[This DBR has been approved by GM/Design/RLDA vide letter No-RLDA/2023/Design unit/DBR correspondence/2863 dated 21.09.2023. The compliance of observation is attached along with DBR in 5 pages.]

STRUCTURAL DESIGN BASIS REPORT
CONCOURSE, FOB AND THROUGH ROOF

"REDEVELOPMENT OF AJNI RAILWAY STATION AT NAGPUR, MAHARASHTRA"

FOR

M/s. KEY STONE INFRA BUILT & GCP (P)Ltd (JV)

CLIENT

RAIL LAND DEVELOPMENT AUTHORITY, NAGPUR

REV NO.	DATE	DESCRIPTION	PREPARED BY	REVIEWED BY
R7	10-08-2023	Preliminary issue	DMS	Amit S.
R8	21-08-2023	Preliminary issue	DMS	Amit S.
R9	27-09-2023	Preliminary issue	DMS	Amit S.

RAJ BAKHTANI Digitally signed by RAJ BAKHTANI Date: 2023.11.09 15:34:03 +05'30'

STRUCTURAL CONSULTANT

STERLING ENGINEERING CONSULTANCY SERVICES PVT. LTD.

6TH Floor, Kohinoor Commercial Tower II, Kohinoor City, Kirol Road, Off L.B.S. Road, Kurla (West), Mumbai-400070.
Telephone: +91-2266744600/01/02/03, Email: adminbkc@sterlingengg.com

Approved By / Countersigned / Countersigned By

Girish Dravid	RAVI NATWARLAL RAMPARIA	Radhey Shyam Jangid 5/10/23 Dr. R. S. JANGID Professor Department of Civil Engineering I.I.T. Bombay, Powai, Mumbai-76			
Girish Dravid Lead Structure Designer - SEC	Ravi Ramparia Lead Detail Designer - KPA	Prof. R.S. Jhangid, Proof Checker, IIT - MUMBAI	Dr. Santosh Kumar Singh StructuralConsultantVoyants Solutions Pvt. Ltd	Authorised Signatory, Authority Engineer, Voyants Solutions Pvt. Ltd	~~Mr. M.P.S. Ghai,~~ JGM/Project RLDA/NGP	Mr. Pawan Patil Chief Project Manager RLDA/NGP

MR. N.S. NEGI

VOYANTS
PARTNERING VISION

CIN-U74140HR2004PTC046918

VSPL/APM/RLDA/NCGA/2223-045/2022-23/COLC-701
Date: 21th Dec 2023

To,
CPM,
RLDA, Nagpur
Ajni Railway Station.

Subject: - Project Management Services for Major Upgradation of Ajni Railway Station.
Reg- "Regarding Approval of structural DBR (R9) for Concourse, FOB, Through Roof & Buildings "

Ref:

1. STR/AJNI/001 Dated: 21.08.2023
2. Contract Agreement No: RLDA/2023/CA-01 of 2023, dated 5th Jan 2023
3. Email sent by contractor on Date 10.05.2023 & 06.04.2023
4. Email sent by PMS Date: 19th April 2023 & 25.04.2023
5. SD/REDEVP/AJNI/RLDA/43 Date: 16th May 2023
6. Email sent by contractor on Date 25.07.2023
7. VSPL/APM/RLDA/NCGA/2223-045/2022-23/CLC-329 Dated 04.09.2023
8. SD/REDEVP/AJNI/RLDA/256A Date :09 th Dec 2023

Dear Sir,

1) In reference to the above correspondence & Agreement Schedule I clause 2.2 Sr No .2 Structure DBR of Fob-Concourse & Building both approved on 21.09.2023 by RLDA HQ with some observation. EPC Contractor submitted the Structural DBR R-9 with compliance of observation given by RLDA HQ.
2) We have reviewed and checked the Structure DBR of Fob-Concourse & Building (R9) along with compliance sheet and found satisfactory as per contract agreement & specification.

3) Therefore, the same is the hereby submitted for your perusal & further process.

With best regards,
For, **Voyants Solutions (P) Limited**

VOYANTS SOLUTIONS PVT. LTD. GURUGRAM

Copy to:
1. JGM/Nagpur,(RLDA)
2. KSIB

KEYSTONE INFRA BUILD

(Formerly known as Hind Himcon Associate)

Letter No: RLDA/AJNI/2023/256A **Date: 09/11/2023**

To,
The Team Leader,
PMS Ajni Works,
Voyants Solutions,

Sub: - Major Up-gradation of Ajni Railway Station of Central on (EPC) Mode.

