}	=	500	N/mm ²	Accidental Combi.
	f_{yd}	=	435	N/mm ²	Combination (2)

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement = $0.87 f_y / E_s$
 $E_s = 2.0E+05$ MPa

$E_c = 32000$ MPa

$$C_u = \frac{f_{cd} \cdot b \cdot (3/7 x_{u,lim} + 2/3 \cdot 4/7 x_{u,lim})}{17/21 \cdot f_{cd} \cdot b \cdot x_u} = 0.8095 \cdot f_{cd} \cdot b \cdot x_u$$

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

cg of compression block from top = $0.416 x_u$

$T_u = f_{yd} \cdot A_{st}$

$$R_{lim} = M_{u,lim} / b d^2 = 0.8095 f_{cd} \cdot (x_{u,lim} / d) \cdot (1 - 0.416 \cdot x_{u,lim} / d)$$

	Basic Comb	Accidental Comb	Seismic Comb
$x_{u,lim} / d$	0.62	0.58	0.62
$R_{lim} = M_{u,lim} / b d^2$	5.80	6.99	5.80

Here R_{lim} is in MPa

Calculation of Reinforcement

Width of section b	=	1000	mm
Depth of section D	=	325	mm
Clear cover at bott.	=	75	mm
Clear cover at top	=		40

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

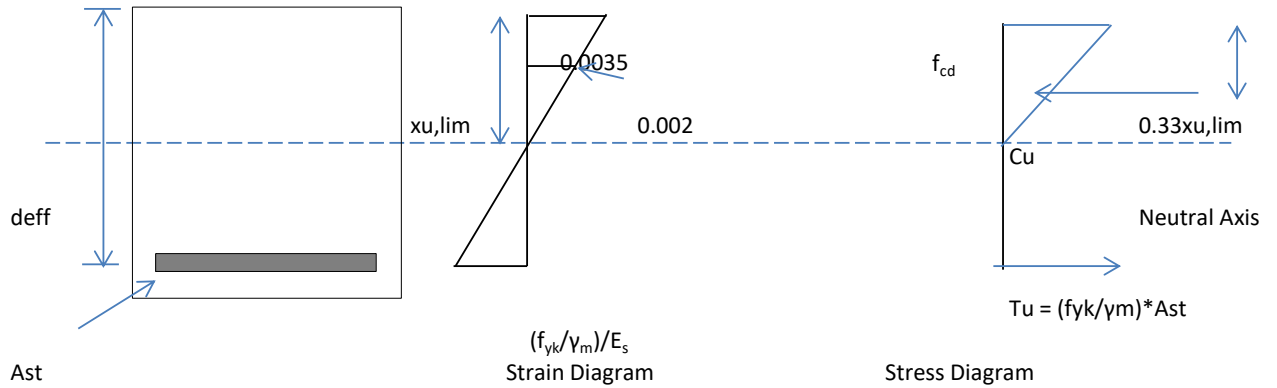
Moment on the section	Bottom End support		Top Mid Span		
	Combinatio n (1)		Combinatio n (2)	Combinatio n (1)	Combinatio n (2)
Actual moment (KNm)	86.0		80.0	65.0	58.0
b	1000		1000	1000	1000
D	325		325	325	325
c	75		75	40	40
d	232.0		232.0	267.0	267.0
f_{cd}	15.63		15.63	15.63	15.63
f_{yd}	435		435	435	435
$x_{u,lim}/d$	0.62		0.62	0.62	0.62
$R_{sls} = M_{u,sls}/bd^2$	5.80		5.80	5.80	5.80
$M_{u,Lim}$ (KNm)	312		312	414	414
	OK		OK	OK	OK
Ast Req.	903		836	578	514
Dia of bar (main tension) (mm)	12		12	12	12
Spacing (mm)	180		180	180	180
+ dia of bar (main tension) (mm)	12		12	12	12
Spacing (mm)	180		180	180	180
Ast provided (sq mm)	1257		1257	1257	1257
Dia of bar (main compression) (mm)	12		12	12	12
Spacing (mm)	180		180	180	180
Area of main compression (mm ²)	628		628	628	628
f_{ctm}	2.8		2.8	2.8	2.8
f_{yk}	435		435	435	435
cl. 16.6.1 (2) of IRC :112-2011					
$A_{s,min} = 0.26 f_{ctm} b_t d / f_{yk} \geq 0.0013 b_t d$	388		388	447	447
A_{ct}	281827		281827	281827	281827
$f_{ct,eff}$	2.9		2.9	2.9	2.9
$k_c = 0.4 \{ 1 - s_c / (k_1 f_{ct,eff} h/h^*) \} \leq 1$	0.4		0.4	0.4	0.4
For Bending or bending combined with axial force					
k	0.9825		0.9825	0.9825	0.9825
s_s	435		435	435	435
$A_{s,max} = 0.025 A_c$ (main tension)	8125		8125	8125	8125
cl. 16.5.1.1 (2) of IRC :112-2011	OK		OK	OK	OK
$A_{s,max} = 0.04 A_c$ (tension + compression)	13000		13000	13000	13000
x (mm)	43		43	43	43
x/d	0.186		0.186	0.162	0.162
	OK		OK	OK	OK
z (mm)	214		214	249	249
MR (KNm)	117		117	136	136
	OK		OK	OK	OK

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Shear on the section	Bottom End support		
Actual shear V_{Ed} (KN)	123.0		122.0
Actual shear stress (N/mm ²)	0.589		0.584
Max shear capacity, $0.135 f_{ck}(1-f_{ck}/310)$	4.2		4.2
	OK.		OK.
Min shear capacity, $0.0924 f_{ck}(1-f_{ck}/310)$	2.9		2.9
$\Theta = 0.5 \times \sin^{-1}$ (Applied shear stress / $0.135/f_{ck}/(1-f_{ck}/310)$)			
Min angle of inclination, Θ (deg)	21.8		21.8
cl. 10.3.2(2) Eq. 10.2 of IRC :112-2010			
$K = 1 + \sqrt{200/d} \leq 2.0$	1.928		1.928
cl. 10.3.2(2) Eq. 10.3 of IRC :112-2010			
$n_{min} = 0.031 K^{3/2} f_{ck}^{1/2}$	0.491		0.491
cl. 10.3.1 of IRC :112-2011			
$r_1 = A_{sl}/(b_w d) \leq 0.02$	0.005		0.005
	OK		OK
$0.12 K (80 r_1 f_{ck})^{0.33}$	0.568		0.6
Axial compressive force N_{Ed} (KN)	0		0
$s_{cp} = N_{Ed} / A_c \leq 0.2 f_{cd}$	0.0		0.0
cl. 10.3.2(2) Eq. 10.1 of IRC :112-2010			
$V_{Rd,c} = [0.12K(80\rho_1 f_{ck})^{0.33} + 0.15\sigma_{cp}]b_w d \leq (n_{min} + 0.15 s_{cp}) b_w d$ (KN)	114		114
	Provide Shear Reinf.		Provide Shear Reinf.

	Project	-	Designed by	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

5.2.2 Verification for serviceability limit state for bottom slab



SERVICEABILITY LIMIT STATE

Grade of Concrete
As per clause 12.2.1, IRC:112-2011

$$f_{ck} = 35 \text{ N/mm}^2$$

$$f_{cd} = 16.80 \text{ N/mm}^2$$

$$f_{cd} = 16.80 \text{ N/mm}^2$$

$$f_{cd} = 12.60 \text{ N/mm}^2$$

For Rare Combination
For Frequent Combination
For Quasi-Perma. Combination

As per clause 12.2.2, IRC:112-2011

Grade of steel

$$f_y = 500 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

For Rare Combination
For Frequent Combination
For Quasi-Perma. Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

$$\text{Minimum strain in steel reinforcement} = 0.87 f_y / E_s$$

$$E_s = 2.0E+05 \text{ MPa}$$

$$E_c = 32000 \text{ MPa}$$

$$C_u = 1/2 \cdot f_{cd} \cdot b \cdot x_u$$

$$= 0.5 \cdot f_{cd} \cdot b \cdot x_u$$

$$\text{cg of compression block from top} = 0.33 x_u$$

$$T_u = f_{yd} \cdot A_{st}$$

$$R_{s_{sls}} = M_{u,sls} / b d^2 = 0.5 f_{cd} \cdot (x_u/d) \cdot (1 - 0.33 \cdot x_u/d)$$

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

	Rare Comb	Frequent Comb	Quasi-Perma. Comb
$x_{u,sls}/d$	0.70	0.70	0.70
$R_{s_{sls}} = M_{u,sls} / b d^2$	4.52	4.52	3.39

Here $R_{s_{sls}}$ is in MPa

Calculation of Reinforcement

$$\text{Width of section } b = 1000 \text{ mm}$$

$$\text{Depth of section } d = 325 \text{ mm}$$

$$\text{Clear cover at bott.} = 75$$

$$\text{Clear cover at top} = 40$$

	Project	-	Designed by	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

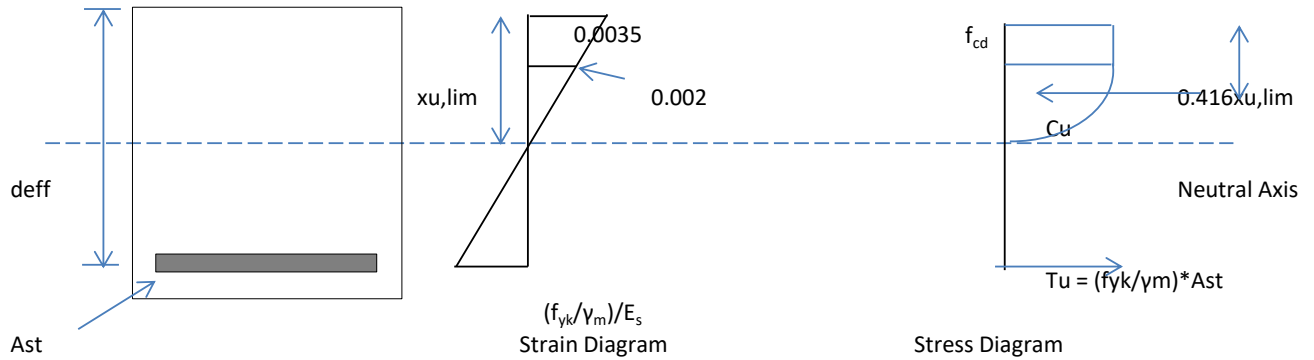
Moment on the section	Bottom End support			Top Mid Span		
	For Rare Combination		For Quasi-Perma. Combination	For Rare Combination		For Quasi-Perma. Combination
Actual moment (KNm)	65.0		15.0	43		6
b	1000		1000	1000		1000
D	325		325	325		325
c	75		75	40		40
d	232.0		232.0	267.0		267.0
f_{cd}	16.80		12.60	16.80		12.60
f_{yd}	300		300	300		300
$x_{u,sls}/d$	0.70		0.70	0.70		0.70
$R_{sls} = M_{u,sls}/bd^2$	4.52		3.39	4.52		3.39
$M_{u,sls}$ (KNm)	243		183	322		242
	OK		OK	OK		OK
Ast Req.	983		219	550		75
Dia of bar (main tension) (mm)	12		12	12		12
Spacing (mm)	180		180	180		180
+ dia of bar (main tension) (mm)	12		12	12		12
Spacing (mm)	180		180	180		180
Ast provided (sq mm)	1257		1257	1257		1257
Dia of bar (main compression) (mm)	12		12	12		12
Spacing (mm)	180		180	180		180
Area of main compression (mm ²)	628		628	628		628
f_{ctm}	2.8		2.8	2.8		2.8
x (mm)	44.9		59.8	44.9		59.8
x/d	0.193		0.258	0.168		0.224
	OK		OK	OK		OK
z (mm)	217		212	252		247
MR_{sls} (KNm)	82		80	95		93
	OK		OK	OK		OK
$s_{sc} = M/(A_s z)$	238		56	136		19
	OK		OK	OK		OK
$s_{ca} = M/(0.8095 z b x_u)$	13.34		2.36	7.60		0.81
	OK		OK	OK		OK

	Project	-	Designed by	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Calculation of crack width	Bottom End support		Top Mid Span	
n_1			6	6
n_2			6	6
$f_{eq} = (n_1 f_1^2 + n_2 f_2^2) / (n_1 f_1 + n_2 f_2)$			12	12
cl. 12.3.4 (3) of IRC :112-2011				
c			75	40
k1			0.8	0.8
k2			0.50	0.50
For skew slab refer				
$r_{p,eff} = A_s / A_{c,eff}$			0.008	0.011
$S_{r,max} = \{ 3.4 c + (0.425 k_1 k_2 f) / r_{p,eff} \}$			519	323
cl. 12.3.4 (3) of IRC :112-2011				
k_t			0.5	0.5
$f_{ct,eff}$			2.90	2.90
E_s			200000	200000
E_{cm}			32000	32000
$a_e = E_s / E_{cm}$			6.25	6.25
$(e_{sm} - e_{cm}) = (s_{sc} - k_t f_{ct,eff} (1 + a_e r_{p,eff}) / r_{p,eff}) / E_s$ $\geq 0.6 s_{sc} / E_s$			0.0002	0.0001
cl. 12.3.4 (2) of IRC :112-2011				
$W_k = S_{r,max} (e_{sm} - e_{cm})$			0.09	0.02
cl. 12.3.4 (1) of IRC :112-2011				
			OK	OK

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

5.3.1 Verification of structural strength for outer wall



ULTIMATE LIMIT STATE

Grade of Concrete	f_{ck}	=	35	N/mm ²	
As per clause 6.4.2.8, IRC:112-2011					
	f_{cd}	=	15.63	N/mm ²	For Basic Combination
	f_{cd}	=	19.54	N/mm ²	For Accidental Combination
	f_{cd}	=	15.63	N/mm ²	For Seismic Combination
	E_c	=	32000	MPa	
Grade of steel	f_y	=	500	N/mm ²	
	f_{yd}	=	435	N/mm ²	For Basic Combination
	f_{yd}	=	500	N/mm ²	For Accidental Combination
	f_{yd}	=	435	N/mm ²	For Seismic Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

Minimum strain in steel reinforcement = $0.87 f_y / E_s$
 $E_s = 2.0E+05$ MPa

$E_c = 32000$ MPa

$$C_u = \frac{f_{cd} \cdot b \cdot (3/7 x_{u,lim} + 2/3 \cdot 4/7 x_{u,lim})}{17/21 \cdot f_{cd} \cdot b \cdot x_u} = 0.8095 \cdot f_{cd} \cdot b \cdot x_u$$

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

cg of compression block from top = $0.416 x_u$

$T_u = f_{yd} \cdot A_{st}$

$$R_{lim} = M_{u,lim} / b d^2 = 0.8095 f_{cd} \cdot (x_{u,lim} / d) \cdot (1 - 0.416 \cdot x_{u,lim} / d)$$

	Basic Comb	Accidental Comb	Seismic Comb
$x_{u,lim} / d$	0.62	0.58	0.62
$R_{lim} = M_{u,lim} / b d^2$	5.80	6.99	5.80

Here R_{lim} is in MPa

Calculation of Reinforcement

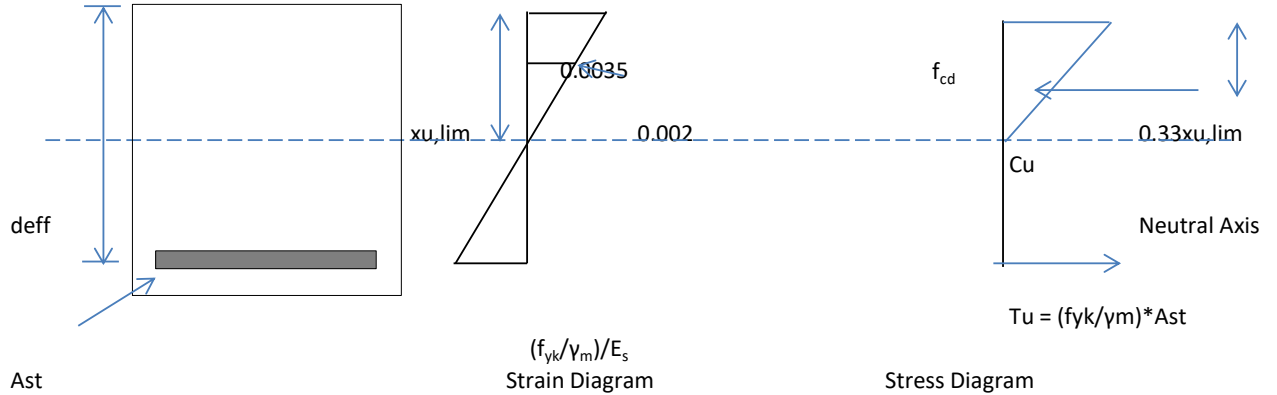
Width of section b	=	1000 mm
Depth of section D	=	300 mm
Clear cover	=	75

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Moment on the section	Bottom End support			Top End support		
	Basic Comb			Basic Comb		
Actual moment (KNm)	80.0			55.0		
b	1000			1000		
D	300			300		
c	75			75		
d	207.0			207.0		
f_{cd}	15.63			15.63		
f_{yd}	435			435		
xu_{lim}/d	0.62			0.62		
$R_{sls} = M_{u,sls}/bd^2$	5.80			5.80		
$M_{u,Lim}$ (KNm)	249			249		
	OK			OK		
Ast Req.	951			639		
Dia of bar (main tension) (mm)	12			12		
Spacing (mm)	180			180		
+ dia of bar (main tension) (mm)	12			12		
Spacing (mm)	180			180		
Ast provided (sq mm)	1257			1257		
Dia of bar (main compression) (mm)	12			12		
Spacing (mm)	180			180		
Area of main compression (mm ²)	628			628		
f_{ctm}	2.8			2.8		
f_{yk}	435			435		
cl. 16.6.1 (2) of IRC :112-2011						
$A_{s,min} = 0.26 f_{ctm} b_t d / f_{yk} \geq 0.0013 b_t d$	347			347		
A_{ct}	256827			256827		
$f_{ct,eff}$	2.9			2.9		
$k_c = 0.4 \{ 1 - s_c / (k_1 f_{ct,eff} h/h^*) \} \leq 1$	0.4			0.4		
For Bending or bending combined with axial force						
k	1.0000			1.0000		
s_s	435			435		
$A_{s,max} = 0.025 A_c$ (main tension)	7500			7500		
cl. 16.5.1.1 (2) of IRC :112-2011	OK			OK		
$A_{s,max} = 0.04 A_c$ (tension + compression)	12000			12000		
x (mm)	43			43		
x/d	0.209			0.209		
	OK			OK		
z (mm)	189			189		
MR (KNm)	103			103		
	OK			OK		

	Project	-	Designed by	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

5.3.2 Verification for serviceability limit state for outer wall



SERVICEABILITY LIMIT STATE

Grade of Concrete
As per clause 12.2.1, IRC:112-2011

$$f_{ck} = 35 \text{ N/mm}^2$$

$$f_{cd} = 16.80 \text{ N/mm}^2$$

$$f_{cd} = 16.80 \text{ N/mm}^2$$

$$f_{cd} = 12.60 \text{ N/mm}^2$$

For Rare Combination
For Frequent Combination
For Quasi-Perma. Combination

As per clause 12.2.2, IRC:112-2011

Grade of steel

$$f_y = 500 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

For Rare Combination
For Frequent Combination
For Quasi-Perma. Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

$$\text{Minimum strain in steel reinforcement} = 0.87 f_y / E_s$$

$$E_s = 2.0E+05 \text{ MPa}$$

$$E_c = 32000 \text{ MPa}$$

$$C_u = 1/2 * f_{cd} * b * x_u$$

$$= 0.5 * f_{cd} * b * x_u$$

cg of compression block from top

$$= 0.33 x_u$$

$$T_u = f_{yd} * A_{st}$$

Refer Chapter 5 of Reinforced Concrete
Limit State Design by Ashok K. Jain

$$R_{sls} = M_{u,sls} / b d^2 = 0.5 f_{cd} * (x_u/d) * (1 - 0.33 * x_u/d)$$

	Rare Comb	Frequent Comb	Quasi-Perma. Comb
$x_{u,sls}/d$	0.70	0.70	0.70
$R_{sls} = M_{u,sls} / b d^2$	4.52	4.52	3.39

Here R_{sls} is in MPa

Calculation of Reinforcement

$$\text{Width of section } b = 1000 \text{ mm}$$

$$\text{Depth of section } d = 300 \text{ mm}$$

$$\text{Clear cover} = 75$$

	Project	-	Designed by	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

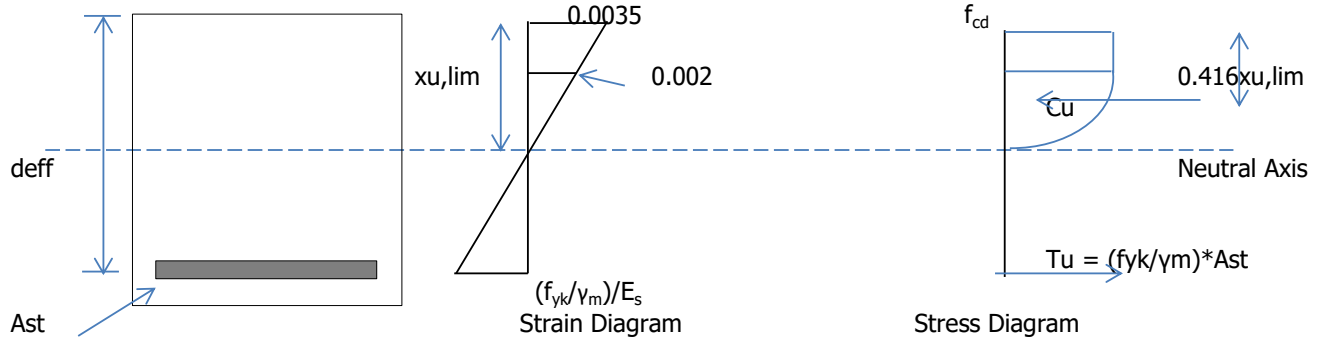
Moment on the section	Bottom End support			Top End support		
	Rare Comb		Quasi-Perma. Comb	Rare Comb		Quasi-Perma. Comb
Actual moment (KNm)	62.0		13.0	39		14
b	1000		1000	1000		1000
D	300		300	300		300
c	75		75	75		75
d	207.0		207.0	207.0		207.0
f_{cd}	16.80		12.60	16.80		12.60
f_{yd}	300		300	300		300
$x_{u,sls}/d$	0.70		0.70	0.70		0.70
$R_{sls} = M_{u,sls}/bd^2$	4.52		3.39	4.52		3.39
$M_{u,sls}$ (KNm)	194		145	194		145
	OK		OK	OK		OK
Ast Req.	1063		213	652		229
Dia of bar (main tension) (mm)	12		12	12		12
Spacing (mm)	180		180	180		180
+ dia of bar (main tension) (mm)	12		12	12		12
Spacing (mm)	180		180	180		180
Ast provided (sq mm)	1257		1257	1257		1257
Dia of bar (main compression) (mm)	12		12	12		12
Spacing (mm)	180		180	180		180
Area of main compression (mm ²)	628		628	628		628
f_{ctm}	2.8		2.8	2.8		2.8
x (mm)	44.9		59.8	44.9		59.8
x/d	0.217		0.289	0.217		0.289
	OK		OK	OK		OK
z (mm)	192		187	192		187
MR_{sls} (KNm)	72		71	72		71
	OK		OK	OK		OK
$s_{sc} = M/(A_s z)$	257		55	161		59
	OK		OK	OK		OK
$s_{ca} = M/(0.8095 z b x_u)$	14.38		2.32	9.04		2.50
	OK		OK	OK		OK

	Project	-	Designed by	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Calculation of crack width	Bottom End support		Top End support	
n_1			6	6
n_2			6	6
$f_{eq} = (n_1 f_1^2 + n_2 f_2^2) / (n_1 f_1 + n_2 f_2)$			12	12
cl. 12.3.4 (3) of IRC :112-2011				
c			75	75
k_1			0.8	0.8
k_2			0.50	0.50
For skew slab refer eq. 12.10 of IRC :112-2011				
$r_{p,eff} = A_s / A_{c,eff}$			0.008	0.008
$S_{r,max} = \{ 3.4 c + (0.425 k_1 k_2 f) / r_{p,eff} \}$			499	499
cl. 12.3.4 (3) of IRC :112-2011				
k_t			0.5	0.5
$f_{ct,eff}$			2.90	2.90
E_s			200000	200000
E_{cm}			32000	32000
$a_e = E_s / E_{cm}$			6.25	6.25
$(e_{sm} - e_{cm}) = (s_{sc} - k_t f_{ct,eff} (1 + a_e r_{p,eff}) / r_{p,eff}) / E_s$ $>= 0.6 s_{sc} / E_s$			0.0002	0.0002
cl. 12.3.4 (2) of IRC :112-2011				
$W_k = S_{r,max} (e_{sm} - e_{cm})$			0.08	0.09
cl. 12.3.4 (1) of IRC :112-2011				
			OK	OK

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

5.4.1 Verification of structural strength for inner wall



ULTIMATE LIMIT STATE

Grade of Concrete
As per clause 6.4.2.8, IRC:112-2011

$$f_{ck} = 35 \text{ N/mm}^2$$

$$f_{cd} = 15.63 \text{ N/mm}^2 \text{ For Basic Combination}$$

$$f_{cd} = 19.54 \text{ N/mm}^2 \text{ For Accidental Combination}$$

$$f_{cd} = 15.63 \text{ N/mm}^2 \text{ For Seismic Combination}$$

$$E_c = 32000 \text{ MPa}$$

Grade of steel

$$f_y = 500 \text{ N/mm}^2$$

$$f_{yd} = 435 \text{ N/mm}^2 \text{ For Basic Combination}$$

$$f_{yd} = 500 \text{ N/mm}^2 \text{ For Accidental Combination}$$

$$f_{yd} = 435 \text{ N/mm}^2 \text{ For Seismic Combination}$$

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

$$\text{Minimum strain in steel reinforcement} = 0.87 f_y / E_s$$

$$E_s = 2.0E+05 \text{ MPa}$$

$$\begin{aligned} C_u &= f_{cd} \cdot b \cdot (3/7 x_{u,lim} + 2/3 \cdot 4/7 x_{u,lim}) \\ &= 17/21 \cdot f_{cd} \cdot b \cdot x_u \\ &= 0.8095 \cdot f_{cd} \cdot b \cdot x_u \end{aligned}$$

$$\text{cg of compression block from top} = 0.416 x_u$$

$$T_u = f_y \cdot A_{st}$$

$$R_{lim} = M_{u,lim} / b d^2 = 0.8095 f_{cd} \cdot (x_{u,lim} / d) \cdot (1 - 0.416 \cdot x_{u,lim} / d)$$

	Basic Comb	Accidental Comb	Seismic Comb
$x_{u,lim} / d$	0.62	0.58	0.62
$R_{lim} = M_{u,lim} / b d^2$	5.80	6.99	5.80

Here R_{lim} is in MPa

Calculation of Reinforcement

$$\text{Width of section } b = 1000 \text{ mm}$$

$$\text{Depth of section } D = 300 \text{ mm}$$

$$\text{Clear cover} = 50$$

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

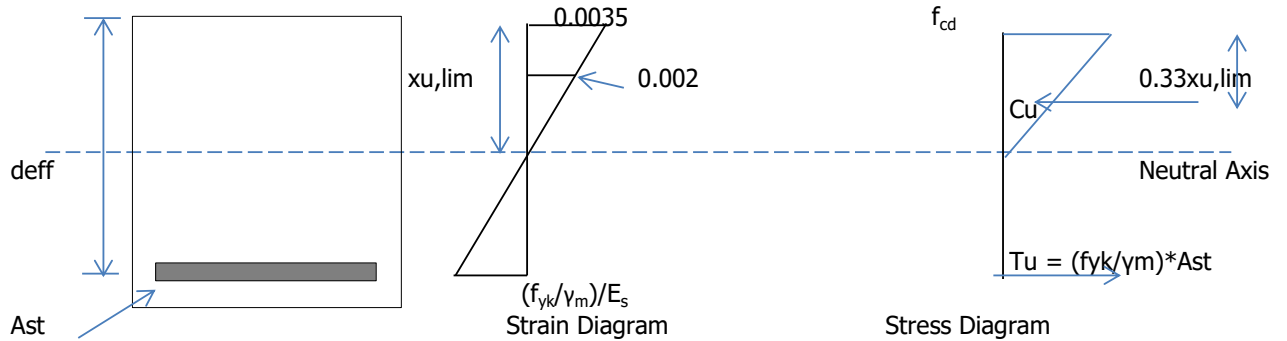
Moment on the section	Bottom End support			Top End support		
	Basic Comb			Basic Comb		
Actual moment (KNm)	37.0			26.0		
b	1000			1000		
D	300			300		
c	50			50		
d	234.0			234.0		
f_{cd}	15.63			15.63		
f_{yd}	435			435		
$x_{u,lim}/d$	0.62			0.62		
$R_{s/s} = M_{u,s/s}/bd^2$	5.80			5.80		
$M_{u,Lim}$ (KNm)	318			318		
	OK			OK		
Ast Req.	372			260		
Dia of bar (main tension) (mm)	12			12		
Spacing (mm)	175			175		
+ dia of bar (main tension) (mm)	0			0		
Spacing (mm)	175			175		
Ast provided (sq mm)	646			646		
Dia of bar (main compression) (mm)	12			12		
Spacing (mm)	175			175		
Area of main compression (mm ²)	646			646		
f_{ctm}	2.8			2.8		
f_{yk}	435			435		
cl. 16.6.1 (2) of IRC :112-2011						
$A_{s,min} = 0.26 f_{ctm} b_t d / f_{yk} \geq 0.0013 b_t d$	392			392		
A_{ct}	277797			277797		
$f_{ct,eff}$	2.9			2.9		
$k_c = 0.4 \{ 1 - \sigma_c / (k_1 f_{ct,eff} h/h^*) \} \leq 1$	0.4			0.4		
For Bending or bending combined with axial force						
k	1.0000			1.0000		
σ_s	435			435		
$A_{s,max} = 0.025 A_c$ (main tension)	7500			7500		
cl. 16.5.1.1 (2) of IRC :112-2011	OK			OK		
$A_{s,max} = 0.04 A_c$ (tension + compression)	12000			12000		
x (mm)	22			22		
x/d	0.095			0.095		
	OK			OK		
z (mm)	225			225		
MR (KNm)	63			63		
	OK			OK		

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Shear on the section	Bottom End support
Actual shear V_{Ed} (KN)	17.0
Actual shear stress (N/mm ²)	0.081
Max shear capacity, $0.135 f_{ck}(1-f_{ck}/310)$	4.2
	OK.
Min shear capacity, $0.0924 f_{ck}(1-f_{ck}/310)$	2.9
$\Theta = 0.5 \times \sin^{-1}$ (Applied shear stress / $0.135/f_{ck}/(1-f_{ck}/310)$)	
Min angle of inclination, Θ (deg)	21.8
cl. 10.3.2(2) Eq. 10.2 of IRC :112-2010	
$K = 1 + \text{Sqrt}(200/d) \leq 2.0$	1.925
cl. 10.3.2(2) Eq. 10.3 of IRC :112-2010	
$v_{min} = 0.031 K^{3/2} f_{ck}^{1/2}$	0.490
cl. 10.3.1 of IRC :112-2011	
$\rho_1 = A_{sl}/(b_w d) \leq 0.02$	0.003
	OK
$0.12 K (80 \rho_1 f_{ck})^{0.33}$	0.454
Axial compressive force N_{Ed} (KN)	18
$\sigma_{cp} = N_{Ed} / A_c \leq 0.2 f_{cd}$	0.1
cl. 10.3.2(2) Eq. 10.1 of IRC :112-2010	
$V_{Rd,c} = [0.12K(80\rho_1 f_{ck})^{0.33} + 0.15\sigma_{cp}]b_w d \leq (v_{min} + 0.15 \sigma_{cp}) b_w d$ (KN)	108
	OK

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

5.4.2 Verification for serviceability limit state for inner wall



SERVICEABILITY LIMIT STATE

Grade of Concrete
As per clause 12.2.1, IRC:112-2011

$$f_{ck} = 35 \text{ N/mm}^2$$

$$f_{cd} = 16.80 \text{ N/mm}^2$$

$$f_{cd} = 16.80 \text{ N/mm}^2$$

$$f_{cd} = 12.60 \text{ N/mm}^2$$

For Rare Combination

For Frequent Combination

For Quasi-Perma. Combination

As per clause 12.2.2, IRC:112-2011

Grade of steel

$$f_y = 500 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

$$f_{yd} = 300 \text{ N/mm}^2$$

For Rare Combination

For Frequent Combination

For Quasi-Perma. Combination

Refer Fig. 6.2 of IRC:112-2011

For steel reinforcement, simplified bilinear diagram is used

$$\text{Minimum strain in steel reinforcement} = 0.87 f_y / E_s$$

$$E_s = 2.0E+05 \text{ MPa}$$

$$E_c = 32000 \text{ MPa}$$

$$C_u = \frac{1}{2} f_{cd} b x_u$$

$$= 0.5 f_{cd} b x_u$$

$$\text{cg of compression block from top} = 0.33 x_u$$

$$T_u = f_{yd} A_{st}$$

$$R_{s_{ls}} = M_{u,s_{ls}} / b d^2 = 0.5 f_{cd} (x_u/d) (1 - 0.33 x_u/d)$$

Refer Chapter 5 of Reinforced Concrete Limit State Design by Ashok K. Jain

	Rare Comb	Frequent Comb	Quasi-Perma. Comb
$x_{u,s_{ls}}/d$	0.70	0.70	0.70
$R_{s_{ls}} = M_{u,s_{ls}}/bd^2$	4.52	4.52	3.39

Here $R_{s_{ls}}$ is in MPa

Calculation of Reinforcement

$$\text{Width of section } b = 1000 \text{ mm}$$

$$\text{Depth of section } d = 300 \text{ mm}$$

$$\text{Clear cover} = 50$$

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Moment on the section	Bottom End support			Top End support		
	Rare Comb	Quasi-Perma. Comb	Rare Comb	Quasi-Perma. Comb		
Actual moment (KNm)	31.0	1.0	20	1		
b	1000	1000	1000	1000		
D	300	300	300	300		
c	50	50	50	50		
d	234.0	234.0	234.0	234.0		
f_{cd}	16.80	12.60	16.80	12.60		
f_{Yd}	300	300	300	300		
$x_{u,sls}/d$	0.70	0.70	0.70	0.70		
$R_{sls} = M_{u,sls}/bd^2$	4.52	3.39	4.52	3.39		
$M_{u,sls}$ (KNm)	248	186	248	186		
	OK	OK	OK	OK		
Ast Req.	452	14	289	14		
Dia of bar (main tension) (mm)	12	12	12	12		
Spacing (mm)	175	175	175	175		
+ dia of bar (main tension) (mm)	0	0	0	0		
Spacing (mm)	175	175	175	175		
Ast provided (sq mm)	646	646	646	646		
Dia of bar (main compression) (mm)	12	12	12	12		
Spacing (mm)	175	175	175	175		
Area of main compression (mm ²)	646	646	646	646		
f_{ctm}	2.8	2.8	2.8	2.8		
x (mm)	23.1	30.8	23.1	30.8		
x/d	0.099	0.132	0.099	0.132		
	OK	OK	OK	OK		
z (mm)	226	224	226	224		
MR_{sls} (KNm)	44	43	44	43		
	OK	OK	OK	OK		
$\sigma_{sc} = M/(A_s z)$	212	7	137	7		
	OK	OK	OK	OK		
$\sigma_{ca} = M/(0.8095 z b x_u)$	11.87	0.29	7.66	0.29		
	OK	OK	OK	OK		

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	RCC BOX OF SIZE 2 x 2 x 2	Date & Rev.	-

Calculation of crack width	Bottom End support		Top End support	
n_1			6	6
n_2			6	6
$\phi_{eq} = (n_1 \phi_1^2 + n_2 \phi_2^2) / (n_1 \phi_1 + n_2 \phi_2)$			12	12
cl. 12.3.4 (3) of IRC :112-2011				
c			50	50
k1			0.8	0.8
k2			0.50	0.50
For skew slab refer eq. 12.10 of IRC :112-2011				
$\rho_{p,eff} = A_s / A_{c,eff}$			0.005	0.005
$S_{r,max} = \{ 3.4 c + (0.425 k_1 k_2 \phi) / \rho_{p,eff} \}$			612	612
cl. 12.3.4 (3) of IRC :112-2011				
k_t			0.5	0.5
$f_{ct,eff}$			2.90	2.90
E_s			200000	200000
E_{cm}			32000	32000
$\alpha_e = E_s / E_{cm}$			6.25	6.25
$(\epsilon_{sm} - \epsilon_{cm}) = (\sigma_{sc} - k_t f_{ct,eff} (1 + \alpha_e \rho_{p,eff}) / \rho_{p,eff}) / E_s$ $>= 0.6 \sigma_{sc} / E_s$			0.0000	0.0000
cl. 12.3.4 (2) of IRC :112-2011				
$W_k = S_{r,max} (\epsilon_{sm} - \epsilon_{cm})$			0.01	0.01
cl. 12.3.4 (1) of IRC :112-2011				
			OK	OK

	Project	-		KB
	Client	-		-
	Job	RCC BOX OF SIZE 2 x 2 x 2		-

7.0 Base Pressure

L/C	Node											Total Wt (KN/m)	Base Pressure (KN/m ²)
	1	2	5	6	7	8	9	10	11	12	13		
299	20	39	38	36	35	34	33	32	31	30	15	343	70
300	22	43	42	41	39	38	37	36	35	35	17	386	79

Max	79
Min.	70
	OK

Bearing capacity = 100 KN/sqm

DESIGN OF BREAST WALL & RETAINING WALL

Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

DESIGN OF STRAIGHT BREAST WALL FOR HEIGHT 3 M FROM G.L

INDEX

Sr. No.	Items
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2	Earth Pressure Calculation
3	Stability of Foundation
4	Design of Foundation
5	Servicibility Check of Foundation
6	Design of Wall
7	Servicibility Check of Wall
8	Summary of Result

	Project	-	Designed by:	KB
	Client	-	Checked by:	-
	Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

Design Input:

Skew Angle of Bridge = 0 Degree = 0 Radians
 COS θ = 1
 SIN θ = 0

Design Length of Wall = 1.000 m

Levels

FRL = 100.000 m (Assumed)
 Wall shaft top level = 100.000 m
 Ground level/LBL/MSL = 97.000 m (Assumed)
Foundation level
 Shaft bottom level = 95.500 m
 Coeff. Of Friction μ = 0.500
FRL - FND LVL. H = 5.000 m
 SBC of soil-Normal Case = 220.000 kN/m²
 Permissible FOS against Sliding = 1.500 Normal Case
 Permissible FOS against Overturning = 2.000 Normal Case

Wall

Thickness of Wall shaft at Top = 0.300 m
 Thickness of Wall shaft at Bottom = 0.550 m

Foundation

Total Width of Footing = 3.650 m
 Width of Toe Slab = 1.100 m
 Width of Heel Slab = 2.000 m
 Thickness of Toe slab at tip = 0.300 m
 Thickness of Toe slab near shaft = 0.500 m
 Thickness of heel slab at tip = 0.300 m
 Thickness of heel slab near shaft = 0.500 m
 Depth of Footing below GL = 2.000 m

Material Specification

Concrete Grade = 30 M
 Characteristic Compressive Strength of Concrete, fck = 30.00 Mpa at 28 days
 Design Compressive strength of Concrete, fcd = 13.400 Mpa at 28 (0.67/1.5 * fck)

Tensile strength of concrete , fctm = 2.50 Mpa
 Strain at reaching Characteristic Strength, ϵ_{cu2} = 0.02
 Ultimate Strain, ϵ_{cu2} = 0.035
 Modulus of Elasticity of Concrete (Ec) = 27386.128 N/mm² (5000 x sqrt (fck))
 Ecm = 31000 N/mm²

Steel Grade = 500 Fe (HYSD Steel) D
 Yield Strength of Reinforcement, fy or fyk = 500 Mpa
 Design Yield Strength of Reinforcement, fyd = 434.783 Mpa (1/1.15 * fy)
 Modulus of Elasticity of Steel (Es) = 200000 Mpa

Dry weight of Concrete = 25 kN/m³
 Dry unit weight of soil = 20 kN/m³
 Permissible Crack Width = 0.3 mm - For Moderate Exposure Condition
 Maximum compressive stress in concrete under rare combination = 0.48 fck

= 14.4 N/mm²
 Maximum tensile stress in steel under rare combination = 0.8 fyk

= 400 N/mm²
 σ_{cbc} = 10.00

σ_{st} = 240

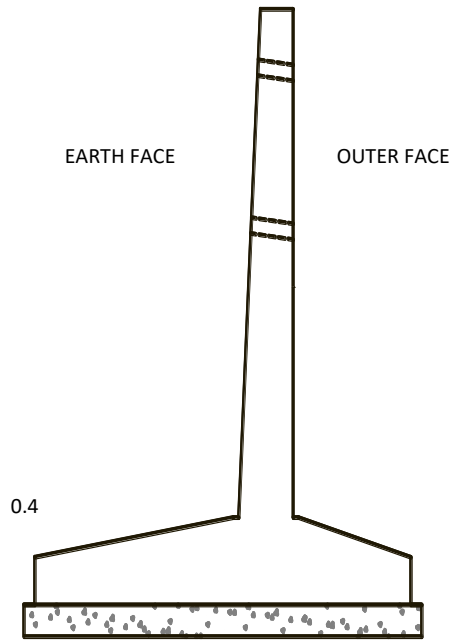
m = 9.3333333

k = 0.280

j = 0.907

Q = 1.27

As per Cl. 214.1 of IRC :6 -2014 (Y fluid) = 4.8



<i>Project</i>	-	<i>Designed by:</i>	<i>KB</i>
<i>Client</i>	-	<i>Checked by:</i>	-
<i>Job Name</i>	<i>Design of Breast Wall for height 3 m from G.L</i>	<i>Date & Rev.</i>	-

Load Factors (As per IRC:6-2014)

Table 3.2 Partial Safety Factor For Verification of Structural Strength: Ultimate Limit State

-Refer Table 3.2 of IRC:6-2014

Loads	Basic Combination
Dead Laod+SIDL except wearing course	1.350
Wearing Course only	1.750
Back Filling Weight	1.500
Earth Pressure due to back filling	1.500
Live Load Surcharge	1.200

Table 3.3 Partial Safety Factor For Verification of Servicibility Limit State

-Refer Table 3.3 of IRC:6-2014

Loads	Rare Combination	Frequent Combination	Quasi-Permanent Combination
Dead Laod+SIDL including wearing course	1.000	1.00	1.00
Back Filling Weight	1.000	1.00	1.00
Shrinkage Creep Effect	1.000	1.00	1.00
Earth Pressure due to back filling	1.000	1.000	1.000
Live Load Surcharge	0.800	0.00	0.00

Table 3.4 Partial Safety Factor For Design of Foundation

-Refer Table 3.4 of IRC:6-2014

Loads	Basic Combination
Dead Laod+SIDL except wearing course	1.35
Wearing Course only	1.750
Back Filling Weight	1.350
Earth Pressure due to back filling	1.500
Live Load Surcharge	1.200

Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L		Date & Rev.