Regarding submission of Structural DBR-R9

Ref: -

1) **Contract Agreement No. RLDA/2023/CA/01/ of 2023 Date: 05.01.2023**

Dear Sir,

With reference to the above-mentioned subject. As per Ajni Agreement Schedule-I Clause 2.2 Sr. No. 2. "Approval of detailed Design Basis Report of development of Civil". Structural DBR for Building and Concourse & FOB's are approved on 21.09.2023 with observation. We KSIB-GCPPL (JV) are hereby submitting compliance of given observation with revised Structural DBR-R9.

This is for your kind information and necessary action.

Thanking you and assuring you our best professional services at times.

Yours Faithfully,

KEYSTONE INFRA BUILD RAIPUR (C.G.)

Authorized Signatory,
M/S Keystone Infra Build & Globe Civil Projects Pvt. Ltd. (J.V.)

Copy To: CPM/Nagpur, RLDA, Nagpur.

रेल भूमि विकास प्राधिकरण
Rail Land Developement Authority
रेल मंत्रालय,भारत सरकार का सांविधिक प्राधिकरण
(A statutory Authority under Ministry of Railways, Government of India)

सत्यमेव जयते

No. RLDA/2023/Design Unit/DBR Correspondence/2863 **Dated 21.09.2023**

CPM/Nagpur
Rail Land Development Authority

Sub.: Approval of Structural DBR for building work and Air Concourse, FOB & Through Roof for Project "Redevelopment of Ajni Railway Station at Nagpur, Maharashtra".

Ref.: (i) This office letter of even no dated 30.06.2023
(ii) Note#10 of eoffice file no. RLDA/CPM/AJNI/STR_DBR/2023

1. Two structural DBR no. Nil Rev. No. R8 dated 21.08.2023 related to Building work and Air Concourse, FOB & Through Roof along with reply of the observation given vide ref (i) above related to project mentioned in subject was received for approval vide ref. (ii).

2. Submitted structural DBRs were scrutinized in light of reply of observations given vide ref. (i). These DBRs are approved for the structures mentioned in them subject to incorporation of points given in Annexure A for Building DBR and Annexure B for Air Concourse, FOB & Through Roof DBR.

3. Above mentioned DBR has been examined by the Design Unit from codal point of view, based on data provided in the DBRs. Correctness of site-specific details included in DBR and compliance of DBR with contractual/ RLDA requirements have not been examined. Compliance of all requirements as per contract agreement, site conditions and railway requirements may be ensured at your end. Notwithstanding the above approval, the designer shall remain responsible for compliance of design from statutory codal requirements, standards, norms, guidelines, regulations at all times.

This is for your kind information and further necessary action.

DA: As above

21.09.23
(Atul Kumar Verma)
GM/Design/RLDA

Annexure A

Points to be incorporated in Structural DBR no. Nil Rev. No. R8 dated 21.08.2023 related to Buildings

SN	Para / Page No. of Design Basis Report	Points to be incorporated
1.	Page no. 14, Cl. 4 (a), Dead Load	• Dead load of most of the typically used material is given. If any material other than mentioned here is required, then the same may be taken from codal reference/vendor specification, as applicable
2.	Page no. 14-16, Cl. 4 (b), LiveLoad	• As per clause 3.1.2 of Is 875 Part 2, maximum load of 1.5 KN/m2 to be taken for light partition load.
3.	Page No. 20-22 / Cl. 4 (d) Wind loads	• At page 22, inter- storey lateral drift computation i.e. 20 years and acceleration computation i.e. 20 years is not matching with the reference of code given. Kindly check. • IS 873 part 3 is wrongly mentioned in this Section instead of IS 875 Part 3. Kindly rectify the same. • Topographical factor, terrain category and other site related parameters are to be verified/confirmed by the Field unit.
4.	Page 24-26, Clause 7.0, Material of construction	• It is mentioned that the amount of fly ash to be added shall not exceed 35% but as per IS 1489 Part 1, Clause-2 it should not exceed 25%. Kindly provide codal reference for the same. • Instead of providing Modulus Elasticity for various grades of concrete in tabular form, it should be written as 5000√ Fck as per clause 6.2.3.1 of IS 456 2000. • Use of high strength steel of E450 may be verified from weldability point of view. • Quality Assurance Plan (QAP) covering the various stages of Fabrication, Materials & related aspects should be approved from Competent Authority before start of Fabrication work. • Fabrication should be done based on IRS B1.
5.	Page no. 24/ Cl. 6.0 (Durability) and Page no. 27-28/ Cl. 8.0 (Exposure condition)	• Exposure conditions may be different for superstructure and substructure because of soil conditions. Hence, exposure conditions should be decided structure wise and component wise according to its intended function and soil conditions etc. While deciding this soil type and its aggressiveness may be kept in mind. • Field unit to verify that exposure conditions are taken as per the site conditions. Please revise the crack width, concrete cover and other dependent factors accordingly if exposure condition changes. • Fire resistance duration of 2 hrs. is specified. Please verify the same with architectural DBR and other applicable local bye laws, etc. • While deciding the maximum crack width, provision of clause 35.3.2 of IS 456 2000 should be adhered to.