VOLUME CALCULATION

C.G. Of Footing = 1.825 m

C.G. Of shaft from toe tip = 1.375 m

Distance between c.g. Of shaft and footing = 0.45 m

Description	No.	LENGTH		WIDTH	HEIGHT		VOLUME	Ecce.(eL) @ abut. Shaft	Ecce.(eL1) @ c.g.of footing	Ecce.(eL2) @ Toe
		m		m	m		m ³	m	m	m
Shaft	1	1.00		0.425	4.500		1.913	0.056	0.506	-1.319
Footing										
Heel Slab	1	1.00		2.000	0.400		0.800		-0.727	-2.552
Toe Slab	1	1.00		1.100	0.400		0.440		1.221	-0.604
Portion between Heel and Toe	1	1.00		0.500	0.500		0.250		0.450	-1.375
Back filling over Heel Slab	1	1.00		2.000	4.600		9.200		-0.771	-2.596
Front Filling over Toe Slab	1	1.00		1.100	1.600		1.760		1.280	-0.545
Back fill on flared portion of stem	1	1.00		0.250	4.500		0.563		0.258	-1.567
				L				eL	eL1	eL2
RCC Railing/Parapet Wall Weight/Crash Barrier	1	0	kN/m	1.000	0	kN		0.275	0.725	-1.100

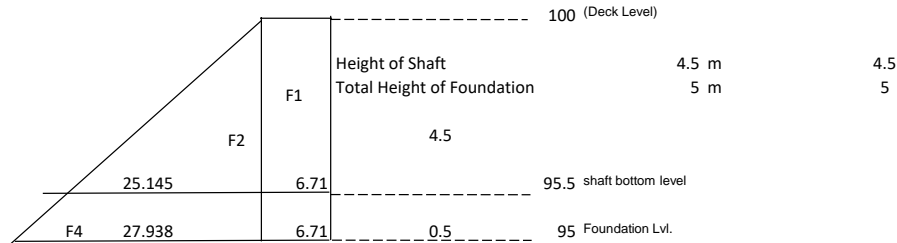
Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

Earth Pressure : Normal Dry Case

Properties of backfill material :

c	=	0				
ϕ	=	30 degree	0.524 radians	0.866	0.5	0.333333
θ	=	86.37 degree	1.507 radians	0.063		
α	=	90 degree	1.571 radians	0.000		
β	=	0 degree	0.000000000 radians	1.000		
δ	=	20 degree	0.349 radians	0.940		
Kah	=	0.279 active component				0.279384
Kph	=	5.737 Passive component				
γ	=	20 kN/m ³				
Equivalent Live Load Surcharge height	=	1.2 m				

Assuming



Horizontal Forces and Moments @ RL

95.5 m (at Shaft Base)
@ RL 95 m (at Foundation Level)

Due to Live Load Surcharge

Intensity for = rectangular portion	0.279	x	20	x	1.2	=	6.71	kN/m ²
F1 =	6.7052073	x	4.5	x	1	=	30.173	kN
M1 =	30.173	x	2.25	=	67.890			kN.m at Shaft Bottom
F3 =	6.7052073	x	5	x	1	=	33.526	kN
M3 =	33.526	x	2.5	=	83.815			kN.m at Foundation

Due to Active Earth Pressure

Intensity for triangular portion (At Shaft bottom level)

=	0.279	x	20	x	4.5	=	25.145	kN/m ²
F2 =	0.5	x	25.145	x	4.5	x	1	= 56.575 KN

(Centre of pressure considered at an elevation of 0.42m of the height of the shaft as per cl. 217.1 of IRC 6-2000

M2 =	56.575	x	1.89	=	106.927			kN.m at Shaft Bottom
------	--------	---	------	---	---------	--	--	----------------------

Intensity for triangular portion (At Foundation level)

=	0.279	x	20	x	5	=	27.938	kN/m ²
F4 =	0.5	x	27.938	x	5	x	1	= 69.846 KN
M4 =	69.846	x	2.1	=	146.676			kN.m at Foundation

Force Due To Fluid Pressure

As per Cl. 214.1 of IRC :6 -2014

γ fluid = 4.8 kN/m³

Intensity for triangular portion (At Shaft bottom level)

=	4.8	x	4.5	=	21.600			kN/m ²
F =	0.5	x	21.600	x	4.5	x	1	= 48.600 KN
M =	48.600	x	1.5	=	72.900			kN.m at Shaft Bottom

Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

Intensity for triangular portion (At Foundation level)

$$= 4.8 \times 5 = 24.000 \text{ kN/m}^2$$

$$F = 0.5 \times 24.000 \times 5 = 60.000 \text{ KN}$$

$$M = 60.000 \times 1.67 = 100.000 \text{ kN.m at Foundation}$$

Intensity of Passive pressure (Considered half depth of embedment of footing)

$$= 5.7371596 \times 20 = 229.486 \text{ kN/m}^2$$

Force due to passive @ Foundation, F

$$= 0.5 \times 229.486 \times 2 = 229.486 \text{ KN}$$

Moment due to passive @ Foundation, M

$$= 229.486 \times 0.667 = 152.991 \text{ kN.m at Foundation}$$

Summary of Moment and Horizontal Force

	Consider (Y or N)	MOMENTS		HORIZONTAL FORCE	
		At Shaft Bottom kN-m	At Foundation Lvl kN-m	At Shaft Bottom Lvl Kn	At Foundation Lvl kN
Due to active Earth Pressure	Y	106.927	146.676	56.575	69.846
Due to Minimum Fluid Pressure	Y	72.900	100.000	48.600	60.000
Governing of Two	Y	106.927	146.676	56.575	69.846
Due to Live Load Surcharge	Y	67.890	83.815	30.173	33.526
Due to Passive pressure	N		0.000		0.000

Project	-		Designed by:	KB
Client	-		Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L		Date & Rev.	-
P	315.513	KN		
ML	162.432	kNm		
MT	0	kNm		
A	3.650	m ²		
ZL	2.220	m ³		
ZT	0.608	m ³		
P/A+ML/ZL+MT/ZT (Max)	159.596	kN/m2	SAFE	
P/A-ML/ZL-MT/ZT (Min)	13.288	kN/m2	SAFE	

Check Against Sliding:

		load factor						
Due to Earth pressure	=	1.000	x	69.846	=	69.8459094	KN	
Due to Live load Surcharge	=	1.000	x	33.526	=	33.5260365	KN	
						103.372		
Total Sliding Force	=	103.372	KN					
Total Restoring Force	=	mP + c.A + Fp =		0.5	x	315.513	+ 0	= 157.7563 KN
FOS against sliding	=	1.5	>	1.5		SAFE		

Check Against Overturning

		load factor					
Moment due to active earth pressure	=	1	x	146.676	=	146.676	kNm
Moment due to Live load surcharge	=	1	x	83.815	=	83.815	kNm
						230.492	
Overturning Moment	=	230.492	kNm				
Restoring Moment	=	S P.e Toe+		Mp	=	643.869	kNm
FOS against overturning	=	2.7934628	>	2		SAFE	

Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

Design of Foundation

Foundation Lvl = 95.000 m

Properties of Footing Base:

A = 3.650 m²
 ZL = 2.220 m³
 ZT = 0.608 m³

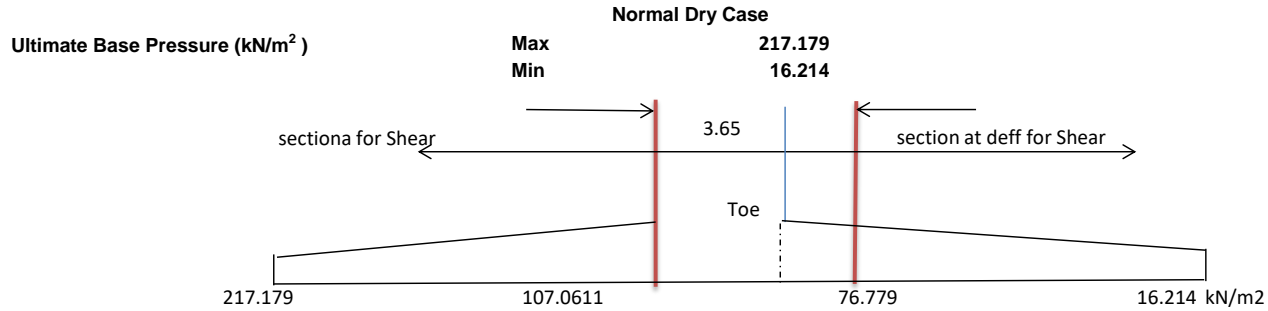
Normal Dry Case

Loads	Load Factor	Unit Weights (kN/m3)	Volume (m3)	Vertical Load(P) kN.	Long. Ecc. (eL1) (m)	ML = PxeL1 (kNm)
Shaft	1.35	25	1.913	64.547	0.450	29.046
Back filling over heel slab	1.350	20	9.200	248.400	-0.771	-191.61
Back filling on flared portion of shaft	1.350	20	0.563	15.188	0.129	1.96
Front Filling over toe slab	1.350	20	1.760	47.520	1.280	60.823
RCC Railing or Crash Barrier	1.35			0.000	0.725	0.000
Heel slab	1.35	25	0.800	27.000	-0.727	-19.63
Toe slab	1.35	25	0.440	14.850	1.221	18.13301471
portion between heel & toe	1.35	25	0.250	8.438	0.450	3.797
Total				425.942		-97.480

load factor
 Moment due to active earth pressure = 1.500 x 146.6764098 = 220.015 kNm
 Moment due to Live load surcharge = 1.200 x 83.8151 = 100.578 kNm
320.593

P	425.942	KN
ML	223.113	kNm
MT	0.000	kNm
A	3.650	m2
ZL	2.220	m3
ZT	0.608	m3
P/A+ML/ZL+MT/ZT (Max)	217.179	kN/m2
P/A-ML/ZL-MT/ZT (Min)	16.214	kN/m2

Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-



Normal Dry Case

Heel Slab - Moment Calculation

Average Base Pressure for Design of Heel Slab	=	162.12	kN/m2												
Upward moment due to Base pressure	=	324.24	kNm/m												
Downward moment due to backfill	=	1.350		x	VOL	9.2	/	1	x	20	x	1	=	248.400	kNm/m
Downward moment due to self weight of Heel	=	1.35		x		0.8	/	1	x	25	x	0.902	=	24.353	kNm/m

Net Moment at face of shaft	=	324.24	-248.40	-24.35	51.49	kNm/m	OK
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Heel Slab - Shear Calculation at Face of Wall

Shear Force due to upward pressure at Face of wall	=	162.12		x	2	x	1	=	324.240	KN
Downward Force due to backfill	=	1.350		x	9.2	x	20	=	248.400	KN
Downward Force due to self weight of Heel slab	=	1.35		x	0.8	x	25	=	27.000	KN
Net Shear Force	=	324.240	-248.400	-27.000				=	48.840	KN
Net Shear Force / unit meter	=	48.840	/	1				=	48.840	KN/m

Toe Slab - Moment Calculation

Average Base Pressure for Design of Toe Slab	=	46.50	kN/m2											
Upward moment due to Base pressure	=	28.13	kNm/m											
Downward moment due to self weight of Toe	=	1.35		x	0.44	/	1	x	25	x	0.496	=	7.367	kNm/m

Net Moment at face of shaft	=	28.13	-7.367	=	20.764	kNm/m	OK
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<i>Project</i>	-	<i>Designed by:</i>	KB
<i>Client</i>	-	<i>Checked by:</i>	-
<i>Job Name</i>	Design of Breast Wall for height 3 m from G.L	<i>Date & Rev.</i>	-

Flexural Reinforcement Calculation:

		Heel Slab	Toe Slab
Ultimate bending moment, Mu (kNm/m)	=	51.487	20.76
Effective depth required (dreq) (mm)	=	111.52	70.82
Effective depth provided (dpro) (mm)	=	419.00	419.00
Check for provided depth	=	SAFE	SAFE
R = Mu/(b d ²)	=	0.29	0.12
Total depth provided (mm)	=	500.00	500.00
Limiting depth of neutral axis (mm)	=	259.78	259.78
Actual depth of neutral axis (mm)	=	37.94	37.94
Check for Neutral axis depth	=	OK	OK
Lever arm (z) , mm	=	403.07	403.07
Moment of Resistance w.r.to steel	=	165.16	165.16
Check for Moment Capacity	=	SAFE	SAFE
Ast reqd (mm ² / m)	=	316.974	127.755
cl. 16.6.1 (2) of IRC :112-2011			
AS.min = 0.26 fctm bt d / fyk >= 0.0013 bt d	=	544.70	544.70
Governing Ast (mm ² / m)	=	544.70	544.70
Tension Reinforcement			
Dia (mm)	=	12.00	12.00
Spacing (mm)	=	207.53	207.53
Spacing provided	=	180.00	180.00
+ Dia (mm)	=	0.00	0.00
Spacing (mm)	=	180.00	180.00
Ast provided (mm ² / m)	=	628.24	628.24
Check for Ast provided	=	OK	OK
As per Clause 16.6.1.1. of IRC:112-2011 , Secondary Reinforcement shall be at least 20 % of the main reinforcement			
Secondary Reinforcement (mm ² /m)	=	125.65	125.65
Dia (mm)	=	10.00	10.00
Spacing (mm)	=	200.00	200.00
Ast provided (mm ² / m)	=	392.65	392.65
Check for Ast provided	=	OK	OK

Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

Shear Reinforcement Calculation:

		Heel Slab	Toe Slab	
Ultimate Shear Force (VEd)	=	48.840	-23.695	kN/m
Ast provided	=	628.240	628.24	mm ² /m
Depth of slab at critical section	=	500.000	454.773	mm
Effective depth at critical section	=	419.000	373.773	mm
percentage of steel provided (τ_1)	=	0.0022	0.0023	
cl. 10.3.1 of IRC :112-2011				
$\tau_1 = A_s / (b_w d) \leq 0.02$	=	OK	OK	
Actual shear stress = $v_{ED} = (VEd / b * 0.9d)$	=	0.130	0.070	N/mm ²
Max shear capacity, $0.135 f_{ck} (1 - f_{ck} / 310)$	=	3.658	3.658	N/mm ²
Depth Check for Shear Resistance	=	SAFE	SAFE	
cl. 10.3.2(2) Eq. 10.2 of IRC :112-2010				
$K = 1 + \sqrt{200/d} \leq 2.0$	=	1.691	1.731	
cl. 10.3.2(2) Eq. 10.3 of IRC :112-2010				
$v_{min} = 0.031 K^{3/2} f_{ck}^{1/2}$	=	0.373	0.387	N/mm ²
$0.12 K (80 \tau_1 f_{ck})^{0.33}$	=	0.351	0.366	N/mm ²
$\sigma_{cp} = N_{Ed} / A_c \leq 0.2 f_{cd}$	=	0.000	0.000	
cl. 10.3.2(2) Eq. 10.1 of IRC :112-2010				
$V_{Rd,c} = [0.12K(80p_1 f_{ck})^{0.33} + 0.15\sigma_{cp}] b_w d$ subjected to minimum ($v_{min} + 0.15 \sigma_{cp}$) $b_w d$	=	147.26	136.76	kN
Check for Shear Reinforcement		No Shear R/f required	No Shear R/f required	

Project:	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

SLS CHECK OF FOUNDATION

Foundation Lvl = 95.000 m

Properties of Footing Base:

A	=	3.650	m ²
ZL	=	2.220	m ³
ZT	=	0.608	m ³

Creep Coeff = 1.2 For Dry atmospheric condition

Ecm = 31000 N/mm2

Es = 200000 N/mm2

Eceff = $\frac{Ecm}{(1 + \phi)}$ = 14090.91

Modular Ratio (m) = $\frac{Es}{Eceff}$ = 14.19

Normal Dry Case

Loads	Load Factor	Unit Weights (kN/m3)	Volume (m3)	Vertical Load (P) kN.	Long. Ecc. (eL1) (m)	ML = PxeL1 (kNm)
Shaft	1	25	1.913	47.813	0.450	21.516
Back filling over heel slab	1	20	9.200	184.000	-0.771	141.936
Back filling on flared portion of shaft	1	20	0.563	11.250	0.258	2.906
Front Filling over toe slab	1	20	1.760	35.200	1.280	45.054
RCC Railing or Crash Barrier	1			0.000	0.725	0.000
Heel slab	1	25	0.800	20.000	-0.727	14.539
Toe slab	1	25	0.440	11.000	1.221	13.432
portion between heel & toe	1	25	0.250	6.250	0.450	2.813
Total				315.513		-70.754

load factor

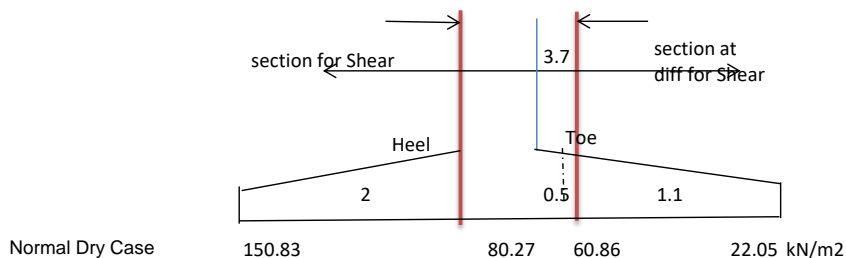
Moment due to active earth pressure = 1.0 x 146.676 = 146.676 kNm

Moment due to Live load surcharge = 0.8 x 83.815 = 67.052 kNm

213.728

P	315.513	KN
ML	142.974	kNm
MT	0.000	kNm
A	3.650	m2
ZL	2.220	m3
ZT	0.608	m3
P/A+ML/ZL+MT/ZT (Max)	150.832	kN/m2
P/A-ML/ZL-MT/ZT (Min)	22.051	kN/m2

Normal Dry Case		
Base Pressure (kN/m2)	Max	150.832
	Min	22.051



Project:	-	Designed by:	KB
Client:	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

Heel Slab - Moment Calculation

Average Base Pressure for Design of Heel Slab	=	115.55	kN/m ²						
Upward moment due to Base pressure	=	231.10	kNm/m						
	factor								
Downward moment due to backfill	=	1.00	x	9.2	x	20	x	1	= 184.00 kNm/m
Downward moment due to self weight of Heel	=	1.00	x	0.800	x	25	x	0.902	= 18.04 kNm/m
Net Moment at face of shaft	=	231.10		-184.00		-18.04			= 29.06 kNm/m

Tension at Bottom of Heel Slab

Toe Slab - Moment Calculation

Average Base Pressure for Design of Toe Slab	=	41.46	kN/m ²						
Upward moment due to Base pressure	=	25.08	kNm/m						
Downward moment due to self weight of Toe	=	1	x	0.44	x	25	x	0.496	= 5.46 kNm/m
Net Moment at face of shaft	=	25.08		-5.46					= 19.62 kNm/m

Tension at Bottom of Heel Slab

		Heel Slab	Toe Slab	
Working bending moment, M	=	29.06	19.62	kNm/m
Dx	=	1.00	1.00	m
Dy	=	0.55	0.55	m
Section Modulus (ZL) of uncracked section	=	0.05	0.05	m ³
Bending Stress (M/ZL)	=	0.576	0.389	N/mm ²
Tensile stress of concrete , fctm	=	2.500	2.500	N/mm ²
Cracked or Uncracked Section	=	Uncracked	Uncracked	
Section properties of Cracked section:				
Note: Stresses under Service load are usually within Linear Elastic Range hence such analysis involved use of Modulus ratio.				
Clear Cover, c	=	75.000	75.000	
Maximum dia used, f	=	12.000	12.000	
Effective Depth deff (dy)	=	419.000	419.000	mm
Ast provided	=	628.240	628.240	mm ² /m
Percentage of steel , pt	=	0.0022	0.0023	
$k = \sqrt{2 pt * m + (pt * m)^2} - pt * m$	=	0.221	0.226	
Depth of neutral axis from extreme Compression face (yc = k * dy)	=	92.472	94.512	mm
Depth of neutral axis from extreme tension face (yt = dy - yc)	=	326.528	324.488	mm
Depth of neutral axis from c.g. Of tension steel (ys)	=	245.528	243.488	mm
Cracked moment of Inertia (Icr)	=	$Dx * (k * dy)^3 / 3 + m Ast * (dy - k * dy)^2$		

Project:	-	Designed by:	KB	
Client:	-	Checked by:	-	
Job Name	Design of Breast Wall for height 3 m from G.L		Date & Rev.	-

Icr	=	625441124.5	617669624.3	mm4
Maximum compressive stress in concrete	=	4.297	3.003	< 14.4, SAFE
Maximum tensile stress in concrete	=	15.172	10.309	
Maximum Tensile stress in steel	=	113.835	76.872	< 400, SAFE

Check For Crack Width				
Crack width , Wk	=	Sr max (esm - ecm)		
Above Formula For Calculation of Sr max is applicable if the spacing between the reinf. is less or equal to 5*(c+φ/2)				
5*(c+φ/2)	=	405.000	405.000	mm
Provided Spacing	=	65.000	65.000	mm
Check for Applicability of Formula	=	OK	OK	
Maximum crack spacing , Sr max	=	3.4 c +	0.425 k1 k2 φ	
			r r eff	
K1	=	0.800	0.800	for deformed bars
K2	=	0.500	0.500	for bending
depth of neutral axis , yc	=	92.472	94.512	mm
r r eff = As/Ac eff	=	, where Ac,eff =effective area of concrete in tension surrounding the reinf.		
hc eff = Min of 2.5 (Dy - dy) ,Dy - yc/3 , Dy/2	=	209.500	209.500	mm
Ac, eff = Dx * hc,eff	=	209500.000	209500.000	mm
r r eff = As/Ac eff	=	0.003	0.003	
Maximum crack spacing , Sr max	=	935.281	935.281	mm
(esm - ecm)	=	$\frac{\sigma_{sc} - k_t f_{ct,eff} (1 + \alpha_e \rho_p,eff)}{\rho_p,eff}$		
tensile stress in steel , σsc	=	113.835	76.872	N/mm2
Kt	=	0.500	0.500	
Tensile strength of concrete = fct eff = fctm	=	2.500	2.500	N/mm2
αe = Es/Ecm	=	6.452	6.452	
(esm - ecm)	=	-0.002	-0.0017	
Crack width , Wk=Sr max (esm - ecm)	=	0.000	0.000	
Check	=	SAFE	SAFE	

424.9

Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

Calculation of Forces For Design of Wall

Wall bottom level = 95.5 m

Normal Dry Case

Loads	Load Factor	Unit Weights (kN/m3)	Volume (m3)	Vertical Load(P) kN.	Long. Ecc. (eL) (m)	ML = PxeL (kNm)
Shaft	1.35	25	1.913	64.546875	0.056	3.639
RCC Railing or Crash Barrier	1.35			0	0.275	0.000
Total				64.547		3.639

Horizontal Force : load factor

Due to Earth pressure 1.5 x 56.58 = 84.86 KN

Due to Live load Surcharge 1.2 x 30.17 = 36.21 KN

121.07

Total Horizontal Force = 121.07 KN

Moment Due to Horizontal Force: load factor

Moment due to active earth pressure = 1.5 x 163.446 = 245.169 kNm

Moment due to Live load surcharge = 1.2 x 67.890 = 81.4683 kNm

326.637

Total Moment due to Horizontal Force = 326.637 kNm

Summary of Forces:

P	64.547	KN
ML	330.276	kNm
FL	121.071	KN

Project	-	Designed by:	KB
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Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

Design of Wall:

Grade of Concrete	=	30.00 M 30
fck	=	30.00 N/mm ²
fcd	=	13.40 N/mm ²
Grade of steel	=	500.00 Fe
fy	=	500.00 N/mm ²
fyd	=	434.78 N/mm ²
Es	=	200000.00 N/mm ²

Cross section of Wall:

Thickness of Wall (B)	=	0.55 m
Depth of Wall (D)	=	1 m
Area of Concrete (Ac)	=	0.55 m ²
Clear Cover to earth faces	=	75 mm
Clear Cover to non earth faces	=	40 mm
Maximum Dia of Vertical Reinf.	=	16 mm
Dia of Horizontal Reinf.	=	12 mm

Summary of Design Forces:

	P(kN)	ML (kNm)	FL (kN)
Case 1 : Normal Dry Case	64.55	330.28	121.07
MAX	64.55	330.28	121.07

As per Clause 7.6.4.1 of IRC:112-2011

Ultimate axial force (Pu)	=	64.55 kN
0.1 fcd Ac	=	0.1 13.4 550000
	=	737000 N
	=	737.0 kN

Since Axial Force is less than axial capacity of section , Section will design as bending element . Neglecting axial force

PART 1: LONGITUDINAL MOMENT : VERTICAL REINFORCEMENT ON EARTH FACE

Ultimate Design bending moment (ML)	=	330.28 kNm	=	330.28 kNm/m
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Check For Depth of Wall :

Mult	=	0.167 x fck x b x d ²
	=	330.28 kNm/m
b	=	1000 mm

Effective Depth Required (dreq) = $\text{SQRT}\left(\frac{597.03 \times 1000000}{0.167 \times 30.00 \times 1000}\right)$

(dreq)	=	256.76 mm
Total Depth Required (Dreq)	=	339.76 mm

Total Depth Provided (Dprov)	=	550 mm	OK
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Effective depth provided(d _{eff})	=	467 mm
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R= Mu/(b d²) = 1.514

Minimum Longitudinal Reinforcement in wall on each face
 =
 = 0.0012 x b x D -Refer Clause 16.9 of IRC:112-2011'

Ast min	=	660 mm ² /m
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Project	-	Designed by:	KB
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Area of Steel Required:

$$\frac{P_t}{100} = \frac{A_{st_{req}}}{bD} = \frac{f_{ck} \{ 1 - \sqrt{1 - 4.598 R/f_{ck}} \}}{2f_y}$$

$$= 0.0037$$

$$A_{st_{req}} = 2041.14 \text{ mm}^2/\text{m}$$

$$\text{Ast required} = \max(A_{st_{min}}, A_{st_{req}}) = 2041.14 \text{ mm}^2/\text{m}$$

Provide	16	mm dia	@	150	mm c/c	=	1340.25	2094.13	mm ² /m	OK
	12	mm dia	@	150	mm c/c	=	753.89			

Percentage of steel = 0.381 %

Check for Moment of Resistance of Section due to Steel

$$\text{Limiting Depth of Neutral Axis, } X_m = \frac{0.0035 \cdot d}{(0.0035 + f_{yd}/E_s)}$$

$$= 288.07 \text{ mm}$$

$$\text{Depth of Neutral Axis, } X = \frac{f_{yd} \cdot A_{st}}{0.36 \cdot f_{ck} \cdot b}$$

$$= 84.30 \text{ mm}$$

OK

Lever Arm (z) between Compressive Force (C) and Tensile Force (T)

$$z = d - 0.416 \times X$$

$$= 431.93 \text{ mm}$$

Moment of Resistance of Section w.r.t. Steel (MR)

$$MR = f_{yd} \cdot A_{st} \cdot Z$$

$$= 393268377.6$$

$$= 3.93E+08 \text{ Nmm /m}$$

$$= \boxed{3.93E+02 \text{ kNm/m} > 330.28 \text{ kNm/m}}$$

Moment of Resistance of Wall is More than Design Bending Moment , HENCE Wall IS SAFE IN BENDING

LONGITUDINAL REINFORCEMENT ON NON EARTH FACE

Minimum Longitudinal Reinforcement in wall on each face

$$= 0.0012 \times b \times D \text{ Refer Clause 16.9 of IRC:112-2011'}$$

$$\text{Ast min} = 660 \text{ mm}^2/\text{m}$$

Provide	12	mm dia		150	mm c/c	=	753.89	mm ² /m	OK
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PART 3 : HORIZONTAL REINFORCEMENT CALCULATION

Horizontal Reinforcement for wall

$$\text{maximum of following} = 0.25 \times 2848.02 = 712.01 \text{ As per IRC:112-2011' Clause 16.32.2}$$

$$= 0.001 \times 5.50E+05 = 550.00$$

Minimum Horizontal Reinf. provided 712.0 mm² per meter

$$\text{Min dia of bar} = 0.25 \times 16 = 4 \text{ mm}$$

or 8 mm

Maximum Spacing between bars <= 300 mm/cc

2 Legged	12	dia	@	200	c/c	=	1130.4	mm ²	OK
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Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

SLS CHECK OF WALL

Foundation Lvl	=	95.5	m
Creep Coeff	(ϕ) =	1.2	For Dry atmospheric condition
Ecm	=	31000	
Es	=	200000	N/mm ²
Eceff	=	$\frac{Ecm}{(1 + \phi)}$	= 14090.90909
Modular Ratio (m)	=	Es/ Eceff	= 14.19

Normal Dry Case

Loads	Load Factor	Unit Weights (kN/m ³)	Volume (m ³)	Vertical Load(P) kN.	Long. Ecc. (eL) (m)	ML = PxeL (kNm)
Shaft	1.000	25	1.913	47.8125	0.056372549	2.695313
RCC Railing or Crash Barrier	1.000			0	0.275	0
Total				47.813		2.695

Horizontal Force :		load factor			
Due to Earth pressure	=	1.000	x	56.57518663	= 56.57519 KN
Due to Live load Surcharge	=	0.800	x	30.17343287	= 24.13875 KN
Total Horizontal Force	=	80.71393292	KN		

Moment Due to Horizontal Force:		load factor			
Moment due to active earth pressure	=	1.000	x	106.927	= 106.927 kNm
Moment due to Live load surcharge	=	0.8	x	67.890	= 54.312 kNm
Total Moment due to Horizontal Force	=	161.239281892	kNm		

Summary of Forces:

	P	ML	FL
	47.813	163.935	80.714
	KN	kNm	KN

Bending Moment, M	=	163.93	kNm
Dx	=	1.00	m
Dy	=	0.55	m
Section Modulus (ZL) of uncracked secti	=	0.05	m ³
Bending Stress (M/ZL)	=	3.252	N/mm ²
Tensile stress of concrete , fctm	=	2.500	N/mm ²
Cracked or Uncracked Section	=	Cracked	
Section properties of Cracked section:			
Note: Stresses under Service load are usually within Linear Elastic Range hence such analysis involved use of Modulus ratio.			
Clear Cover, c	=	75.000	mm
Maximum dia used (Vertical), f	=	16.000	mm
Horizontal Reinf. Dia used	=	12.000	mm
Effective Depth deff (dy)	=	467.000	mm
Ast provided	=	2094.133	mm ² /m
Percentage of steel, pt	=	0.0071	
$k = \sqrt{2 \cdot pt \cdot m + (pt \cdot m)^2} - pt \cdot m$	=	0.359	
Depth of neutral axis from extreme Compression face (yc = k * dy)	=	167.664	mm
Depth of neutral axis from extreme tension face (yt = dy-yc)	=	299.336	mm

Depth of neutral axis from c.g. Of tesnion steel (ys)	=	216.336	mm
Cracked moment of Inertia (Icr)	=	$Dx \cdot (k \cdot dy)^3 / 3 + m \cdot Ast \cdot (dy - k \cdot dy)^2$	
Icr	=	1752863282	mm ⁴
Maximum compressive stress in concrete	=	15.7	< 14.4, SAFE
Maximum tensile stress in concrete	=	27.995	
Maximum Tensile stress in steel	=	172.295	< 400, SAFE

Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-

Check For Crack Width			
Crack width , Wk	=	Sr max (esm - εcm)	
Above Formula For Calculation of Sr max is applicable if the spacing between the reinf. is less or equal to 5*(c+φ/2)			
5*(c+φ/2)	=	415.000	mm
Provided Spacing	=	160.000	mm
Check for Applicability of Formula	=	OK	
Maximum crack spacing , Sr max	=	3.4 c +	0.425 k1 k2 φ P p eff
K1	=	0.700	for deformed b
K2	=	0.500	for bending
depth of neutral axis , yc	=	167.664	mm
z r eff = As/Ac eff	=	, where Ac,eff =effective area of concrete in tension surrounding the reinf.	
hc eff = Min of 2.5 (Dy - dy) ,Dy - yc/3 , Dy/2	=	207.500	mm
Ac, eff = Dx * hc,eff	=	207500.000	mm
z r eff = As/Ac eff	=	0.010	
Maximum crack spacing , Sr max	=	490.825	mm
(εsm - εcm)	=	$\frac{\sigma_{sc} - k t f_{ct\ eff} (1 + \alpha_e r r\ eff)}{r r\ eff}$	/ Es
tensile stress in steel , σsc	=	172.295	N/mm2
Kt	=	0.500	
Tensile strength of concrete = fct eff = fctm	=	2.500	N/mm2
αe = Es/Ecm	=	6.452	
(esm - εcm)	=	0.00020	
Crack width , Wk=Sr max (esm - εcm)	=	0.099	
Check	=	SAFE	

Project	-	Designed by:	KB		
Client	-	Checked by:	-		
Job Name	Design of Breast Wall for height 3 m from G.L	Date & Rev.	-		

Stability Check Summary

Description	P (kN/m2 max)	P (kN/m2 min)	Sliding	Overturning	Shear (Heel slab)	Shear (Toe slab)
Normal Dry case	159.60	13.29	1.53	2.79	0.130	-0.070
Permissible	220	0	1.5	2	3.658	3.658
Remarks	OK	OK	OK	OK	OK	OK

Reinforcement summary

Type of reinforcement	Area of steel required	Area of steel provided						
Straight Portion of Shaft								
Vertical steel at earth face	2041	16	mm bar @	150	mm c/c (i.e.)	2094	mm2	OK
		12	mm bar @	150	mm c/c (i.e.)			
Vertical steel at non-earth face	660	12	mm bar @	150	mm c/c (i.e.)	754	mm2	OK
Distribution steel	712	12	mm 2 Legged bar @	200	mm c/c (i.e.)	1130	mm2	OK
Heel Slab								
Main steel at top face	545	12	mm bar @	180	mm c/c (i.e.)	628	mm2	OK
		0	mm bar @	180	mm c/c (i.e.)			
Steel at bottom face	250	12	mm bar @	180	mm c/c (i.e.)	628	mm2	OK
Distribution reinforcement	126	10	mm bar @	200	mm c/c (i.e.)	393	mm2	OK
Shear Reinforcement	No Shear R/f required							
Toe Slab								
Main steel at bottom face	545	12	mm bar @	180	mm c/c (i.e.)	628	mm2	OK
		0	mm bar @	180	mm c/c (i.e.)			
Steel at top face	250	12	mm bar @	180	mm c/c (i.e.)	628	mm2	OK
Distribution reinforcement	126	10	mm bar @	200	mm c/c (i.e.)	393	mm2	OK
Shear Reinforcement	No Shear R/f required							

Project	-	Designed by:	KB
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Job Name	Design of Retaining Wall for height 5 m from G.L	Date & Rev.	-

DESIGN OF STRAIGHT RETAINING WALL FOR HEIGHT 5 M FROM G.L

INDEX

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	Project	-	Designed by:	KB
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Design Input:

Skew Angle of Bridge = 0 Degree = 0 Radians
 COS θ = 1
 SIN θ = 0

Design Length of Wall = 1.000 m

Levels

FRL = 100.000 m (Assumed)
 Wall shaft top level = 100.000 m
 Ground level/LBL/MSL = 95.000 m (Assumed)
Foundation level = 93.000 m
 Shaft bottom level = 93.550 m
 Coeff. Of Friction μ = 0.500
FRL - FND LVL. H = 7.000 m
 SBC of soil-Normal Case = 220.000 kN/m²
 Permissible FOS against Sliding = 1.500 Normal Case
 Permissible FOS against Overturning = 2.000 Normal Case

Wall

Thickness of Wall shaft at Top = 0.300 m
 Thickness of Wall shaft at Bottom = 0.700 m

Foundation

Total Width of Footing = 4.600 m
 Width of Toe Slab = 1.500 m
 Width of Heel Slab = 2.400 m
 Thickness of Toe slab at tip = 0.300 m
 Thickness of Toe slab near shaft = 0.550 m
 Thickness of heel slab at tip = 0.300 m
 Thickness of heel slab near shaft = 0.550 m
 Depth of Footing below GL = 2.000 m

Material Specification

Concrete Grade = 30 M
 Characteristic Compressive Strength of Concrete, fck = 30.00 Mpa at 28 days
 Design Compressive strength of Concrete, fcd = 13.400 Mpa at 28 (0.67/1.5 * fck)

Tensile strength of concrete , fctm = 2.50 Mpa
 Strain at reaching Characteristic Strength, ϵ_{cu2} = 0.02
 Ultimate Strain, ϵ_{cu} = 0.035
 Modulus of Elasticity of Concrete (Ec) = 27386.128 N/mm² (5000 x sqrt (fck))
 Ecm = 31000 N/mm²

Steel Grade = 500 Fe (HYSD Steel) D
 Yield Strength of Reinforcement, fy or fyk = 500 Mpa
 Design Yield Strength of Reinforcement, fyd = 434.783 Mpa (1/1.15 * fy)
 Modulus of Elasticity of Steel (Es) = 200000 Mpa

Dry weight of Concrete = 25 kN/m³
 Dry unit weight of soil = 20 kN/m³
 Permissible Crack Width = 0.3 mm - For Moderate Exposure Condition
 Maximum compressive stress in concrete under rare combination = 0.48 fck

= 14.4 N/mm²
 Maximum tensile stress in steel under rare combination = 0.8 fyk

= 400 N/mm²
 σ_{cbc} = 10.00

σ_{st} = 240

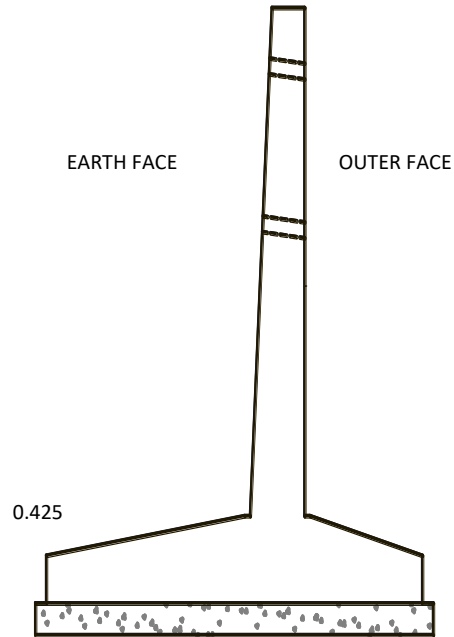
m = 9.3333333

k = 0.280

j = 0.907

Q = 1.27

As per Cl. 214.1 of IRC :6 -2014 (Y fluid) = 4.8



<i>Project</i>	-	<i>Designed by:</i>	<i>KB</i>
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Load Factors (As per IRC:6-2014)

Table 3.2 Partial Safety Factor For Verification of Structural Strength: Ultimate Limit State

-Refer Table 3.2 of IRC:6-2014

Loads	Basic Combination
Dead Laod+SIDL except wearing course	1.350
Wearing Course only	1.750
Back Filling Weight	1.500
Earth Pressure due to back filling	1.500
Live Load Surcharge	1.200

Table 3.3 Partial Safety Factor For Verification of Servicibility Limit State

-Refer Table 3.3 of IRC:6-2014

Loads	Rare Combination	Frequent Combination	Quasi-Permanent Combination
Dead Laod+SIDL including wearing course	1.000	1.00	1.00
Back Filling Weight	1.000	1.00	1.00
Shrinkage Creep Effect	1.000	1.00	1.00
Earth Pressure due to back filling	1.000	1.000	1.000
Live Load Surcharge	0.800	0.00	0.00

Table 3.4 Partial Safety Factor For Design of Foundation

-Refer Table 3.4 of IRC:6-2014

Loads	Basic Combination
Dead Laod+SIDL except wearing course	1.35
Wearing Course only	1.750
Back Filling Weight	1.350
Earth Pressure due to back filling	1.500
Live Load Surcharge	1.200

Project	-	Designed by:	KB
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VOLUME CALCULATION

C.G. Of Footing = 2.3 m

C.G. Of shaft from toe tip = 1.85 m

Distance between c.g. Of shaft and footing = 0.45 m

Description	No.	LENGTH		WIDTH	HEIGHT		VOLUME	Ecce.(eL) @ abut. Shaft	Ecce.(eL1) @ c.g.of footing	Ecce.(eL2) @ Toe
		m		m	m		m ³	m	m	m
Shaft	1	1.00		0.500	6.450		3.225	0.087	0.537	-1.763
Footing										
Heel Slab	1	1.00		2.400	0.425		1.020		-0.940	-3.240
Toe Slab	1	1.00		1.500	0.425		0.638		1.450	-0.850
Portion between Heel and Toe	1	1.00		0.550	0.550		0.303		0.450	-1.850
Back filling over Heel Slab	1	1.00		2.400	6.575		15.780		-1.004	-3.304
Front Filling over Toe Slab	1	1.00		1.500	1.575		2.363		1.558	-0.742
Back fill on flared portion of stem	1	1.00		0.400	6.450		1.290		0.233	-2.067
				L				eL	eL1	eL2
RCC Railing/Parapet Wall Weight/Crash Barrier	1	0	kN/m	1.000	0	kN		0.350	0.800	-1.500

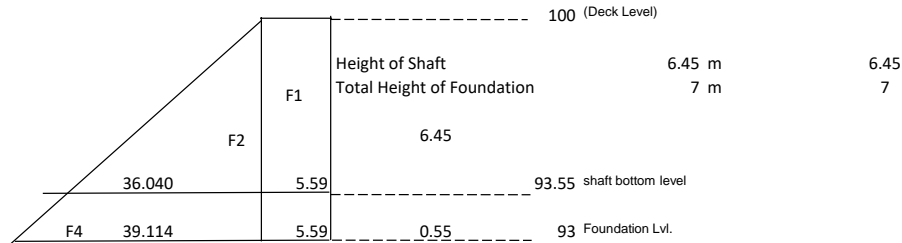
Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Retaining Wall for height 5 m from G.L	Date & Rev.	-

Earth Pressure : Normal Dry Case

Properties of backfill material :

c	=	0				
ϕ	=	30 degree	0.524 radians	0.866	0.5	0.333333
θ	=	86.37 degree	1.507 radians	0.063		
α	=	90 degree	1.571 radians	0.000		
β	=	0 degree	0.000000000 radians	1.000		
δ	=	20 degree	0.349 radians	0.940		
Kah	=	0.279 active component				0.279384
Kph	=	5.737 Passive component				
γ	=	20 kN/m ³				
Equivalent Live Load Surcharge height	=	1.2 m				

Assuming



Horizontal Forces and Moments @ RL

93.55 m (at Shaft Base)
@ RL 93 m (at Foundation Level)

Due to Live Load Surcharge

Intensity for = rectangular portion	0.279	x	20	x	1.2	=	5.59	kN/m ²
F1 =	5.5876728	x	6.45	x	1	=	36.040	kN
M1 =	36.040	x	3.225	=	116.231	kN.m at Shaft Bottom		
F3 =	5.5876728	x	7	x	1	=	39.114	kN
M3 =	39.114	x	3.5	=	136.898	kN.m at Foundation		

Due to Active Earth Pressure

Intensity for triangular portion (At Shaft bottom level)

=	0.279	x	20	x	6.45	=	36.040	kN/m ²
F2 =	0.5	x	36.040	x	6.45	x 1	=	116.231 KN

(Centre of pressure considered at an elevation of 0.42m of the height of the shaft as per cl. 217.1 of IRC 6-2000

M2 =	116.231	x	2.71	=	314.869	kN.m at Shaft Bottom
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Intensity for triangular portion (At Foundation level)

=	0.279	x	20	x	7	=	39.114	kN/m ²
F4 =	0.5	x	39.114	x	7	x 1	=	136.898 KN
M4 =	136.898	x	2.94	=	402.480	kN.m at Foundation		

Force Due To Fluid Pressure

As per Cl. 214.1 of IRC :6 -2014

Y fluid = 4.8 kN/m³

Intensity for triangular portion (At Shaft bottom level)

=	4.8	x	6.45	=	30.960	kN/m ²		
F =	0.5	x	30.960	x	6.45	x 1	=	99.846 KN
M =	99.846	x	2.15	=	214.669	kN.m at Shaft Bottom		

Project	-	Designed by:	KB
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Intensity for triangular portion (At Foundation level)

$$= 4.8 \times 7 = 33.600 \text{ kN/m}^2$$

$$F = 0.5 \times 33.600 \times 7 = 117.600 \text{ KN}$$

$$M = 117.600 \times 2.33 = 274.400 \text{ kN.m at Foundation}$$

Intensity of Passive pressure (Considered half depth of embedment of footing)

$$= 5.7371596 \times 20 = 229.486 \text{ kN/m}^2$$

Force due to passive @ Foundation, F

$$= 0.5 \times 229.486 \times 2 = 229.486 \text{ KN}$$

Moment due to passive @ Foundation, M

$$= 229.486 \times 0.667 = 152.991 \text{ kN.m at Foundation}$$

Summary of Moment and Horizontal Force

	Consider (Y or N)	MOMENTS		HORIZONTAL FORCE	
		At Shaft Bottom kN-m	At Foundation Lvl kN-m	At Shaft Bottom Lvl Kn	At Foundation Lvl kN
Due to active Earth Pressure	Y	314.869	402.480	116.231	136.898
Due to Minimum Fluid Pressure	Y	214.669	274.400	99.846	117.600
Governing of Two	Y	314.869	402.480	116.231	136.898
Due to Live Load Surcharge	Y	116.231	136.898	36.040	39.114
Due to Passive pressure	N		0.000		0.000

Project	-	Designed by:	KB
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P	518.275	KN	
ML	347.958	kNm	
MT	0	kNm	
A	4.600	m ²	
ZL	3.527	m ³	
ZT	0.767	m ³	
P/A+ML/ZL+MT/ZT (Max)	211.333	kN/m2	SAFE
P/A-ML/ZL-MT/ZT (Min)	14.004	kN/m2	SAFE