SN	Para / Page No. of Design Basis Report	Points to be incorporated
6.	Page 31/ Cl. 11.0	• Deflection limits of structural steel should be taken as per IS 800.
7.	Page 35, Clause 17.0, Erection Methodology	• Irrelevant description about the erection of structure above track is given here may be replaced with the Erection methodology of the buildings mentioned in this DBR.
8.	Other points to be incorporated/added in DBR at suitable place	• Design of structure during various construction stages considering sequence of construction/ erection and launching along with applicable construction loads need to be done apart from design of final structure considering serviceability and ultimate limit states. • The Geotechnical report and data provided from the geotechnical report may be verified by the Field units.

Annexure B

Points to be incorporated in Structural DBR no. Nil Rev. No. R8 dated 21.08.2023 related to Air Concourse, FOB and Through Roof

SN	Para / Page No. of Design Basis Report	Points to be Incorporated
1.	Page no. 5-9/ Cl 2.0	• In FOB 10 m wide GOB - North side (NGP) and South side (WR), it mentioned that columns are at 18 m * 18 m grid (approximately). How 18m * 18m grid is possible in a 10 m wide FOB. Field unit to check and rectify the same.
2.	Page no. 16-17/ Cl. 4 (a), (b), Dead and Imposed loads	• Dead load of most of the typically used material is given. If any material other than mentioned here is required, then the same may be taken from codal reference/vendor specification. • For FOB the live load is taken based on IRC-6. It again reiterated here that Live load should be taken on the basis of IRS Bridge Rules. • Reference of calculation for AAC Block and its units weight should be suitably incorporated. • As per clause 3.1.2 of Is 875 Part 2, maximum load of 1.5 KN/m2 to be taken for light partition load. • Apart from UDL live load, suitable applicable concentrated loads as per IS 875 Part 2 Table 1(iv) for assembly building should be taken.
3.	Page No. 18-22 / Cl. 4 (c) Seismic loads	• Soil type 1 is considered at Page 20, which implies that soil is Rock/hard soil whereas at Page 7–9, it is written that SBC is 9.5 to 12 T/sqm. Field unit should look into this aspect as generally the SBC of Rock will be higher than this value. • Further, in Building DBR at 3 m below the ground the SBC is 43 T/sqm and in Concourse and FOB DBR at 3 m below the ground the SBC is 9.5 to 12 T/sqm. Feild unit to verify and rectify, the same if there is any discrepancy.
4.	Page No. 19-21 / Cl. 4 (d) Wind loads	• At page 24, inter- storey lateral drift computation i.e. 20 years and acceleration computation i.e. 20 years is not matching with the reference of code given. Kindly check. • IS 873 part 3 is wrongly mentioned in this Section instead of IS 875 Part 3. Kindly rectify the same. • Topographical factor, terrain category and other site related parameters are to be verified/confirmed by the Field unit.
5.	Page no. 24/ Cl 4 (e), Vibration loads	• Structural design related points related to Vibration to be incorporated in the Detailed structural design of structure based on the finding of the vibration study.

SN	Para / Page No. of Design Basis Report	Points to be incorporated
6.	Page 26-27, Clause 7.0, Material of construction	• It is mentioned that the amount of fly ash to be added shall not exceed 35% but as per Is 1489 Part 1, Clause-2 it should not exceed 25%. Kindly provide codal reference for the same. • Instead of providing Modulus Elasticity for various grades of concrete in tabular form, it should be written as 5000√ Fck as per clause 6.2.3.1 of IS 456 2000 • Use of high strength steel of E450 may be verified from weldability point of view. • Quality Assurance Plan (QAP) covering the various stages of Fabrication, Materials & related aspects should be approved from Competent Authority before start of Fabrication work. • It is written in DBR that fabrication shall comply with the requirement of IS 800: 2007. It is to be mentioned here that Fabrication of structural steel should only be done based on IRS B1 & IRS Welded bridge code.
7.	Page no. 28-29/ Cl. 8.0 (Exposure condition)	• Exposure conditions may be different for superstructure and substructure because of soil conditions. Hence, exposure conditions should be decided structure wise and component wise according to its intended function and soil conditions etc. While deciding this soil type and its aggressiveness may be kept in mind. • Field unit to verify that exposure conditions are taken as per the site conditions. May revise the crack width, concrete cover and other dependent factors accordingly if required. • Fire resistance duration of 2 hrs is taken which should be on the basis of architectural DBR and other applicable local bye laws, etc. • While deciding the maximum crack width, provision of clause 35.3.2 of IS 456 2000 should be followed.
8.	Page 31, Cl. 10.0	• Deflection limit of Air concourse girder should be as per the IRS steel Bridge Code and should not exceed L/325 limit. For other structural steel members limit as per IS 800 may be taken.
9.	Page 35/ Cl. 15.0	• Design of structure during various construction stages considering sequence of construction/ erection and launching along with applicable construction loads need to be done apart from design of final structure considering serviceability and ultimate limit states.
10.	Other points to be incorporated/added in DBR at suitable place	• The Geotechnical report and data provided from the geotechnical report may be verified by the Field units.

TABLE OF CONTENTS

1.0 FOREWORD

The intent of this document is to identify and record all the pertinent input requirements, analysis & design criteria for structural design of the building. It is aimed at formulating the basis of the structural analysis, design & detailing work that the Structural Engineer is planning in delivering the structural scheme of the building. The scheme will be compatible with the architectural theme, satisfy the functional needs, at the same time confirming to the Indian Standards and other applicable building norms to achieve safe, stable, strong, and yet optimally economical structures.

The parameters adopted in this report are going to be the basis of the structural design calculations. Hence it is expected that the planning and design team members - architects, services consultants and project management team - give their feedback and approval to the parameters, suggestions, recommendations mentioned in the report.

Design basis report shall remain in updation during the course of the project and shall be revised as per requirements.

This report covers the minimum design requirement to establish the unified design basis that will form the overall design philosophy to be adopted in the structural design of the proposed building.

The design will aim to achieve:

- Structural & functional integrity.
- Desirable Structural performance under characteristic service design loads.
- Resistance to loads due to natural phenomena i.e. wind and earthquakes.
- Structural durability & maintainability.

The Structural system will be based on Modular Concept. Modular design represents the repetition of Modulus which in turn, guarantees the speed of construction. It becomes a tool for bringing together and setting out all individual elements. The following Modular elements will be used in this project.

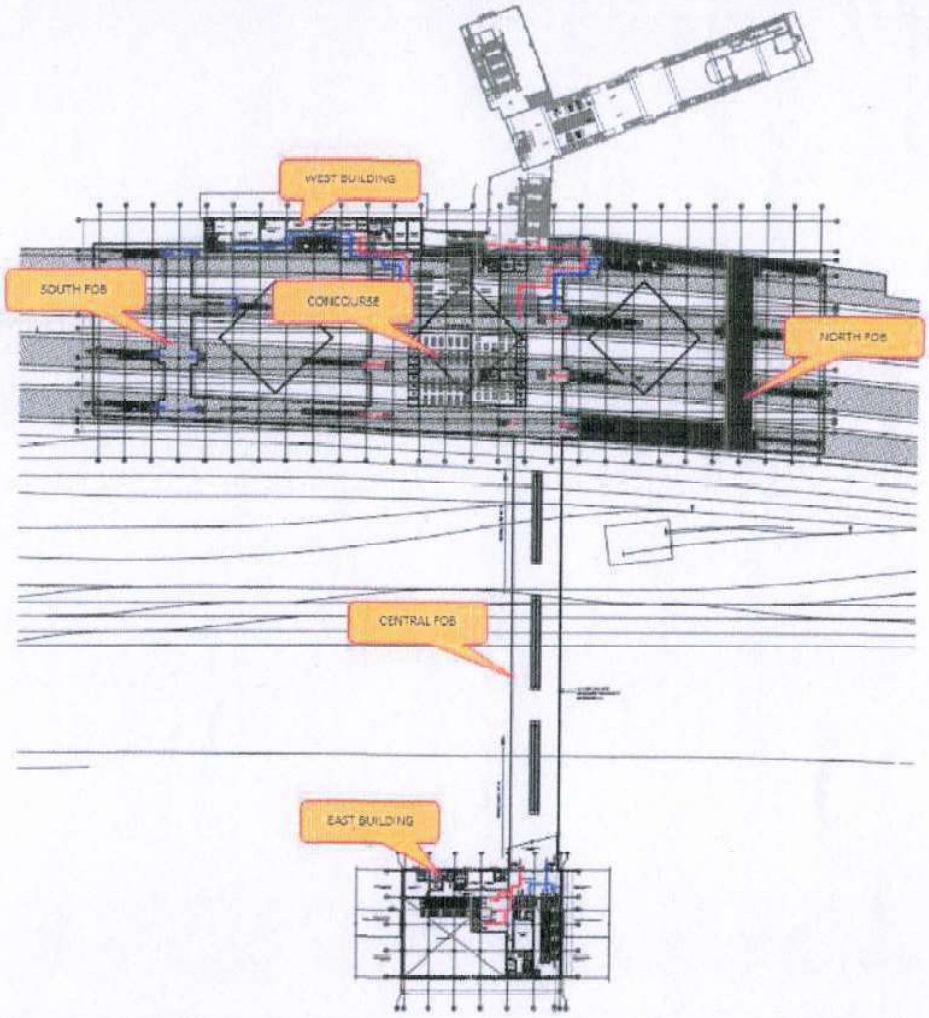
- Grid system used
- Modularity of columns/Beams/Slabs.
- Modularity of through roof.
- Modularity of foundations.