Check Against Sliding:

		load factor						
Due to Earth pressure	=	1.000	x	136.898	=	136.897982	KN	
Due to Live load Surcharge	=	1.000	x	39.114	=	39.1137093	KN	
						176.012		
Total Sliding Force	=	176.012	KN					
Total Restoring Force	=	mP + c.A + Fp =		0.5	x	518.275	+ 0	= 259.1375 KN
FOS against sliding	=	1.5	>	1.5		SAFE		

Check Against Overturning

		load factor					
Moment due to active earth pressure	=	1	x	402.480	=	402.480	kNm
Moment due to Live load surcharge	=	1	x	136.898	=	136.898	kNm
						539.378	
Overturning Moment	=	539.378	kNm				
Restoring Moment	=	S P.e Toe+		Mp	=	1383.453	kNm
FOS against overturning	=	2.5649034	>	2		SAFE	

Project	-	Designed by:	KB
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Job Name	Design of Retaining Wall for height 5 m from G.L	Date & Rev.	-

Design of Foundation

Foundation Lvl = 93.000 m

Properties of Footing Base:

A = 4.600 m²
 ZL = 3.527 m³
 ZT = 0.767 m³

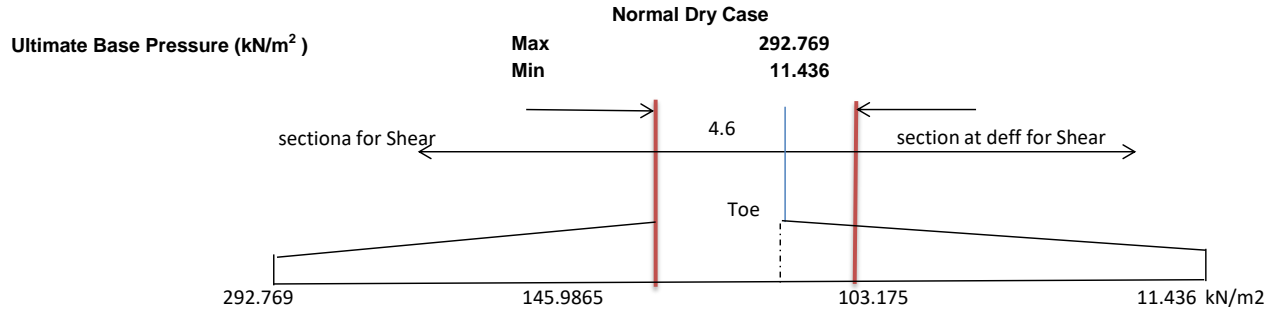
Normal Dry Case

Loads	Load Factor	Unit Weights (kN/m ³)	Volume (m ³)	Vertical Load(P) kN.	Long. Ecc. (eL1) (m)	ML = PxeL1 (kNm)
Shaft	1.35	25	3.225	108.844	0.450	48.980
Back filling over heel slab	1.350	20	15.780	426.060	-1.004	-427.74
Back filling on flared portion of shaft	1.350	20	1.290	34.830	0.117	4.06
Front Filling over toe slab	1.350	20	2.363	63.788	1.558	99.350
RCC Railing or Crash Barrier	1.35			0.000	0.800	0.000
Heel slab	1.35	25	1.020	34.425	-0.940	-32.36
Toe slab	1.35	25	0.638	21.516	1.450	31.19765625
portion between heel & toe	1.35	25	0.303	10.209	0.450	4.594
Total				699.671		-271.914

load factor
 Moment due to active earth pressure = 1.500 x 402.4800684 = 603.720 kNm
 Moment due to Live load surcharge = 1.200 x 136.8980 = 164.278 kNm
767.998

P	699.671	KN
ML	496.084	kNm
MT	0.000	kNm
A	4.600	m ²
ZL	3.527	m ³
ZT	0.767	m ³
P/A+ML/ZL+MT/ZT (Max)	292.769	kN/m ²
P/A-ML/ZL-MT/ZT (Min)	11.436	kN/m ²

Project	-	Designed by:	KB
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Normal Dry Case

Heel Slab - Moment Calculation

Average Base Pressure for Design of Heel Slab	=	219.38	kN/m ²											
Upward moment due to Base pressure	=	631.81	kNm/m											
Downward moment due to backfill	=	1.350	x	VOL	15.78	/	1	x	20	x	1.2	=	511.272	kNm/m
Downward moment due to self weight of Heel	=	1.35	x		1.02	/	1	x	25	x	1.040	=	35.802	kNm/m

Net Moment at face of shaft	=	631.81	-511.27	-35.80	84.73	kNm/m	OK
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Heel Slab - Shear Calculation at Face of Wall

Shear Force due to upward pressure at Face of wall	=	219.38	x	2.4	x	1	=	526.507	KN
Downward Force due to backfill	=	1.350	x	15.78	x	20	=	426.060	KN
Downward Force due to self weight of Heel slab	=	1.35	x	1.02	x	25	=	34.425	KN
Net Shear Force	=	526.507	-426.060	-34.425	=	66.022	KN		
Net Shear Force / unit meter	=	66.022	/	1	=	66.022	KN/m		

Toe Slab - Moment Calculation

Average Base Pressure for Design of Toe Slab	=	57.31	kN/m ²											
Upward moment due to Base pressure	=	64.47	kNm/m											
Downward moment due to self weight of Toe	=	1.35	x	0.6375	/	1	x	25	x	0.650	=	13.985	kNm/m	

Net Moment at face of shaft	=	64.47	-13.985	=	50.483	kNm/m	OK
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<i>Project</i>	-	<i>Designed by:</i>	KB
<i>Client</i>	-	<i>Checked by:</i>	-
<i>Job Name</i>	Design of Retaining Wall for height 5 m from G.L	<i>Date & Rev.</i>	-

Flexural Reinforcement Calculation:

		Heel Slab	Toe Slab
Ultimate bending moment, Mu (kNm/m)	=	84.734	50.48
Effective depth required (dreq) (mm)	=	143.06	110.43
Effective depth provided (dpro) (mm)	=	469.00	469.00
Check for provided depth	=	SAFE	SAFE
R = Mu/(b d ²)	=	0.39	0.23
Total depth provided (mm)	=	550.00	550.00
Limiting depth of neutral axis (mm)	=	290.78	290.78
Actual depth of neutral axis (mm)	=	37.94	37.94
Check for Neutral axis depth	=	OK	OK
Lever arm (z) , mm	=	453.07	453.07
Moment of Resistance w.r.to steel	=	185.64	185.64
Check for Moment Capacity	=	SAFE	SAFE
Ast reqd (mm ² / m)	=	394.729	235.087
cl. 16.6.1 (2) of IRC :112-2011			
AS.min = 0.26 fctm bt d / fyk >= 0.0013 bt d	=	609.70	609.70
Governing Ast (mm ² / m)	=	609.70	609.70
Tension Reinforcement			
Dia (mm)	=	12.00	12.00
Spacing (mm)	=	185.40	185.40
Spacing provided	=	120.00	120.00
+ Dia (mm)	=	0.00	0.00
Spacing (mm)	=	120.00	120.00
Ast provided (mm ² / m)	=	942.36	942.36
Check for Ast provided	=	OK	OK
As per Clause 16.6.1.1. of IRC:112-2011 , Secondary Reinforcement shall be at least 20 % of the main reinforcement			
Secondary Reinforcement (mm ² /m)	=	188.47	188.47
Dia (mm)	=	10.00	10.00
Spacing (mm)	=	200.00	200.00
Ast provided (mm ² / m)	=	392.65	392.65
Check for Ast provided	=	OK	OK

Project	-	Designed by:	KB
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Shear Reinforcement Calculation:

		Heel Slab	Toe Slab	
Ultimate Shear Force (VEd)	=	66.022	-23.187	kN/m
Ast provided	=	942.360	942.36	mm ² /m
Depth of slab at critical section	=	550.000	574.933	mm
Effective depth at critical section	=	469.000	493.933	mm
percentage of steel provided (τ 1)	=	0.0019	0.0019	
cl. 10.3.1 of IRC :112-2011				
τ 1 = $A_s / (b_w d) \leq 0.02$	=	OK	OK	
Actual shear stress= $v_{ED} = (V_{ED} / b * 0.9d)$	=	0.156	0.052	N/mm ²
Max shear capacity, $0.135 f_{ck} (1 - f_{ck} / 310)$	=	3.658	3.658	N/mm ²
Depth Check for Shear Resistance	=	SAFE	SAFE	
cl. 10.3.2(2) Eq. 10.2 of IRC :112-2010				
$K = 1 + \sqrt{200/d} \leq 2.0$	=	1.653	1.636	
cl. 10.3.2(2) Eq. 10.3 of IRC :112-2010				
$V_{min} = 0.031 K^{3/2} f_{ck}^{1/2}$	=	0.361	0.355	N/mm ²
$0.12 K (80 \tau$ 1 $f_{ck})^{0.33}$	=	0.330	0.324	N/mm ²
$\sigma_{cp} = N_{Ed} / A_c \leq 0.2 f_{cd}$	=	0.000	0.000	
cl. 10.3.2(2) Eq. 10.1 of IRC :112-2010				
$V_{Rd,c} = [0.12K(80p1 f_{ck})^{0.33} + 0.15\sigma_{cp}] b_w d$ subjected to minimum ($v_{min} + 0.15 \sigma_{cp}) b_w d$	=	154.79	159.92	kN
Check for Shear Reinforcement		No Shear R/f required	No Shear R/f required	

Project:	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Retaining Wall for height 5 m from G.L	Date & Rev.	-

SLS CHECK OF FOUNDATION

Foundation Lvl = 93.000 m

Properties of Footing Base:

A	=	4.600	m ²
ZL	=	3.527	m ³
ZT	=	0.767	m ³

Creep Coeff = 1.2 For Dry atmospheric condition

Ecm = 31000 N/mm²

Es = 200000 N/mm²

Eceff = $\frac{Ecm}{(1 + \phi)}$ = 14090.91

Modular Ratio (m) = $\frac{Es}{Eceff}$ = 14.19

Normal Dry Case

Loads	Load Factor	Unit Weights (kN/m ³)	Volume (m ³)	Vertical Load (P) kN.	Long. Ecc. (eL1) (m)	ML = PxeL1 (kNm)
Shaft	1	25	3.225	80.625	0.450	36.281
Back filling over heel slab	1	20	15.780	315.600	-1.004	316.844
Back filling on flared portion of shaft	1	20	1.290	25.800	0.233	6.020
Front Filling over toe slab	1	20	2.363	47.250	1.558	73.593
RCC Railing or Crash Barrier	1			0.000	0.800	0.000
Heel slab	1	25	1.020	25.500	-0.940	23.970
Toe slab	1	25	0.638	15.938	1.450	23.109
portion between heel & toe	1	25	0.303	7.563	0.450	3.403
Total				518.275		-198.408

load factor

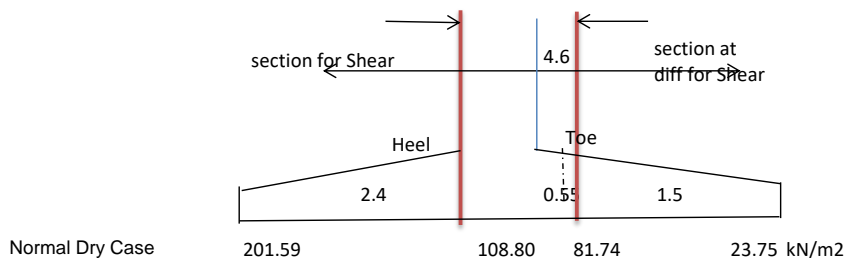
Moment due to active earth pressure = 1.0 x 402.480 = 402.480 kNm

Moment due to Live load surcharge = 0.8 x 136.898 = 109.518 kNm

511.998

P	518.275	KN
ML	313.591	kNm
MT	0.000	kNm
A	4.600	m ²
ZL	3.527	m ³
ZT	0.767	m ³
P/A+ML/ZL+MT/ZT (Max)	201.588	kN/m ²
P/A-ML/ZL-MT/ZT (Min)	23.749	kN/m ²

Normal Dry Case		
Base Pressure (kN/m ²)	Max	201.588
	Min	23.749



Project:	-	Designed by:	KB	
Client:	-	Checked by:	-	
Job Name	Design of Retaining Wall for height 5 m from G.L		Date & Rev.	-

Heel Slab - Moment Calculation

Average Base Pressure for Design of Heel Slab	=	155.20	kN/m ²						
Upward moment due to Base pressure	=	446.96	kNm/m						
	factor								
Downward moment due to backfill	=	1.00	x	15.78	x	20	x	1.2	= 378.72 kNm/m
Downward moment due to self weight of Heel	=	1.00	x	1.020	x	25	x	1.040	= 26.52 kNm/m
Net Moment at face of shaft	=	446.96		-378.72		-26.52			= 41.72 kNm/m

Tension at Bottom of Heel Slab

Toe Slab - Moment Calculation

Average Base Pressure for Design of Toe Slab	=	52.74	kN/m ²						
Upward moment due to Base pressure	=	59.34	kNm/m						
Downward moment due to self weight of Toe	=	1	x	0.6375	x	25	x	0.650	= 10.36 kNm/m
Net Moment at face of shaft	=	59.34		-10.36					= 48.98 kNm/m

Tension at Bottom of Heel Slab

		Heel Slab	Toe Slab	
Working bending moment, M	=	41.72	48.98	kNm/m
Dx	=	1.00	1.00	m
Dy	=	0.70	0.70	m
Section Modulus (ZL) of uncracked section	=	0.08	0.08	m ³
Bending Stress (M/ZL)	=	0.511	0.600	N/mm ²
Tensile stress of concrete , fctm	=	2.500	2.500	N/mm ²
Cracked or Uncracked Section	=	Uncracked	Uncracked	
Section properties of Cracked section:				
Note: Stresses under Service load are usually within Linear Elastic Range hence such analysis involved use of Modulus ratio.				
Clear Cover, c	=	75.000	75.000	
Maximum dia used, f	=	12.000	12.000	
Effective Depth deff (dy)	=	469.000	469.000	mm
Ast provided	=	942.360	942.360	mm ² /m
Percentage of steel , pt	=	0.0019	0.0019	
$k = \sqrt{2 pt * m + (pt * m)^2} - pt * m$	=	0.209	0.207	
Depth of neutral axis from extreme Compression face (yc = k * dy)	=	98.100	96.922	mm
Depth of neutral axis from extreme tension face (yt = dy - yc)	=	370.900	372.078	mm
Depth of neutral axis from c.g. Of tension steel (ys)	=	289.900	291.078	mm
Cracked moment of Inertia (Icr)	=	$Dx * (k * dy)^3 / 3 + m Ast * (dy - k * dy)^2$		

Project:	-	Designed by:	KB	
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Job Name	Design of Retaining Wall for height 5 m from G.L		Date & Rev.	-

lcr	=	1210265626	1217947941	mm4
Maximum compressive stress in concrete	=	3.382	3.898	< 14.4, SAFE
Maximum tensile stress in concrete	=	12.786	14.963	
Maximum Tensile stress in steel	=	97.018	113.889	< 400, SAFE

Check For Crack Width				
Crack width , Wk	=	Sr max (esm - ecm)		
Above Formula For Calculation of Sr max is applicable if the spacing between the reinf. is less or equal to 5*(c+φ/2)				
5*(c+φ/2)	=	405.000	405.000	mm
Provided Spacing	=	65.000	65.000	mm
Check for Applicability of Formula	=	OK	OK	
Maximum crack spacing , Sr max	=	3.4 c +	0.425 k1 k2 φ	
			r r eff	
K1	=	0.800	0.800	for deformed bars
K2	=	0.500	0.500	for bending
depth of neutral axis , yc	=	98.100	96.922	mm
r r eff = As/Ac eff	=	, where Ac,eff =effective area of concrete in tension surrounding the reinf.		
hc eff = Min of 2.5 (Dy - dy) ,Dy - yc/3 , Dy/2	=	234.500	234.500	mm
Ac, eff = Dx * hc,eff	=	234500.000	234500.000	mm
r r eff = As/Ac eff	=	0.004	0.004	
Maximum crack spacing , Sr max	=	762.640	762.640	mm
(esm - ecm)	=	$\frac{\sigma_{sc} - k_t f_{ct,eff} (1 + \alpha_e \rho_{p,eff})}{\rho_{p,eff}}$		
tensile stress in steel , σsc	=	97.018	113.889	N/mm2
Kt	=	0.500	0.500	
Tensile strength of concrete = fct eff = fctm	=	2.500	2.500	N/mm2
αe = Es/Ecm	=	6.452	6.452	
(esm - ecm)	=	-0.001	-0.0010	
Crack width , Wk=Sr max (esm - ecm)	=	0.000	0.000	
Check	=	SAFE	SAFE	

319.12

Project	-	Designed by:	KB
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Job Name	Design of Retaining Wall for height 5 m from G.L	Date & Rev.	-

Calculation of Forces For Design of Wall

Wall bottom level = 93.55 m

Normal Dry Case

Loads	Load Factor	Unit Weights (kN/m3)	Volume (m3)	Vertical Load(P) kN.	Long. Ecc. (eL) (m)	ML = PxeL (kNm)
Shaft	1.35	25	3.225	108.84375	0.087	9.433
RCC Railing or Crash Barrier	1.35			0	0.35	0.000
Total				108.844		9.433

Horizontal Force : load factor

Due to Earth pressure 1.5 x 116.23 = 174.35 KN

Due to Live load Surcharge 1.2 x 36.04 = 43.25 KN

217.59

Total Horizontal Force = 217.59 KN

Moment Due to Horizontal Force: load factor

Moment due to active earth pressure = 1.5 x 293.753 = 440.629 kNm

Moment due to Live load surcharge = 1.2 x 116.231 = 139.4767 kNm

580.105

Total Moment due to Horizontal Force = 580.105 kNm

Summary of Forces:

P	108.844	KN
ML	589.539	kNm
FL	217.594	KN

Project	-	Designed by:	KB
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Design of Wall:

Grade of Concrete	=	30.00 M 30
fck	=	30.00 N/mm ²
fcd	=	13.40 N/mm ²
Grade of steel	=	500.00 Fe
fy	=	500.00 N/mm ²
fyd	=	434.78 N/mm ²
Es	=	200000.00 N/mm ²

Cross section of Wall:

Thickness of Wall (B)	=	0.7 m
Depth of Wall (D)	=	1 m
Area of Concrete (Ac)	=	0.7 m ²
Clear Cover to earth faces	=	75 mm
Clear Cover to non earth faces	=	40 mm
Maximum Dia of Vertical Reinf.	=	16 mm
Dia of Horizontal Reinf.	=	12 mm

Summary of Design Forces:

	P(kN)	ML (kNm)	FL (kN)
Case 1 : Normal Dry Case	108.84	589.54	217.59
MAX	108.84	589.54	217.59

As per Clause 7.6.4.1 of IRC:112-2011

Ultimate axial force (Pu)	=	108.84 kN
0.1 fcd Ac	=	0.1 13.4 700000
	=	938000 N
	=	938.0 kN

Since Axial Force is less than axial capacity of section , Section will design as bending element . Neglecting axial force

PART 1: LONGITUDINAL MOMENT : VERTICAL REINFORCEMENT ON EARTH FACE

Ultimate Design bending moment (ML)	=	589.54 kNm	=	589.54 kNm/m
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Check For Depth of Wall :

Mult	=	0.167 x fck x b x d ²
	=	589.54 kNm/m
b	=	1000 mm

Effective Depth Required (dreq) = $\text{SQRT}\left(\frac{597.03 \times 1000000}{0.167 \times 30.00 \times 1000}\right)$

(dreq)	=	343.03 mm	
Total Depth Required (Dreq)	=	426.03 mm	
Total Depth Provided (Dprov)	=	700 mm	OK
Effective depth provided(d _{eff})	=	617 mm	
R= Mu/(b d ²)	=	1.549	

Minimum Longitudinal Reinforcement in wall on each face

=

= 0.0012 x b x D -Refer Clause 16.9 of IRC:112-2011'

Ast min	=	840 mm ² /m
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Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Retaining Wall for height 5 m from G.L	Date & Rev.	-

Area of Steel Required:

$$\frac{P_t}{100} = \frac{A_{st_{req}}}{bD} = \frac{f_{ck} \{ 1 - \sqrt{1 - 4.598 R/f_{ck}} \}}{2f_y}$$

$$= 0.0038$$

$$A_{st_{req}} = 2660.74 \text{ mm}^2/\text{m}$$

$$\text{Ast required} = \max(A_{st_{min}}, A_{st_{req}}) = 2660.74 \text{ mm}^2/\text{m}$$

Provide	16	mm dia	@	120	mm c/c	=	1675.31	2617.67	mm ² /m	REVISE
	12	mm dia	@	120	mm c/c	=	942.36			

Percentage of steel = 0.374 %

Check for Moment of Resistance of Section due to Steel

$$\text{Limiting Depth of Neutral Axis, } X_m = \frac{0.0035 \cdot d}{(0.0035 + f_{yd}/E_s)}$$

$$= 380.60 \text{ mm}$$

$$\text{Depth of Neutral Axis, } X = \frac{f_{yd} \cdot A_{st}}{0.36 \cdot f_{ck} \cdot b}$$

$$= 105.38 \text{ mm}$$

OK

$$\text{Lever Arm (} z \text{) between Compressive Force (C) and Tensile Force (T)}$$

$$z = d - 0.416 \times X$$

$$= 573.16 \text{ mm}$$

Moment of Resistance of Section w.r.t. Steel (MR)

$$\text{MR} = f_{yd} \cdot A_{st} \cdot Z$$

$$= 652324195.0$$

$$= 6.52\text{E}+08 \text{ Nmm /m}$$

$$= \boxed{6.52\text{E}+02 \text{ kNm/m} > 589.54 \text{ kNm/m}}$$

Moment of Resistance of Wall is More than Design Bending Moment , HENCE Wall IS SAFE IN BENDING

LONGITUDINAL REINFORCEMENT ON NON EARTH FACE

Minimum Longitudinal Reinforcement in wall on each face

$$= 0.0012 \times b \times D \text{ Refer Clause 16.9 of IRC:112-2011'}$$

$$\text{Ast min} = 840 \text{ mm}^2/\text{m}$$

Provide	12	mm dia	120	mm c/c	=	942.36	mm ² /m	OK
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PART 3 : HORIZONTAL REINFORCEMENT CALCULATION