2.0 PROJECT DESCRIPTION

The project consists of a Multiple Buildings of a Railway Station. The applicable Structures for this DBR are as follows:

STRUCTURE NAME	STRUCTURE TYPE
72mt Wide Elevated Concourse	Permanent
18 mt Wide Central FOB	Permanent
10 mt Wide North side (NGP) FOB	Permanent
10 mt Wide South side (WR) FOB	Permanent
Cover Over Platform	Permanent
Through Roof	Permanent

SITE LOCATION MAP



3D VIEWS

MS Structure-1	Elevated Concourse
Total Number of Floors	Platform +Concourse + Roof
Floor Heights	
Platform level	0.902 m
Concourse level	9.369 m from track level
Structural System Proposed	Structural system for elevated concourse shall be an Ordinary Moment resisting frame. Since the columns are at 18mx18m grid (approximately) proper frame structure is formed with connections at concourse level and roof level.
Design Life	100 Years
Type of Foundation Proposed	SBC of 12.0 T/sqm has been recommended at 3m below ground level for Elevated Concourse. Depending on the site constraints and feasibility Isolated footings or pile foundation shall be proposed.

Structure Description:

MS Structure-2	10m Wide FOB -North Side (NGP)
Total Number of Floors	FOB + Roof
Floor Heights	
10 m wide FOB	9.369m (From Track lvl)
Structural System Proposed	Structural system for North FOB shall be an Ordinary Moment resisting frame. Since the columns are at 18mx18m grid (approximately) proper frame structure is formed with connections at concourse level and roof level.
Design Life	100 Years
Type of Foundation Proposed	SBC of 9.5 T/sqm has been recommended at 3m below ground level for North FOB. Depending on the site constraints and feasibility Isolated footings or pile foundation shall be proposed.

MS Structure-3	10m Wide FOB -South Side (WR)
Total Number of Floors	FOB+ Roof
Floor Heights	
10 m wide FOB	9.369m (From Track lvl)
Structural System Proposed	Structural system for South FOB shall be an Ordinary Moment resisting frame. Since the columns are at 18mx18m grid

	(approximately) proper frame structure is formed with connections at concourse level and roof level.
Design Life	100 Years
Type of Foundation Proposed	SBC of 12.0 T/sqm has been recommended at 3m below ground level for South FOB. Depending on the site constraints and feasibility Isolated footings or pile foundation shall be proposed.

MS Structure-4	**18m Wide FOB (Central FOB)**
Total Number of Floors	FOB + Roof
Floor Heights	
10 m wide FOB	9.369m (From Track lvl)
Structural System Proposed	Structural system for Central FOB shall be an Ordinary Moment resisting frame. Since the columns are at 18mx18m grid (approximately) proper frame structure is formed with connections at concourse level and roof level.
Design Life	100 Years
Type of Foundation Proposed	SBC of 12.0 T/sqm has been recommended at 3m below ground level for Central FOB. Depending on the site constraints and feasibility Isolated footings or pile foundation shall be proposed.

MS Structure-5	**Cover Over Platform**
Total Number of Floors	Platform + Roof
Structural System Proposed	Columns for COP forms moment resisting frame in one direction and these columns act as cantilever in other direction. The columns shall be designed as cantilever with lumped mass at top.
Design Life	100 Years
Type of Foundation Proposed	SBC of 12.0 T/sqm has been recommended at 3m below ground level for Cover Over Platform. Depending on the site constraints and feasibility Isolated footings or pile foundation shall be proposed.

MS Structure-6	**Through Roof**
Total Number of Floors	Roof
Structural System Proposed	Structural system for Through Roof shall be an Ordinary Moment resisting frame. The entire Through roof is divided in three parts namely South, Concourse and North. Since the columns are at 36mx36m grid (approximately) proper frame structure is formed with connections at concourse level and roof level.
Design Life	100 Years
Type of Foundation Proposed	Through roof is mainly divided in 3 parts namely South, Concourse and North. SBC for column foundation in these particular parts shall be 24.0 T/sqm, 12.0 T/sqm and 9.5 T/sqm respectively.

SOD clearances for near track structures shall be maintained as per railways.

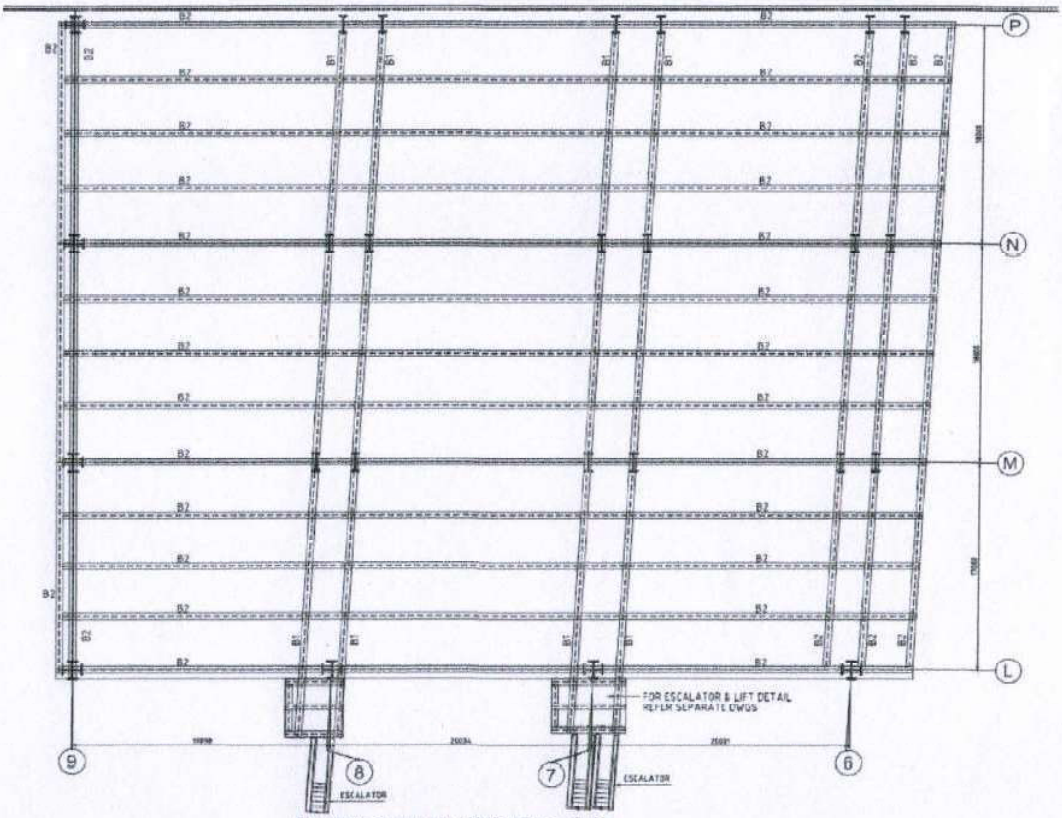
Structural System

Concourse & FOBs:

Steel-concrete composite systems have become quite popular inrecent times because of their advantages against conventional construction. Compositeconstruction has the biggest advantage of combined action of steel and concrete instructural design as well as construction. This system results in speedy construction with apossibility of working on parallel front.

The lateral load will be resisted by shear walls, Braces & the columns, thus the connecting beams being moment connected with columns. The proposed system will comply with provision of IRS Seismic Code suitably considering aspect force transfer mechanism suggested as well as like lateral vertical/lateral Displacement provision of elements/frame.