Horizontal Reinforcement for wall

$$\text{maximum of following} = 0.25 \times 3560.03 = 890.01 \text{ As per IRC:112-2011' Clause 16.32.2}$$

$$= 0.001 \times 7.00\text{E}+05 = 700.00$$

Minimum Horizontal Reinf. provided 890.0 mm² per meter

$$\text{Min dia of bar} = 0.25 \times 16 = 4 \text{ mm}$$

$$\text{or } 8 \text{ mm}$$

Maximum Spacing between bars <= 300 mm/cc

2 Legged	12	dia	@	200	c/c	=	1130.4	mm ²	OK
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Project	-	Designed by:	KB
Client	-	Checked by:	-
Job Name	Design of Retaining Wall for height 5 m from G.L	Date & Rev.	-

SLS CHECK OF WALL

Foundation Lvl	=	93.55	m
Creep Coeff	(ϕ) =	1.2	For Dry atmospheric condition
Ecm	=	31000	
Es	=	200000	N/mm ²
Eceff	=	$\frac{Ecm}{(1 + \phi)}$	= 14090.90909
Modular Ratio (m)	=	Es/ Eceff	= 14.19

Normal Dry Case

Loads	Load Factor	Unit Weights (kN/m ³)	Volume (m ³)	Vertical Load(P) kN.	Long. Ecc. (eL) (m)	ML = PxeL (kNm)
Shaft	1.000	25	3.225	80.625	0.086666667	6.9875
RCC Railing or Crash Barrier	1.000			0	0.35	0
Total				80.625		6.988

Horizontal Force :		load factor			
Due to Earth pressure	=	1.000	x	116.2305779	= 116.2306 KN
Due to Live load Surcharge	=	0.800	x	36.04048926	= 28.83239 KN
Total Horizontal Force	=	145.0629693	KN		

Moment Due to Horizontal Force:		load factor			
Moment due to active earth pressure	=	1.000	x	314.869	= 314.869 kNm
Moment due to Live load surcharge	=	0.8	x	116.231	= 92.984 kNm
Total Moment due to Horizontal Force	=	407.853097721	kNm		

Summary of Forces:

P	80.625	KN
ML	414.841	kNm
FL	145.063	KN

Bending Moment, M	=	414.84	kNm
Dx	=	1.00	m
Dy	=	0.70	m
Section Modulus (ZL) of uncracked secti	=	0.08	m ³
Bending Stress (M/ZL)	=	5.080	N/mm ²
Tensile stress of concrete , fctm	=	2.500	N/mm ²
Cracked or Uncracked Section	=	Cracked	
Section properties of Cracked section:			
Note: Stresses under Service load are usually within Linear Elastic Range hence such analysis involved use of Modulus ratio.			
Clear Cover, c	=	75.000	mm
Maximum dia used (Vertical), f	=	16.000	mm
Horizontal Reinf. Dia used	=	12.000	mm
Effective Depth deff (dy)	=	617.000	mm
Ast provided	=	2617.667	mm ² /m
Percentage of steel, pt	=	0.0048	
$k = \sqrt{2 \cdot pt \cdot m + (pt \cdot m)^2} - pt \cdot m$	=	0.307	
Depth of neutral axis from extreme Compression face (yc = k * dy)	=	189.642	mm
Depth of neutral axis from extreme tension face (yt = dy-yc)	=	427.358	mm

Depth of neutral axis from c.g. Of tesnion steel (ys)	=	344.358	mm
Cracked moment of Inertia (Icr)	=	$Dx \cdot (k \cdot dy)^3 / 3 + m \cdot Ast \cdot (dy - k \cdot dy)^2$	
Icr	=	4464336844	mm ⁴
Maximum compressive stress in concrete	=	17.6	< 14.4, SAFE
Maximum tensile stress in concrete	=	39.712	
Maximum Tensile stress in steel	=	262.226	< 400, SAFE

Project	-	Designed by:	KB
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Job Name	Design of Retaining Wall for height 5 m from G.L	Date & Rev.	-

Check For Crack Width			
Crack width , Wk	=	Sr max (esm - εcm)	
Above Formula For Calculation of Sr max is applicable if the spacing between the reinf. is less or equal to 5*(c+φ/2)			
5*(c+φ/2)	=	415.000	mm
Provided Spacing	=	120.000	mm
Check for Applicability of Formula	=	OK	
Maximum crack spacing , Sr max	=	3.4 c +	0.425 k1 k2 φ P p eff
K1	=	0.700	for deformed b
K2	=	0.500	for bending
depth of neutral axis , yc	=	189.642	mm
z r eff = As/Ac eff	=	, where Ac,eff =effective area of concrete in tension surrounding the reinf.	
hc eff = Min of 2.5 (Dy - dy) ,Dy - yc/3 , Dy/2	=	207.500	mm
Ac, eff = Dx * hc,eff	=	207500.000	mm
z r eff = As/Ac eff	=	0.013	
Maximum crack spacing , Sr max	=	443.660	mm
(εsm - εcm)	=	$\frac{\sigma_{sc} - k_t f_{ct,eff} (1 + \alpha_e r r_{eff})}{r r_{eff}}$	/ Es
tensile stress in steel , σsc	=	262.226	N/mm2
Kt	=	0.500	
Tensile strength of concrete = fct eff = fctm	=	2.500	N/mm2
αe = Es/Ecm	=	6.452	
(esm - εcm)	=	0.00078	
Crack width , Wk=Sr max (esm - εcm)	=	0.344	
Check	=	UNSAFE	

Project	-	Designed by:	KB		
Client	-	Checked by:	-		
Job Name	Design of Retaining Wall for height 5 m from G.L	Date & Rev.	-		

Stability Check Summary

Description	P (kN/m2 max)	P (kN/m2 min)	Sliding	Overturning	Shear (Heel slab)	Shear (Toe slab)
Normal Dry case	211.33	14.00	1.47	2.56	0.156	-0.052
Permissible	220	0	1.5	2	3.658	3.658
Remarks	OK	OK	REVISE	OK	OK	OK

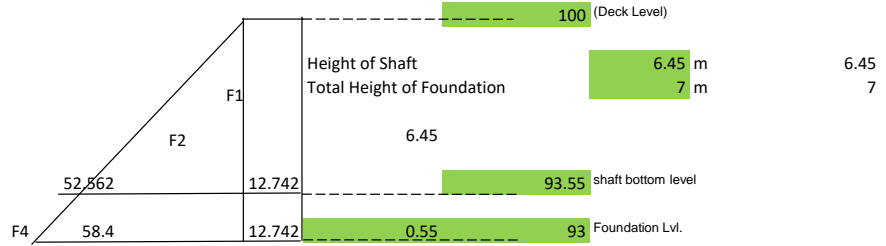
Reinforcement summary

Type of reinforcement	Area of steel required	Area of steel provided						
		Straight Portion of Shaft						
Vertical steel at earth face	2661	16	mm bar @	120	mm c/c (i.e.)	2618	mm2	REVISE
		12	mm bar @	120	mm c/c (i.e.)			
Vertical steel at non-earth face	840	12	mm bar @	120	mm c/c (i.e.)	942	mm2	OK
Distribution steel	890	12	mm 2 Legged bar @	200	mm c/c (i.e.)	1130	mm2	OK
Heel Slab								
Main steel at top face	610	12	mm bar @	120	mm c/c (i.e.)	942	mm2	OK
		0	mm bar @	120	mm c/c (i.e.)			
Steel at bottom face	250	12	mm bar @	120	mm c/c (i.e.)	942	mm2	OK
Distribution reinforcement	188	10	mm bar @	200	mm c/c (i.e.)	393	mm2	OK
Shear Reinforcement	No Shear R/f required							
Toe Slab								
Main steel at bottom face	610	12	mm bar @	120	mm c/c (i.e.)	942	mm2	OK
		0	mm bar @	120	mm c/c (i.e.)			
Steel at top face	250	12	mm bar @	120	mm c/c (i.e.)	942	mm2	OK
Distribution reinforcement	188	10	mm bar @	200	mm c/c (i.e.)	393	mm2	OK
Shear Reinforcement	No Shear R/f required							

Earth Pressure : Normal Dry Case

Properties of backfill material :

c	=	0		
ϕ	=	30 degree	0.524 radians	0.866
θ	=	87.11 degree	1.520 radians	0.050
θ_1	=	90 degree	1.571 radians	0.000
β	=	26.5 degree	0.462512252 radians	0.895
δ	=	20 degree	0.349 radians	0.940
Kah	=	0.279 active component		
Kph	=	5.737 Passive component		
γ	=	20 kN/m ³		
Equivalent Live Load Surcharge height	=	1.2 m		
Assuming				



HORIZONTAL ALIGNMENT REPORT

Horizontal Alignment Report											
S.NO.	Type	Start Station	End Station	Length	Radius	A	Direction	Delta angle	Start Direction	End Direction	Incurve
1	Line	20500	20541.262	41.262			S54° 25' 34.06"W				
2	Spiral-Curve-Spiral	20541.262	20571.262	30		38.730m		17.1887 (d)	S54° 25' 34.06"W	S71° 36' 53.50"W	Incurve
3	Spiral-Curve-Spiral	20571.262	20620.631	49.369	50.000m			56.5732 (d)	S71° 36' 53.50"W	N51° 48' 43.01"W	
4	Spiral-Curve-Spiral	20620.631	20650.631	30		38.730m		17.1887 (d)	N51° 48' 43.01"W	N34° 37' 23.56"W	Outcurve
5	Line	20650.631	20911.471	260.84			N34° 37' 23.56"W				
6	Spiral-Curve-Spiral	20911.471	20946.471	35		66.144m		8.0214 (d)	N34° 37' 23.56"W	N26° 36' 06.49"W	Incurve
7	Spiral-Curve-Spiral	20946.471	21059.302	112.831	125.000m			51.7179 (d)	N26° 36' 06.49"W	N25° 06' 57.90"E	
8	Spiral-Curve-Spiral	21059.302	21094.302	35		66.144m		8.0214 (d)	N25° 06' 57.90"E	N33° 08' 14.97"E	Outcurve
9	Line	21094.302	21103.738	9.437			N33° 08' 14.97"E				
10	Spiral-Curve-Spiral	21103.738	21113.738	10		70.711m		0.5730 (d)	N33° 08' 14.97"E	N32° 33' 52.33"E	Incurve
11	Spiral-Curve-Spiral	21113.738	21292.493	178.755	500.000m			20.4838 (d)	N32° 33' 52.33"E	N12° 04' 50.69"E	
12	Spiral-Curve-Spiral	21292.493	21302.493	10		70.711m		0.5730 (d)	N12° 04' 50.69"E	N11° 30' 28.04"E	Outcurve
13	Line	21302.493	21346.838	44.345			N11° 30' 28.04"E				
14	Spiral-Curve-Spiral	21346.838	21356.838	10		70.711m		0.5730 (d)	N11° 30' 28.04"E	N10° 56' 05.39"E	Incurve
15	Spiral-Curve-Spiral	21356.838	21382.78	25.943	500.000m			2.9728 (d)	N10° 56' 05.39"E	N7° 57' 43.31"E	
16	Spiral-Curve-Spiral	21382.78	21392.78	10		70.711m		0.5730 (d)	N7° 57' 43.31"E	N7° 23' 20.66"E	Outcurve
17	Line	21392.78	21503.72	110.939			N7° 23' 20.66"E				
18	Spiral-Curve-Spiral	21503.72	21523.72	20		63.246m		2.8648 (d)	N7° 23' 20.66"E	N4° 31' 27.42"E	Incurve
19	Spiral-Curve-Spiral	21523.72	21657.818	134.098	200.000m			38.4162 (d)	N4° 31' 27.42"E	N33° 53' 30.84"W	
20	Spiral-Curve-Spiral	21657.818	21677.818	20		63.246m		2.8648 (d)	N33° 53' 30.84"W	N36° 45' 24.08"W	Outcurve
21	Line	21677.818	21807.448	129.63			N36° 45' 24.08"W				
22	Spiral-Curve-Spiral	21807.448	21842.448	35		66.144m		8.0214 (d)	N36° 45' 24.08"W	N44° 46' 41.15"W	Incurve
23	Spiral-Curve-Spiral	21842.448	21931.523	89.075	125.000m			40.8291 (d)	N44° 46' 41.15"W	N85° 36' 26.09"W	
24	Spiral-Curve-Spiral	21931.523	21950	18.477		66.144m		8.0214 (d)	N85° 36' 26.09"W	S86° 22' 16.84"W	Outcurve
25	Line	21950	22001.947	51.947			S86° 45' 08.88"W				
26	Spiral-Curve-Spiral	22001.947	22026.947	25		43.301m		9.5493 (d)	S86° 45' 08.88"W	S77° 12' 11.42"W	Incurve
27	Spiral-Curve-Spiral	22026.947	22035.275	8.328	75.000m			6.3621 (d)	S77° 12' 11.42"W	S70° 50' 28.01"W	
28	Spiral-Curve-Spiral	22035.275	22060.275	25		43.301m		9.5493 (d)	S70° 50' 28.01"W	S61° 17' 30.54"W	Outcurve
29	Line	22060.275	22066.569	6.293			S61° 17' 30.54"W				
30	Spiral-Curve-Spiral	22066.569	22096.569	30		47.434m		11.4592 (d)	S61° 17' 30.54"W	S72° 45' 03.50"W	Incurve
31	Spiral-Curve-Spiral	22096.569	22151.499	54.93	75.000m			41.9637 (d)	S72° 45' 03.50"W	N65° 17' 07.32"W	
32	Spiral-Curve-Spiral	22151.499	22181.499	30		47.434m		11.4592 (d)	N65° 17' 07.32"W	N53° 49' 34.36"W	Outcurve
33	Line	22181.499	22312.838	131.34			N53° 49' 34.36"W				
34	Spiral-Curve-Spiral	22312.838	22322.838	10		17.321m		9.5493 (d)	N53° 49' 34.36"W	N44° 16' 36.89"W	Incurve
35	Spiral-Curve-Spiral	22322.838	22362.718	39.88	30.000m			76.1652 (d)	N44° 16' 36.89"W	N31° 53' 17.79"E	
36	Spiral-Curve-Spiral	22362.718	22372.718	10		17.321m		9.5493 (d)	N31° 53' 17.79"E	N41° 26' 15.26"E	Outcurve
37	Line	22372.718	22390.589	17.87			N41° 26' 15.26"E				
38	Spiral-Curve-Spiral	22390.589	22410.589	20		31.623m		11.4592 (d)	N41° 26' 15.26"E	N52° 53' 48.22"E	Incurve
39	Spiral-Curve-Spiral	22410.589	22448.554	37.965	50.000m			43.5048 (d)	N52° 53' 48.22"E	S83° 35' 54.35"E	
40	Spiral-Curve-Spiral	22448.554	22468.554	20		31.623m		11.4592 (d)	S83° 35' 54.35"E	S72° 08' 21.39"E	Outcurve
41	Line	22468.554	22471.902	3.348			S72° 08' 21.39"E				

Horizontal Alignment Report											
S.NO.	Type	Start Station	End Station	Length	Radius	A	Direction	Delta angle	Start Direction	End Direction	Incurve
42	Spiral-Curve-Spiral	22471.902	22491.902	20		31.623m		11.4592 (d)	S72° 08' 21.39"E	S83° 35' 54.35"E	Incurve
43	Spiral-Curve-Spiral	22491.902	22532.843	40.942	50.000m			46.9156 (d)	S83° 35' 54.35"E	N49° 29' 09.62"E	
44	Spiral-Curve-Spiral	22532.843	22552.843	20		31.623m		11.4592 (d)	N49° 29' 09.62"E	N38° 01' 36.66"E	Outcurve
45	Line	22552.843	22873.378	320.535			N38° 01' 36.66"E				
46	Spiral-Curve-Spiral	22873.378	22903.378	30		67.082m		5.7296 (d)	N38° 01' 36.66"E	N32° 17' 50.18"E	Incurve
47	Spiral-Curve-Spiral	22903.378	23155.128	251.75	150.000m			96.1615 (d)	N32° 17' 50.18"E	N63° 51' 51.23"W	
48	Spiral-Curve-Spiral	23155.128	23185.128	30		67.082m		5.7296 (d)	N63° 51' 51.23"W	N69° 35' 37.71"W	Outcurve
49	Line	23185.128	23320.632	135.503			N69° 35' 37.71"W				
50	Spiral-Curve-Spiral	23320.632	23350.632	30		77.460m		4.2972 (d)	N69° 35' 37.71"W	N65° 17' 47.85"W	Incurve
51	Spiral-Curve-Spiral	23350.632	23376.171	25.54	200.000m			7.3166 (d)	N65° 17' 47.85"W	N57° 58' 48.21"W	
52	Spiral-Curve-Spiral	23376.171	23406.171	30		77.460m		4.2972 (d)	N57° 58' 48.21"W	N53° 40' 58.35"W	Outcurve
53	Line	23406.171	23570.547	164.376			N53° 40' 58.35"W				
54	Spiral-Curve-Spiral	23570.547	23600.547	30		67.082m		5.7296 (d)	N53° 40' 58.35"W	N47° 57' 11.87"W	Incurve
55	Spiral-Curve-Spiral	23600.547	23719.475	118.928	150.000m			45.4271 (d)	N47° 57' 11.87"W	N2° 31' 34.22"W	
56	Spiral-Curve-Spiral	23719.475	23749.475	30		67.082m		5.7296 (d)	N2° 31' 34.22"W	N3° 12' 12.26"E	Outcurve
57	Line	23749.475	24123.194	373.719			N3° 12' 12.26"E				
58	Spiral-Curve-Spiral	24123.194	24143.194	20		26.458m		16.3702 (d)	N3° 12' 12.26"E	N13° 10' 00.54"W	Incurve
59	Spiral-Curve-Spiral	24143.194	24227.843	84.649	35.000m			138.5716 (d)	N13° 10' 00.54"W	S28° 15' 41.61"W	
60	Spiral-Curve-Spiral	24227.843	24247.843	20		26.458m		16.3702 (d)	S28° 15' 41.61"W	S11° 53' 28.81"W	Outcurve
61	Line	24247.843	24657.592	409.749			S11° 53' 28.81"W				
62	Spiral-Curve-Spiral	24657.592	24687.592	30		67.082m		5.7296 (d)	S11° 53' 28.81"W	S6° 09' 42.33"W	Incurve
63	Spiral-Curve-Spiral	24687.592	24733.327	45.735	150.000m			17.4696 (d)	S6° 09' 42.33"W	S11° 18' 28.17"E	
64	Spiral-Curve-Spiral	24733.327	24763.327	30		67.082m		5.7296 (d)	S11° 18' 28.17"E	S17° 02' 14.65"E	Outcurve
65	Line	24763.327	24913.101	149.774			S17° 02' 14.65"E				
66	Spiral-Curve-Spiral	24913.101	24943.101	30		38.730m		17.1887 (d)	S17° 02' 14.65"E	S0° 09' 04.80"W	Incurve
67	Spiral-Curve-Spiral	24943.101	25010.75	67.649	50.000m			77.5199 (d)	S0° 09' 04.80"W	S77° 40' 16.53"W	
68	Spiral-Curve-Spiral	25010.75	25040.75	30		38.730m		17.1887 (d)	S77° 40' 16.53"W	N85° 08' 24.03"W	Outcurve
69	Line	25040.75	25341.115	300.366			N85° 08' 24.03"W				
70	Spiral-Curve-Spiral	25341.115	25361.115	20		24.495m		19.0986 (d)	N85° 08' 24.03"W	N66° 02' 29.10"W	Incurve
71	Spiral-Curve-Spiral	25361.115	25430.129	69.014	30.000m			131.8072 (d)	N66° 02' 29.10"W	N65° 45' 56.83"E	
72	Spiral-Curve-Spiral	25430.129	25450.129	20		24.495m		19.0986 (d)	N65° 45' 56.83"E	N84° 51' 51.77"E	Outcurve
73	Line	25450.129	25584.689	134.56			N84° 51' 51.77"E				
74	Spiral-Curve-Spiral	25584.689	25604.689	20		31.623m		11.4592 (d)	N84° 51' 51.77"E	N73° 24' 18.81"E	Incurve
75	Spiral-Curve-Spiral	25604.689	25670.043	65.353	50.000m			74.8896 (d)	N73° 24' 18.81"E	N1° 29' 03.73"W	
76	Spiral-Curve-Spiral	25670.043	25690.043	20		31.623m		11.4592 (d)	N1° 29' 03.73"W	N12° 56' 36.69"W	Outcurve
77	Line	25690.043	25880.757	190.714			N12° 56' 36.69"W				
78	Spiral-Curve-Spiral	25880.757	25900.757	20		54.772m		3.8197 (d)	N12° 56' 36.69"W	N9° 07' 25.71"W	Incurve
79	Spiral-Curve-Spiral	25900.757	25903.228	2.471	150.000m			0.9438 (d)	N9° 07' 25.71"W	N8° 10' 48.14"W	
80	Spiral-Curve-Spiral	25903.228	25923.228	20		54.772m		3.8197 (d)	N8° 10' 48.14"W	N4° 21' 37.15"W	Outcurve
81	Line	25923.228	26089.89	166.662			N4° 21' 37.15"W				
82	Spiral-Curve-Spiral	26089.89	26119.89	30		38.730m		17.1887 (d)	N4° 21' 37.15"W	N21° 32' 56.60"W	Incurve

Horizontal Alignment Report											
S.NO.	Type	Start Station	End Station	Length	Radius	A	Direction	Delta angle	Start Direction	End Direction	Incurve
83	Spiral-Curve-Spiral	26119.89	26152.268	32.378	50.000m			37.1029 (d)	N21° 32' 56.60"W	N58° 39' 06.94"W	
84	Spiral-Curve-Spiral	26152.268	26182.268	30		38.730m		17.1887 (d)	N58° 39' 06.94"W	N75° 50' 26.38"W	Outcurve
85	Line	26182.268	26309.552	127.283			N75° 50' 26.38"W				
86	Spiral-Curve-Spiral	26309.552	26339.552	30		48.990m		10.7430 (d)	N75° 50' 26.38"W	N65° 05' 51.73"W	Incurve
87	Spiral-Curve-Spiral	26339.552	26394.328	54.776	80.000m			39.2308 (d)	N65° 05' 51.73"W	N25° 52' 01.02"W	
88	Spiral-Curve-Spiral	26394.328	26424.328	30		48.990m		10.7430 (d)	N25° 52' 01.02"W	N15° 07' 26.37"W	Outcurve
89	Line	26424.328	26565.901	141.573			N15° 07' 26.37"W				
90	Spiral-Curve-Spiral	26565.901	26575.901	10		17.321m		9.5493 (d)	N15° 07' 26.37"W	N24° 40' 23.84"W	Incurve
91	Spiral-Curve-Spiral	26575.901	26648.709	72.808	30.000m			139.0525 (d)	N24° 40' 23.84"W	S16° 16' 27.18"W	
92	Spiral-Curve-Spiral	26648.709	26658.709	10		17.321m		9.5493 (d)	S16° 16' 27.18"W	S6° 43' 29.71"W	Outcurve
93	Line	26658.709	26720.606	61.897			S6° 43' 29.71"W				
94	Spiral-Curve-Spiral	26720.606	26740.606	20		54.772m		3.8197 (d)	S6° 43' 29.71"W	S2° 54' 18.72"W	Incurve
95	Spiral-Curve-Spiral	26740.606	26856.369	115.763	150.000m			44.2182 (d)	S2° 54' 18.72"W	S41° 18' 46.77"E	
96	Spiral-Curve-Spiral	26856.369	26876.369	20		54.772m		3.8197 (d)	S41° 18' 46.77"E	S45° 07' 57.75"E	Outcurve
97	Line	26876.369	27014.585	138.215			S45° 07' 57.75"E				
98	Spiral-Curve-Spiral	27014.585	27034.585	20		54.772m		3.8197 (d)	S45° 07' 57.75"E	S41° 18' 46.77"E	Incurve
99	Spiral-Curve-Spiral	27034.585	27104.291	69.706	150.000m			26.6257 (d)	S41° 18' 46.77"E	S14° 41' 14.36"E	
100	Spiral-Curve-Spiral	27104.291	27124.291	20		54.772m		3.8197 (d)	S14° 41' 14.36"E	S10° 52' 03.37"E	Outcurve
101	Line	27124.291	27212.891	88.6			S10° 52' 03.37"E				
102	Spiral-Curve-Spiral	27212.891	27232.891	20		44.721m		5.7296 (d)	S10° 52' 03.37"E	S5° 08' 16.89"E	Incurve
103	Spiral-Curve-Spiral	27232.891	27373.042	140.151	100.000m			80.3004 (d)	S5° 08' 16.89"E	S75° 09' 44.66"W	
104	Spiral-Curve-Spiral	27373.042	27393.042	20		44.721m		5.7296 (d)	S75° 09' 44.66"W	S80° 53' 31.14"W	Outcurve
105	Line	27393.042	27608.188	215.146			S80° 53' 31.14"W				
106	Spiral-Curve-Spiral	27608.188	27628.188	20		24.495m		19.0986 (d)	S80° 53' 31.14"W	N80° 00' 33.92"W	Incurve
107	Spiral-Curve-Spiral	27628.188	27701.365	73.178	30.000m			139.7592 (d)	N80° 00' 33.92"W	N59° 44' 59.31"E	
108	Spiral-Curve-Spiral	27701.365	27721.365	20		24.495m		19.0986 (d)	N59° 44' 59.31"E	N78° 50' 54.25"E	Outcurve
109	Line	27721.365	27858.476	137.11			N78° 50' 54.25"E				
110	Spiral-Curve-Spiral	27858.476	27878.476	20		40.000m		7.1620 (d)	N78° 50' 54.25"E	N71° 41' 11.15"E	Incurve
111	Spiral-Curve-Spiral	27878.476	28020.248	141.772	80.000m			101.5370 (d)	N71° 41' 11.15"E	N29° 51' 02.00"W	
112	Spiral-Curve-Spiral	28020.248	28040.248	20		40.000m		7.1620 (d)	N29° 51' 02.00"W	N37° 00' 45.10"W	Outcurve
113	Line	28040.248	28204.562	164.314			N37° 00' 45.10"W				
114	Spiral-Curve-Spiral	28204.562	28224.562	20		70.711m		2.2918 (d)	N37° 00' 45.10"W	N34° 43' 14.51"W	Incurve
115	Spiral-Curve-Spiral	28224.562	28252.743	28.181	250.000m			6.4586 (d)	N34° 43' 14.51"W	N28° 15' 43.41"W	
116	Spiral-Curve-Spiral	28252.743	28272.743	20		70.711m		2.2918 (d)	N28° 15' 43.41"W	N25° 58' 12.82"W	Outcurve
117	Line	28272.743	28476.952	204.209			N25° 58' 12.82"W				
118	Spiral-Curve-Spiral	28476.952	28496.952	20		70.711m		2.2918 (d)	N25° 58' 12.82"W	N28° 15' 43.41"W	Incurve
119	Spiral-Curve-Spiral	28496.952	28559.873	62.921	250.000m			14.4203 (d)	N28° 15' 43.41"W	N42° 40' 56.63"W	
120	Spiral-Curve-Spiral	28559.873	28579.873	20		70.711m		2.2918 (d)	N42° 40' 56.63"W	N44° 58' 27.22"W	Outcurve
121	Line	28579.873	28656.883	77.01			N44° 58' 27.22"W				
122	Spiral-Curve-Spiral	28656.883	28686.883	30		77.460m		4.2972 (d)	N44° 58' 27.22"W	N40° 40' 37.36"W	Incurve
123	Spiral-Curve-Spiral	28686.883	28714.261	27.378	200.000m			7.8432 (d)	N40° 40' 37.36"W	N32° 50' 01.97"W	

Horizontal Alignment Report											
S.NO.	Type	Start Station	End Station	Length	Radius	A	Direction	Delta angle	Start Direction	End Direction	Incurve
124	Spiral-Curve-Spiral	28714.261	28744.261	30		77.460m		4.2972 (d)	N32° 50' 01.97"W	N28° 32' 12.11"W	Outcurve
125	Line	28744.261	28825.876	81.615			N28° 32' 12.11"W				
126	Spiral-Curve-Spiral	28825.876	28845.876	20		24.495m		19.0986 (d)	N28° 32' 12.11"W	N47° 38' 07.05"W	Incurve
127	Spiral-Curve-Spiral	28845.876	28913.751	67.875	30.000m			129.6322 (d)	N47° 38' 07.05"W	S2° 43' 56.89"W	
128	Spiral-Curve-Spiral	28913.751	28933.751	20		24.495m		19.0986 (d)	S2° 43' 56.89"W	S16° 21' 58.05"E	Outcurve
129	Line	28933.751	29045.552	111.801			S16° 21' 58.05"E				
130	Spiral-Curve-Spiral	29045.552	29065.552	20		54.772m		3.8197 (d)	S16° 21' 58.05"E	S20° 11' 09.03"E	Incurve
131	Spiral-Curve-Spiral	29065.552	29137.577	72.025	150.000m			27.5116 (d)	S20° 11' 09.03"E	S47° 41' 50.68"E	
132	Spiral-Curve-Spiral	29137.577	29157.577	20		54.772m		3.8197 (d)	S47° 41' 50.68"E	S51° 31' 01.67"E	Outcurve
133	Line	29157.577	29223.097	65.52			S51° 31' 01.67"E				
134	Spiral-Curve-Spiral	29223.097	29243.097	20		63.246m		2.8648 (d)	S51° 31' 01.67"E	S48° 39' 08.43"E	Incurve
135	Spiral-Curve-Spiral	29243.097	29405.426	162.328	200.000m			46.5036 (d)	S48° 39' 08.43"E	S2° 08' 55.29"E	
136	Spiral-Curve-Spiral	29405.426	29425.426	20		63.246m		2.8648 (d)	S2° 08' 55.29"E	S0° 42' 57.95"W	Outcurve
137	Line	29425.426	29497.829	72.403			S0° 42' 57.95"W				
138	Spiral-Curve-Spiral	29497.829	29517.829	20		44.721m		5.7296 (d)	S0° 42' 57.95"W	S6° 26' 44.43"W	Incurve
139	Spiral-Curve-Spiral	29517.829	29664.023	146.194	100.000m			83.7631 (d)	S6° 26' 44.43"W	N89° 47' 28.43"W	
140	Spiral-Curve-Spiral	29664.023	29684.023	20		44.721m		5.7296 (d)	N89° 47' 28.43"W	N84° 03' 41.95"W	Outcurve
141	Line	29684.023	29915.39	231.366			N84° 03' 41.95"W				
142	Spiral-Curve-Spiral	29915.39	29935.39	20		24.495m		19.0986 (d)	N84° 03' 41.95"W	N64° 57' 47.01"W	Incurve
143	Spiral-Curve-Spiral	29935.39	30005.846	70.456	30.000m			134.5613 (d)	N64° 57' 47.01"W	N69° 35' 53.79"E	
144	Spiral-Curve-Spiral	30005.846	30025.846	20		24.495m		19.0986 (d)	N69° 35' 53.79"E	N88° 41' 48.72"E	Outcurve
145	Line	30025.846	30170.071	144.226			N88° 41' 48.72"E				
146	Spiral-Curve-Spiral	30170.071	30190.071	20		40.000m		7.1620 (d)	N88° 41' 48.72"E	N81° 32' 05.62"E	Incurve
147	Spiral-Curve-Spiral	30190.071	30357.508	167.436	80.000m			119.9175 (d)	N81° 32' 05.62"E	N38° 22' 57.38"W	
148	Spiral-Curve-Spiral	30357.508	30377.508	20		40.000m		7.1620 (d)	N38° 22' 57.38"W	N45° 32' 40.48"W	Outcurve
149	Line	30377.508	30649.795	272.287			N45° 32' 40.48"W				
150	Spiral-Curve-Spiral	30649.795	30669.795	20		44.721m		5.7296 (d)	N45° 32' 40.48"W	N51° 16' 26.96"W	Incurve
151	Spiral-Curve-Spiral	30669.795	30727.166	57.371	100.000m			32.8713 (d)	N51° 16' 26.96"W	N84° 08' 43.81"W	
152	Spiral-Curve-Spiral	30727.166	30747.166	20		44.721m		5.7296 (d)	N84° 08' 43.81"W	N89° 52' 30.29"W	Outcurve
153	Line	30747.166	30800	52.834			N89° 52' 30.29"W				

VERTICAL ALIGNMENT REPORT

Vertical Alignment Report									
No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value	Curve Radius
1	20598.384m	188.518m	-5.22%	0.00%	5.22%	Sag	50.710m	9.717	971.661m
2	20781.673m	188.518m	0.00%	6.88%	6.88%	Sag	64.055m	8.128	812.814m
3	22000.000m	287.880m	6.88%						
4	22000.00m	289.520m		6.56%					
5	23833.949m	409.781m	6.56%	0.00%	6.56%	Crest	100.000m	15.25	1524.975m
6	23974.455m	409.781m	0.00%	5.25%	5.25%	Sag	100.000m	19.053	1905.314m
7	26265.700m	530.036m	5.25%	6.50%	1.25%	Sag	300.000m	239.708	23970.814m
8	32650.507m	945.049m	6.50%	-1.16%	7.66%	Crest	300.000m	39.16	3916.009m

PCL COORDINATES

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
20500	2,771,723.3439m	547,768.6770m	S54° 25' 34.06"W
20525	2,771,708.8001m	547,748.3428m	S54° 25' 34.06"W
20550	2,771,694.3170m	547,727.9660m	S55° 53' 04.23"W
20575	2,771,683.4228m	547,705.6115m	S75° 53' 55.74"W
20600	2,771,683.5190m	547,680.8713m	N75° 27' 11.86"W
20625	2,771,695.4576m	547,659.1997m	N47° 10' 11.88"W
20650	2,771,714.8700m	547,643.5306m	N34° 37' 50.94"W
20675	2,771,735.4426m	547,629.3262m	N34° 37' 23.56"W
20700	2,771,756.0153m	547,615.1217m	N34° 37' 23.56"W
20725	2,771,776.5879m	547,600.9173m	N34° 37' 23.56"W
20750	2,771,797.1606m	547,586.7129m	N34° 37' 23.56"W
20775	2,771,817.7332m	547,572.5084m	N34° 37' 23.56"W
20800	2,771,838.3059m	547,558.3040m	N34° 37' 23.56"W
20825	2,771,858.8786m	547,544.0996m	N34° 37' 23.56"W
20850	2,771,879.4512m	547,529.8952m	N34° 37' 23.56"W
20875	2,771,900.0239m	547,515.6907m	N34° 37' 23.56"W
20900	2,771,920.5965m	547,501.4863m	N34° 37' 23.56"W
20925	2,771,941.2223m	547,487.3598m	N33° 25' 28.65"W
20950	2,771,962.8855m	547,474.9282m	N24° 59' 02.63"W
20975	2,771,986.4477m	547,466.6979m	N13° 31' 29.67"W
21000	2,772,011.1754m	547,463.3126m	N2° 03' 56.71"W
21025	2,772,036.0828m	547,464.9075m	N9° 23' 36.26"E
21050	2,772,060.1768m	547,471.4190m	N20° 51' 09.22"E
21075	2,772,082.5706m	547,482.4598m	N30° 41' 52.80"E
21100	2,772,103.6514m	547,495.8947m	N33° 08' 14.97"E
21125	2,772,124.7322m	547,509.3310m	N31° 16' 26.49"E
21150	2,772,146.4150m	547,521.7698m	N28° 24' 33.25"E
21175	2,772,168.6924m	547,533.1094m	N25° 32' 40.01"E
21200	2,772,191.5088m	547,543.3214m	N22° 40' 46.77"E
21225	2,772,214.8070m	547,552.3803m	N19° 48' 53.53"E
21250	2,772,238.5288m	547,560.2635m	N16° 57' 00.29"E
21275	2,772,262.6150m	547,566.9512m	N14° 05' 07.05"E

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
21300	2,772,287.0025m	547,572.4405m	N11° 32' 36.23"E
21325	2,772,311.4998m	547,577.4285m	N11° 30' 28.04"E
21350	2,772,335.9975m	547,582.4150m	N11° 27' 01.80"E
21375	2,772,360.5953m	547,586.8682m	N8° 51' 12.99"E
21400	2,772,385.3642m	547,590.2534m	N7° 23' 20.66"E
21425	2,772,410.1566m	547,593.4685m	N7° 23' 20.66"E
21450	2,772,434.9490m	547,596.6837m	N7° 23' 20.66"E
21475	2,772,459.7414m	547,599.8989m	N7° 23' 20.66"E
21500	2,772,484.5338m	547,603.1140m	N7° 23' 20.66"E
21525	2,772,509.3710m	547,605.9303m	N4° 09' 27.08"E
21550	2,772,534.3535m	547,606.1817m	N3° 00' 16.02"W
21575	2,772,559.1724m	547,603.3164m	N10° 09' 59.12"W
21600	2,772,583.4404m	547,597.3793m	N17° 19' 42.22"W
21625	2,772,606.7788m	547,588.4628m	N24° 29' 25.32"W
21650	2,772,628.8235m	547,576.7062m	N31° 39' 08.43"W
21675	2,772,649.3575m	547,562.4618m	N36° 41' 59.40"W
21700	2,772,669.3877m	547,547.5021m	N36° 45' 24.08"W
21725	2,772,689.4173m	547,532.5416m	N36° 45' 24.08"W
21750	2,772,709.4469m	547,517.5812m	N36° 45' 24.08"W
21775	2,772,729.4765m	547,502.6207m	N36° 45' 24.08"W
21800	2,772,749.5061m	547,487.6603m	N36° 45' 24.08"W
21825	2,772,769.4106m	547,472.5361m	N38° 46' 26.62"W
21850	2,772,787.6805m	547,455.5148m	N48° 14' 23.45"W
21875	2,772,802.3614m	547,435.3309m	N59° 41' 56.41"W
21900	2,772,812.7398m	547,412.6327m	N71° 09' 29.37"W
21925	2,772,818.4019m	547,388.3251m	N82° 37' 02.34"W
21950	2,772,819.4937m	547,363.2649m	S86° 45' 08.88"W
21975	2,772,818.0775m	547,338.3051m	S86° 45' 08.88"W
22000	2,772,816.6612m	547,313.3452m	S86° 45' 08.88"W
22025	2,772,814.1619m	547,288.4932m	S78° 37' 58.59"W
22050	2,772,805.5546m	547,265.1127m	S62° 54' 17.99"W
22075	2,772,793.6699m	547,243.1190m	S62° 11' 49.07"W

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
22100	2,772,784.1349m	547,220.0707m	S75° 22' 20.78"W
22125	2,772,781.9322m	547,195.2840m	N85° 31' 44.29"W
22150	2,772,787.9609m	547,171.1409m	N66° 25' 49.35"W
22175	2,772,800.7810m	547,149.7338m	N54° 21' 50.25"W
22200	2,772,815.5205m	547,129.5411m	N53° 49' 34.36"W
22225	2,772,830.2764m	547,109.3604m	N53° 49' 34.36"W
22250	2,772,845.0323m	547,089.1796m	N53° 49' 34.36"W
22275	2,772,859.7882m	547,068.9988m	N53° 49' 34.36"W
22300	2,772,874.5441m	547,048.8181m	N53° 49' 34.36"W
22325	2,772,890.0560m	547,029.2799m	N40° 08' 55.04"W
22350	2,772,913.3658m	547,022.4745m	N7° 35' 52.30"E
22375	2,772,934.8005m	547,034.4327m	N41° 26' 15.26"E
22400	2,772,953.4491m	547,051.0807m	N43° 58' 29.92"E
22425	2,772,967.4696m	547,071.5087m	N69° 24' 39.01"E
22450	2,772,970.1701m	547,096.1014m	S82° 00' 04.27"E
22475	2,772,963.5351m	547,120.1716m	S72° 24' 51.43"E
22500	2,772,959.3878m	547,144.6746m	N87° 07' 17.57"E
22525	2,772,966.7047m	547,168.3083m	N58° 28' 25.17"E
22550	2,772,983.9476m	547,186.2096m	N38° 15' 30.37"E
22575	2,773,003.6383m	547,201.6134m	N38° 01' 36.66"E
22600	2,773,023.3313m	547,217.0142m	N38° 01' 36.66"E
22625	2,773,043.0244m	547,232.4150m	N38° 01' 36.66"E
22650	2,773,062.7174m	547,247.8157m	N38° 01' 36.66"E
22675	2,773,082.4105m	547,263.2165m	N38° 01' 36.66"E
22700	2,773,102.1036m	547,278.6173m	N38° 01' 36.66"E
22725	2,773,121.7966m	547,294.0180m	N38° 01' 36.66"E
22750	2,773,141.4897m	547,309.4188m	N38° 01' 36.66"E
22775	2,773,161.1827m	547,324.8196m	N38° 01' 36.66"E
22800	2,773,180.8758m	547,340.2203m	N38° 01' 36.66"E
22825	2,773,200.5688m	547,355.6211m	N38° 01' 36.66"E
22850	2,773,220.2619m	547,371.0219m	N38° 01' 36.66"E
22875	2,773,239.9550m	547,386.4225m	N38° 00' 36.38"E

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
22900	2,773,260.0653m	547,401.2630m	N33° 30' 53.95"E
22925	2,773,281.9456m	547,413.2967m	N24° 02' 18.02"E
22950	2,773,305.5186m	547,421.5351m	N14° 29' 20.55"E
22975	2,773,330.1316m	547,425.7486m	N4° 56' 23.09"E
23000	2,773,355.1026m	547,425.8205m	N4° 36' 34.38"W
23025	2,773,379.7395m	547,421.7489m	N14° 09' 31.85"W
23050	2,773,403.3595m	547,413.6465m	N23° 42' 29.32"W
23075	2,773,425.3081m	547,401.7380m	N33° 15' 26.79"W
23100	2,773,444.9770m	547,386.3532m	N42° 48' 24.25"W
23125	2,773,461.8210m	547,367.9187m	N52° 21' 21.72"W
23150	2,773,475.3734m	547,346.9452m	N61° 54' 19.19"W
23175	2,773,485.5295m	547,324.1191m	N68° 56' 26.65"W
23200	2,773,494.2824m	547,300.7015m	N69° 35' 37.71"W
23225	2,773,502.9992m	547,277.2704m	N69° 35' 37.71"W
23250	2,773,511.7161m	547,253.8393m	N69° 35' 37.71"W
23275	2,773,520.4329m	547,230.4082m	N69° 35' 37.71"W
23300	2,773,529.1497m	547,206.9771m	N69° 35' 37.71"W
23325	2,773,537.8687m	547,183.5468m	N69° 30' 09.72"W
23350	2,773,547.2373m	547,160.3744m	N65° 28' 32.48"W
23375	2,773,559.0063m	547,138.3362m	N58° 18' 56.24"W
23400	2,773,573.1282m	547,117.7148m	N53° 51' 52.99"W
23425	2,773,587.9293m	547,097.5671m	N53° 40' 58.35"W
23450	2,773,602.7357m	547,077.4233m	N53° 40' 58.35"W
23475	2,773,617.5420m	547,057.2796m	N53° 40' 58.35"W
23500	2,773,632.3484m	547,037.1358m	N53° 40' 58.35"W
23525	2,773,647.1547m	547,016.9920m	N53° 40' 58.35"W
23550	2,773,661.9611m	546,996.8482m	N53° 40' 58.35"W
23575	2,773,676.7701m	546,976.7064m	N53° 33' 23.87"W
23600	2,773,692.3195m	546,957.1428m	N48° 09' 36.99"W
23625	2,773,710.4666m	546,939.9894m	N38° 36' 46.38"W
23650	2,773,731.2079m	546,926.0843m	N29° 03' 48.91"W
23675	2,773,753.9686m	546,915.8127m	N19° 30' 51.44"W

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
23700	2,773,778.1180m	546,909.4594m	N9° 57' 53.97"W
23725	2,773,802.9865m	546,907.1941m	N0° 36' 36.15"W
23750	2,773,827.9670m	546,908.0486m	N3° 12' 12.26"E
23775	2,773,852.9279m	546,909.4456m	N3° 12' 12.26"E
23800	2,773,877.8889m	546,910.8426m	N3° 12' 12.26"E
23825	2,773,902.8498m	546,912.2396m	N3° 12' 12.26"E
23850	2,773,927.8107m	546,913.6367m	N3° 12' 12.26"E
23875	2,773,952.7717m	546,915.0337m	N3° 12' 12.26"E
23900	2,773,977.7326m	546,916.4307m	N3° 12' 12.26"E
23925	2,774,002.6935m	546,917.8277m	N3° 12' 12.26"E
23950	2,774,027.6545m	546,919.2247m	N3° 12' 12.26"E
23975	2,774,052.6154m	546,920.6218m	N3° 12' 12.26"E
24000	2,774,077.5764m	546,922.0188m	N3° 12' 12.26"E
24025	2,774,102.5373m	546,923.4158m	N3° 12' 12.26"E
24050	2,774,127.4982m	546,924.8128m	N3° 12' 12.26"E
24075	2,774,152.4592m	546,926.2098m	N3° 12' 12.26"E
24100	2,774,177.4201m	546,927.6069m	N3° 12' 12.26"E
24125	2,774,202.3811m	546,929.0025m	N3° 04' 11.76"E
24150	2,774,226.9252m	546,925.9379m	N24° 18' 29.69"W
24175	2,774,244.2984m	546,908.7030m	N65° 14' 01.69"W
24200	2,774,246.1348m	546,884.3000m	S73° 50' 26.30"W
24225	2,774,231.5364m	546,864.6592m	S32° 54' 54.30"W
24250	2,774,207.9575m	546,856.8279m	S11° 53' 28.81"W
24275	2,774,183.4940m	546,851.6765m	S11° 53' 28.81"W
24300	2,774,159.0305m	546,846.5251m	S11° 53' 28.81"W
24325	2,774,134.5670m	546,841.3737m	S11° 53' 28.81"W
24350	2,774,110.1035m	546,836.2223m	S11° 53' 28.81"W
24375	2,774,085.6400m	546,831.0708m	S11° 53' 28.81"W
24400	2,774,061.1765m	546,825.9194m	S11° 53' 28.81"W
24425	2,774,036.7130m	546,820.7680m	S11° 53' 28.81"W
24450	2,774,012.2495m	546,815.6166m	S11° 53' 28.81"W
24475	2,773,987.7860m	546,810.4652m	S11° 53' 28.81"W

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
24500	2,773,963.3225m	546,805.3138m	S11° 53' 28.81"W
24525	2,773,938.8590m	546,800.1624m	S11° 53' 28.81"W
24550	2,773,914.3955m	546,795.0110m	S11° 53' 28.81"W
24575	2,773,889.9320m	546,789.8596m	S11° 53' 28.81"W
24600	2,773,865.4685m	546,784.7082m	S11° 53' 28.81"W
24625	2,773,841.0050m	546,779.5568m	S11° 53' 28.81"W
24650	2,773,816.5415m	546,774.4054m	S11° 53' 28.81"W
24675	2,773,792.0396m	546,769.4456m	S9° 57' 43.35"W
24700	2,773,767.2023m	546,766.8231m	S1° 25' 19.54"W
24725	2,773,742.2739m	546,768.2834m	S8° 07' 37.93"E
24750	2,773,717.8873m	546,773.6936m	S15° 54' 24.24"E
24775	2,773,693.9592m	546,780.9345m	S17° 02' 14.65"E
24800	2,773,670.0564m	546,788.2594m	S17° 02' 14.65"E
24825	2,773,646.1536m	546,795.5843m	S17° 02' 14.65"E
24850	2,773,622.2507m	546,802.9092m	S17° 02' 14.65"E
24875	2,773,598.3479m	546,810.2341m	S17° 02' 14.65"E
24900	2,773,574.4450m	546,817.5590m	S17° 02' 14.65"E
24925	2,773,550.4899m	546,824.7042m	S14° 19' 59.61"E
24950	2,773,525.7434m	546,826.7652m	S8° 03' 25.94"W
24975	2,773,502.8667m	546,817.3449m	S36° 42' 18.34"W
25000	2,773,487.3068m	546,798.1101m	S65° 21' 10.74"W
25025	2,773,482.5523m	546,773.7772m	N89° 52' 38.95"W
25050	2,773,484.2371m	546,748.8410m	N85° 08' 24.03"W
25075	2,773,486.3551m	546,723.9309m	N85° 08' 24.03"W
25100	2,773,488.4732m	546,699.0208m	N85° 08' 24.03"W
25125	2,773,490.5912m	546,674.1107m	N85° 08' 24.03"W
25150	2,773,492.7092m	546,649.2006m	N85° 08' 24.03"W
25175	2,773,494.8272m	546,624.2905m	N85° 08' 24.03"W
25200	2,773,496.9453m	546,599.3803m	N85° 08' 24.03"W
25225	2,773,499.0633m	546,574.4702m	N85° 08' 24.03"W
25250	2,773,501.1813m	546,549.5601m	N85° 08' 24.03"W
25275	2,773,503.2994m	546,524.6500m	N85° 08' 24.03"W

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
25300	2,773,505.4174m	546,499.7399m	N85° 08' 24.03"W
25325	2,773,507.5354m	546,474.8298m	N85° 08' 24.03"W
25350	2,773,509.8472m	546,449.9400m	N81° 22' 15.93"W
25375	2,773,521.0964m	546,428.2927m	N39° 31' 25.65"W
25400	2,773,544.4789m	546,421.7420m	N8° 13' 21.69"E
25425	2,773,565.0504m	546,434.6444m	N55° 58' 09.02"E
25450	2,773,571.4993m	546,458.4927m	N84° 51' 48.88"E
25475	2,773,573.7371m	546,483.3924m	N84° 51' 51.77"E
25500	2,773,575.9749m	546,508.2920m	N84° 51' 51.77"E
25525	2,773,578.2128m	546,533.1916m	N84° 51' 51.77"E
25550	2,773,580.4506m	546,558.0913m	N84° 51' 51.77"E
25575	2,773,582.6885m	546,582.9909m	N84° 51' 51.77"E
25600	2,773,585.5196m	546,607.8161m	N78° 08' 56.13"E
25625	2,773,596.2049m	546,630.1343m	N50° 07' 51.69"E
25650	2,773,616.2692m	546,644.6088m	N21° 28' 59.28"E
25675	2,773,640.8186m	546,647.7124m	N6° 27' 38.89"W
25700	2,773,665.2916m	546,642.6693m	N12° 56' 36.69"W
25725	2,773,689.6564m	546,637.0696m	N12° 56' 36.69"W
25750	2,773,714.0212m	546,631.4698m	N12° 56' 36.69"W
25775	2,773,738.3860m	546,625.8700m	N12° 56' 36.69"W
25800	2,773,762.7508m	546,620.2703m	N12° 56' 36.69"W
25825	2,773,787.1155m	546,614.6705m	N12° 56' 36.69"W
25850	2,773,811.4803m	546,609.0707m	N12° 56' 36.69"W
25875	2,773,835.8451m	546,603.4710m	N12° 56' 36.69"W
25900	2,773,860.2914m	546,598.2585m	N9° 24' 27.14"W
25925	2,773,885.1477m	546,595.6673m	N4° 21' 37.15"W
25950	2,773,910.0753m	546,593.7666m	N4° 21' 37.15"W
25975	2,773,935.0030m	546,591.8659m	N4° 21' 37.15"W
26000	2,773,959.9306m	546,589.9652m	N4° 21' 37.15"W
26025	2,773,984.8583m	546,588.0645m	N4° 21' 37.15"W
26050	2,774,009.7859m	546,586.1637m	N4° 21' 37.15"W
26075	2,774,034.7136m	546,584.2630m	N4° 21' 37.15"W

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
26100	2,774,059.6313m	546,582.2479m	N6° 18' 44.80"W
26125	2,774,083.6276m	546,575.7821m	N27° 24' 17.03"W
26150	2,774,102.0915m	546,559.3148m	N56° 03' 09.43"W
26175	2,774,111.6588m	546,536.3432m	N74° 49' 54.16"W
26200	2,774,117.8156m	546,512.1133m	N75° 50' 26.38"W
26225	2,774,123.9311m	546,487.8729m	N75° 50' 26.38"W
26250	2,774,130.0466m	546,463.6324m	N75° 50' 26.38"W
26275	2,774,136.1621m	546,439.3919m	N75° 50' 26.38"W
26300	2,774,142.2776m	546,415.1514m	N75° 50' 26.38"W
26325	2,774,148.6403m	546,390.9773m	N72° 59' 31.25"W
26350	2,774,158.7454m	546,368.1979m	N57° 36' 52.96"W
26375	2,774,175.1907m	546,349.5034m	N39° 42' 35.20"W
26400	2,774,196.5819m	546,336.7586m	N22° 11' 19.81"W
26425	2,774,220.4197m	546,329.2813m	N15° 07' 26.37"W
26450	2,774,244.5538m	546,322.7586m	N15° 07' 26.37"W
26475	2,774,268.6879m	546,316.2359m	N15° 07' 26.37"W
26500	2,774,292.8220m	546,309.7132m	N15° 07' 26.37"W
26525	2,774,316.9561m	546,303.1904m	N15° 07' 26.37"W
26550	2,774,341.0902m	546,296.6677m	N15° 07' 26.37"W
26575	2,774,365.0985m	546,289.7461m	N23° 01' 46.28"W
26600	2,774,381.7133m	546,272.0370m	N70° 41' 54.37"W
26625	2,774,379.7778m	546,247.8313m	S61° 33' 18.30"W
26650	2,774,360.5603m	546,232.9866m	S13° 58' 03.91"W
26675	2,774,335.7890m	546,229.6967m	S6° 43' 29.71"W
26700	2,774,310.9610m	546,226.7691m	S6° 43' 29.71"W
26725	2,774,286.1325m	546,223.8462m	S6° 32' 26.12"W
26750	2,774,261.2005m	546,222.2741m	S0° 40' 58.30"E
26775	2,774,236.3426m	546,224.6491m	S10° 13' 55.76"E
26800	2,774,212.2232m	546,231.1149m	S19° 46' 53.23"E
26825	2,774,189.5106m	546,241.4925m	S29° 19' 50.70"E
26850	2,774,168.8344m	546,255.4942m	S38° 52' 48.17"E
26875	2,774,150.5106m	546,272.4809m	S45° 06' 53.29"E

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
26900	2,774,132.8738m	546,290.1994m	S45° 07' 57.75"E
26925	2,774,115.2371m	546,307.9180m	S45° 07' 57.75"E
26950	2,774,097.6005m	546,325.6365m	S45° 07' 57.75"E
26975	2,774,079.9638m	546,343.3551m	S45° 07' 57.75"E
27000	2,774,062.3271m	546,361.0737m	S45° 07' 57.75"E
27025	2,774,044.6462m	546,378.7477m	S44° 05' 48.63"E
27050	2,774,025.5394m	546,394.8300m	S35° 25' 29.38"E
27075	2,774,004.0569m	546,407.5601m	S25° 52' 31.91"E
27100	2,773,980.7601m	546,416.5500m	S16° 19' 34.44"E
27125	2,773,956.3804m	546,422.0363m	S10° 52' 03.37"E
27150	2,773,931.8287m	546,426.7498m	S10° 52' 03.37"E
27175	2,773,907.2771m	546,431.4633m	S10° 52' 03.37"E
27200	2,773,882.7255m	546,436.1768m	S10° 52' 03.37"E
27225	2,773,858.1475m	546,440.7447m	S8° 46' 02.37"E
27250	2,773,833.2304m	546,441.7907m	S4° 39' 52.89"W
27275	2,773,808.8248m	546,436.6802m	S18° 59' 19.09"W
27300	2,773,786.4422m	546,425.6906m	S33° 18' 45.29"W
27325	2,773,767.4743m	546,409.5050m	S47° 38' 11.49"W
27350	2,773,753.1005m	546,389.1299m	S61° 57' 37.70"W
27375	2,773,744.2137m	546,365.8323m	S76° 13' 46.15"W
27400	2,773,739.7752m	546,341.2367m	S80° 53' 31.14"W
27425	2,773,735.8178m	546,316.5519m	S80° 53' 31.14"W
27450	2,773,731.8604m	546,291.8671m	S80° 53' 31.14"W
27475	2,773,727.9030m	546,267.1823m	S80° 53' 31.14"W
27500	2,773,723.9456m	546,242.4975m	S80° 53' 31.14"W
27525	2,773,719.9882m	546,217.8128m	S80° 53' 31.14"W
27550	2,773,716.0308m	546,193.1280m	S80° 53' 31.14"W
27575	2,773,712.0734m	546,168.4432m	S80° 53' 31.14"W
27600	2,773,708.1160m	546,143.7584m	S80° 53' 31.14"W
27625	2,773,705.4715m	546,118.9573m	N85° 36' 44.02"W
27650	2,773,716.7967m	546,097.4733m	N38° 21' 03.25"W
27675	2,773,740.3084m	546,091.4025m	N9° 23' 44.09"E

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
27700	2,773,760.6115m	546,104.7233m	N57° 08' 31.43"E
27725	2,773,768.0173m	546,128.4318m	N78° 50' 54.25"E
27750	2,773,772.8524m	546,152.9597m	N78° 50' 54.25"E
27775	2,773,777.6876m	546,177.4877m	N78° 50' 54.25"E
27800	2,773,782.5227m	546,202.0157m	N78° 50' 54.25"E
27825	2,773,787.3578m	546,226.5436m	N78° 50' 54.25"E
27850	2,773,792.1930m	546,251.0716m	N78° 50' 54.25"E
27875	2,773,797.4867m	546,275.4969m	N73° 57' 34.33"E
27900	2,773,807.9253m	546,298.1022m	N56° 16' 15.35"E
27925	2,773,824.8045m	546,316.4058m	N38° 21' 57.60"E
27950	2,773,846.4934m	546,328.6336m	N20° 27' 39.85"E
27975	2,773,870.8913m	546,333.6013m	N2° 33' 22.10"E
28000	2,773,895.6347m	546,330.8274m	N15° 20' 55.66"W
28025	2,773,918.3329m	546,320.5903m	N32° 50' 58.03"W
28050	2,773,938.5113m	546,305.8402m	N37° 00' 45.10"W
28075	2,773,958.4739m	546,290.7905m	N37° 00' 45.10"W
28100	2,773,978.4365m	546,275.7407m	N37° 00' 45.10"W
28125	2,773,998.3991m	546,260.6910m	N37° 00' 45.10"W
28150	2,774,018.3617m	546,245.6413m	N37° 00' 45.10"W
28175	2,774,038.3243m	546,230.5915m	N37° 00' 45.10"W
28200	2,774,058.2869m	546,215.5418m	N37° 00' 45.10"W
28225	2,774,078.4179m	546,200.7214m	N34° 37' 13.25"W
28250	2,774,099.6666m	546,187.5695m	N28° 53' 26.77"W
28275	2,774,121.9653m	546,176.2727m	N25° 58' 12.82"W
28300	2,774,144.4408m	546,165.3250m	N25° 58' 12.82"W
28325	2,774,166.9164m	546,154.3774m	N25° 58' 12.82"W
28350	2,774,189.3919m	546,143.4298m	N25° 58' 12.82"W
28375	2,774,211.8675m	546,132.4822m	N25° 58' 12.82"W
28400	2,774,234.3430m	546,121.5346m	N25° 58' 12.82"W
28425	2,774,256.8186m	546,110.5870m	N25° 58' 12.82"W
28450	2,774,279.2941m	546,099.6394m	N25° 58' 12.82"W
28475	2,774,301.7696m	546,088.6918m	N25° 58' 12.82"W

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
28500	2,774,324.0611m	546,077.3811m	N28° 57' 37.91"W
28525	2,774,345.2938m	546,064.2033m	N34° 41' 24.39"W
28550	2,774,365.1048m	546,048.9716m	N40° 25' 10.88"W
28575	2,774,383.3776m	546,031.9200m	N44° 50' 17.44"W
28600	2,774,401.0659m	546,014.2530m	N44° 58' 27.22"W
28625	2,774,418.7515m	545,996.5833m	N44° 58' 27.22"W
28650	2,774,436.4371m	545,978.9136m	N44° 58' 27.22"W
28675	2,774,454.2385m	545,961.3617m	N43° 24' 25.39"W
28700	2,774,473.2680m	545,945.1700m	N36° 55' 09.40"W
28725	2,774,494.1229m	545,931.4098m	N30° 18' 28.71"W
28750	2,774,515.9893m	545,919.2933m	N28° 32' 12.11"W
28775	2,774,537.9520m	545,907.3503m	N28° 32' 12.11"W
28800	2,774,559.9148m	545,895.4072m	N28° 32' 12.11"W
28825	2,774,581.8776m	545,883.4642m	N28° 32' 12.11"W
28850	2,774,601.5310m	545,868.4318m	N55° 30' 42.80"W
28875	2,774,606.0041m	545,844.5645m	S76° 44' 29.86"W
28900	2,774,591.3458m	545,825.2049m	S28° 59' 42.52"W
28925	2,774,567.0807m	545,822.6505m	S12° 42' 34.60"E
28950	2,774,543.0447m	545,829.5153m	S16° 21' 58.05"E
28975	2,774,519.0577m	545,836.5596m	S16° 21' 58.05"E
29000	2,774,495.0706m	545,843.6040m	S16° 21' 58.05"E
29025	2,774,471.0836m	545,850.6483m	S16° 21' 58.05"E
29050	2,774,447.0980m	545,857.6974m	S16° 33' 18.22"E
29075	2,774,423.5493m	545,866.0358m	S23° 47' 41.07"E
29100	2,774,401.6187m	545,877.9776m	S33° 20' 38.54"E
29125	2,774,381.9731m	545,893.3920m	S42° 53' 36.01"E
29150	2,774,365.0744m	545,911.7847m	S50° 58' 08.00"E
29175	2,774,349.4985m	545,931.3395m	S51° 31' 01.67"E
29200	2,774,333.9415m	545,950.9094m	S51° 31' 01.67"E
29225	2,774,318.3843m	545,970.4790m	S51° 29' 28.32"E
29250	2,774,302.2165m	545,989.5366m	S46° 40' 29.44"E
29275	2,774,283.9725m	546,006.6054m	S39° 30' 46.34"E

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
29300	2,774,263.7428m	546,021.2664m	S32° 21' 03.24"E
29325	2,774,241.8431m	546,033.2909m	S25° 11' 20.14"E
29350	2,774,218.6151m	546,042.4913m	S18° 01' 37.04"E
29375	2,774,194.4213m	546,048.7239m	S10° 51' 53.94"E
29400	2,774,169.6391m	546,051.8915m	S3° 42' 10.83"E
29425	2,774,144.6487m	546,052.2571m	S0° 42' 53.28"W
29450	2,774,119.6507m	546,051.9446m	S0° 42' 57.95"W
29475	2,774,094.6527m	546,051.6322m	S0° 42' 57.95"W
29500	2,774,069.6546m	546,051.3189m	S0° 47' 00.98"W
29525	2,774,044.7646m	546,049.3713m	S10° 33' 15.59"W
29550	2,774,021.0122m	546,041.7835m	S24° 52' 41.79"W
29575	2,773,999.8754m	546,028.5552m	S39° 12' 07.99"W
29600	2,773,982.6685m	546,010.5087m	S53° 31' 34.19"W
29625	2,773,970.4613m	545,988.7663m	S67° 51' 00.40"W
29650	2,773,964.0128m	545,964.6796m	S82° 10' 26.60"W
29675	2,773,963.6139m	545,939.7378m	N85° 13' 40.39"W
29700	2,773,966.1395m	545,914.8660m	N84° 03' 41.95"W
29725	2,773,968.7259m	545,890.0002m	N84° 03' 41.95"W
29750	2,773,971.3124m	545,865.1343m	N84° 03' 41.95"W
29775	2,773,973.8988m	545,840.2685m	N84° 03' 41.95"W
29800	2,773,976.4853m	545,815.4027m	N84° 03' 41.95"W
29825	2,773,979.0717m	545,790.5368m	N84° 03' 41.95"W
29850	2,773,981.6582m	545,765.6710m	N84° 03' 41.95"W
29875	2,773,984.2446m	545,740.8051m	N84° 03' 41.95"W
29900	2,773,986.8311m	545,715.9393m	N84° 03' 41.95"W
29925	2,773,989.6621m	545,691.1046m	N79° 39' 06.52"W
29950	2,774,001.7642m	545,669.9433m	N37° 03' 33.40"W
29975	2,774,025.4069m	545,664.4040m	N10° 41' 13.94"E
30000	2,774,045.4045m	545,678.1791m	N58° 26' 01.28"E
30025	2,774,050.5961m	545,702.3037m	N88° 39' 45.77"E
30050	2,774,051.1648m	545,727.2973m	N88° 41' 48.72"E
30075	2,774,051.7334m	545,752.2908m	N88° 41' 48.72"E

Proposed Centre Line Coordinates

Station	Northing	Easting	Tangential Direction
30100	2,774,052.3019m	545,777.2843m	N88° 41' 48.72"E
30125	2,774,052.8705m	545,802.2779m	N88° 41' 48.72"E
30150	2,774,053.4390m	545,827.2714m	N88° 41' 48.72"E
30175	2,774,054.0200m	545,852.2646m	N88° 15' 42.90"E
30200	2,774,057.2482m	545,876.9870m	N74° 25' 26.33"E
30225	2,774,067.5847m	545,899.6384m	N56° 31' 08.58"E
30250	2,774,084.3845m	545,918.0150m	N38° 36' 50.83"E
30275	2,774,106.0202m	545,930.3366m	N20° 42' 33.08"E
30300	2,774,130.3963m	545,935.4098m	N2° 48' 15.33"E
30325	2,774,155.1515m	545,932.7432m	N15° 06' 02.43"W
30350	2,774,177.8879m	545,922.5950m	N33° 00' 20.18"W
30375	2,774,196.8049m	545,906.3344m	N45° 25' 55.13"W
30400	2,774,214.3150m	545,888.4906m	N45° 32' 40.48"W
30425	2,774,231.8238m	545,870.6458m	N45° 32' 40.48"W
30450	2,774,249.3327m	545,852.8009m	N45° 32' 40.48"W
30475	2,774,266.8415m	545,834.9560m	N45° 32' 40.48"W
30500	2,774,284.3504m	545,817.1111m	N45° 32' 40.48"W
30525	2,774,301.8592m	545,799.2662m	N45° 32' 40.48"W
30550	2,774,319.3681m	545,781.4213m	N45° 32' 40.48"W
30575	2,774,336.8769m	545,763.5764m	N45° 32' 40.48"W
30600	2,774,354.3858m	545,745.7315m	N45° 32' 40.48"W
30625	2,774,371.8947m	545,727.8866m	N45° 32' 40.48"W
30650	2,774,389.4035m	545,710.0418m	N45° 32' 42.65"W
30675	2,774,405.9266m	545,691.3163m	N54° 15' 23.22"W
30700	2,774,417.8557m	545,669.4200m	N68° 34' 49.42"W
30725	2,774,423.9967m	545,645.2531m	N82° 54' 15.62"W
30750	2,774,424.9569m	545,620.2885m	N89° 52' 30.29"W
30775	2,774,425.0114m	545,595.2885m	N89° 52' 30.29"W
30800	2,774,425.0660m	545,570.2886m	N89° 52' 30.29"W