Encased steel columns ("I" section) laid out in rectangular/square grid according to architectural& structural need. The floor system consists of primary & secondary steel beams supporting on overlaid deck slab.



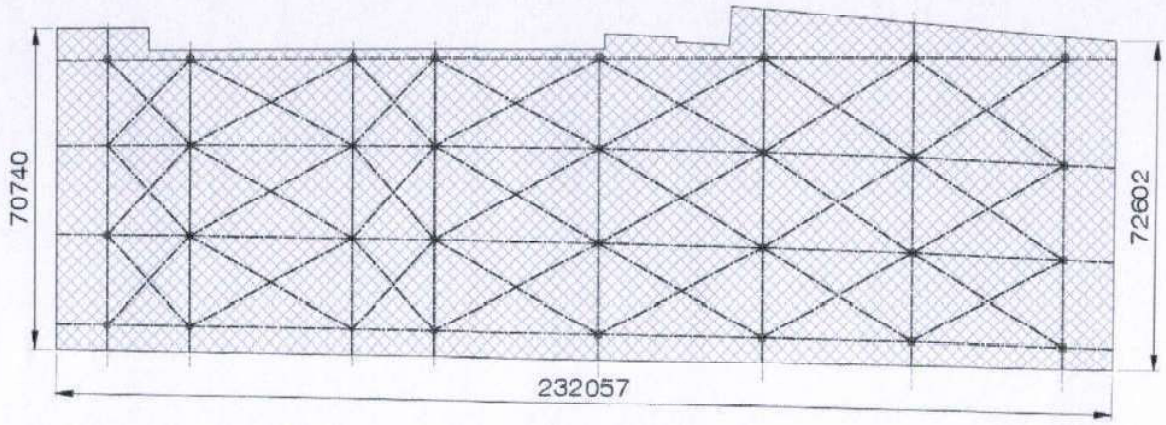
FRAMING PLAN AT CONCOURSE LEVEL
ELEVATED CONCOURSE

Plan at Concourse Level (Source: Tender document)

Through Roof & Platform Cover:

Structural steel framing has been proposed to match the architectural profile of roof and providing adequate stiffness to cater lateral loads. Moment resisting frames with truss/ box member shall be used along with colour coated sheet with thermal insulation for through roof and corrugatedcolour coated sheet for Roof.

The Through roof Columns and platform covering columns in Structural Steelwill be laid out according to architectural and structural need. The roof system consists of primary and secondary trusses.



Plan at Through Roof Level

3.0 LIST OF CODES

In the analysis, design and detailing of the building, the following Indian Standards have been used.

a) Imposed Loads:

IS875 Code of Practice for Design Loads for Buildings and Structures

Part 1 –Dead Loads

Part 2 - Imposed Loads

Part 3 - Wind Loads (2015)

Part 5 – Special loads and load combinations

b) Design for Earthquake Resistance:

IS1893:2016 Criteria for Earthquake Resistant Design of Structures

IS4326:1993 Code of Practice for Earthquake Resistant Design and Construction of Buildings

SP22 Explanatory Handbooks on Codes for Earthquake Engineering

IRS Seismic Code: 2020For Earthquake resistant of railway bridges

c) Design of Concrete Elements:

IS 12269Specifications for 53 Grade Ordinary Portland cement

IS 383 Specifications for Coarse and Fine Aggregate from Natural Sources for Concrete

IS 456:2000 Plain and Reinforced Concrete – Code of Practice

IS1786 Specification for High Strength Deformed Steel Bars and Wires for Concrete

d) Structural Steel Elements:

IS 800:2007 Use of Steel in Construction–Code of Practice

IS 2062 Steel for General Structural Purpose

AWS D1.1 - American Welding Society (AWS): Structural Welding (Steel).

ASME Sec II –Part C Specifications for welding Rods, Electrodes and Filler Metals.

e) Earthwork:

IS 3764 Code of Safety for Excavation Work

f) Soil and Foundation:

IS1080	Code of Practice for Design and Construction of Spread Foundations
IS1904	Code of Practice for Design and Construction of Foundations in Soils
IS2950	Code of Practice for Design and Construction of Raft Foundation (Part –1)
IS2911	Code of Practice for Design and Construction of Pile Foundations

g) Reinforcement:

IS 2502	Code of Practice for Bending and Fixing of Bars for Concrete Reinforcement
IS 8112	Specification for 53 Grade Ordinary Portland cement
IS 9103	Specification for Admixtures for Concrete
IS 10262	Recommended Guidelines for Concrete Mix Design
SP16	Design Aids for Reinforced Concrete to IS456
SP24	Explanatory Handbook on IS Code for Plain Reinforced Concrete, IS456
SP34	Handbooks on Concrete Reinforcement and Detailing
SP7	National Building of India

h) Indian Railway Standards (IRS) Codes and Manual

IRS	Manuals for Standards and Specifications for Railway Stations 2009 issued by Ministry of Railways, Railway Board
IRS	Indian Railway Works Manual 2000 issued by Ministry of Railways, Railway Board
IRS	Indian Railways Permanent Way Manual
IRS	Indian Railways Telecom Manual 2007
IRS	Indian Railways Coaching Maintenance Manual
IRS	Indian Railways Medical Maintenance
IRS	Indian Railways Manual of AC Traction Maintenance and Operation, Volume – I
IRS	Indian Railways Manual of AC Traction Maintenance and Operation, Volume – II (Part 1)
IRS	Indian Railways Manual of AC Traction Maintenance and Operation, Volume – II (Part II)
IRS	Indian Railways Manual of AC Traction Maintenance and Operation, Volume – III
IRS	Signal Engineering Manual, Part I
IRS	Signal Engineering Manual, Part II

IRS	Indian Railways Schedule of Dimensions 1676mm Gauge (BG), Revised 2022
IRS	All Pertinent IRS Specifications issued by the various Directorates of the Ministry of Railways (e.g., Signal Directorate, Bridges and Structures Directorate, track Directorate, Telecom Directorate, Traction Installation Directorate, Electrical Directorate, etc.)
IRS	IRS Bridge Rules for Loading
IRS	IRS Codes of Practice for Steel Bridges
IRS	IRS Code of Practice for Plain, Reinforced and Pre-stressed Concrete for general Bridge Construction
IRS	IRS Code of Practice for Design of Substructures and Foundation of Bridges
CT-38	RDSO Guidelines for Noise and Vibrations

i) Indian Road Congress Standards (IRC)

IRC 5	Standards Specifications and Code of Practice for Road Bridges, Section I - General Features of Design
IRC 6	Standards Specifications and Code of Practice for Road Bridges, Section II – Load and Stresses
IRC 11	Recommended Practice for the Design of Layout of Cycle Tracks
IRC 19	Standards Specifications and Code of Practice for Water Bound Macadam
IRC 112	Standards Specifications and Code of Practice for Road Bridges, Section III – Cement Concrete (Plain and Reinforced)
IRC 22	Standards Specifications and Code of Practice for Road Bridges, Section IV – Composite Construction
IRC 24	Standards Specifications and Code of Practice for Road Bridges, Section IV – Steel Road Bridges
IRC 37	Guidelines for the Design of Flexible Pavement
IRC 45	Recommendations for Estimating the Resistance of soil below the maximum Scour Level in the design of Well Foundations of Bridges
IRC 48	Tentative Specifications for Bituminous Surface Dressing Using Pre-Coated Aggregates
IRC 78	Standards Specifications and Code of Practice for Road Bridges, Section VII Parts 1 and 2, Foundations and Substructure
IRC 87	Guidelines for the Design and Erection of False Work for Road Bridges
IRC 89	Guidelines for the Design and Erection of River Training and Control Works for Road Bridges

j) Other Indian Standards

IS: 458	Specification for precast concrete pipes (with and without reinforcement)
IS: 5525	Recommendations for detailing of reinforcement in reinforced concrete works
IS: 816	Code of practice for use of metal arc welding for general construction in mild steel
IS: 4000	Code of practice for high strength bolts in steel structures
IS: 7215	Tolerances for fabrication of steel structure

IS: 432 Indian Standard Specification for Mild Steel and Medium Tensile Steel Bars and Hard-Drawn Steel wire for Concrete Reinforcement
IS: 6313 Code of practice for anti-termite measures in buildings
IS: 269 Ordinary Portland cement, 33 grade-specification
IS: 4031 Methods of physical tests for hydraulic cement
IS: 383 Specifications for course and fine aggregates from natural sources for concrete
IS: 516 Method of tests for strength of concrete
IS: 3935 Code of practice for composite construction
IS: 11384 Code of practice for composite construction in structural steel and concrete

Many of above listed standards may not be directly used in detailed design, however, thecomprehensive list is captured so that an approval for their use is obtained at DBR stage itself. Wherever appropriate Indian standard does not exist for any item, appropriate British standards/American standards will be used.

Code Hierarchy: -
Order of preferences of codes shall be as follows:
1. IRS
2. IS
3. IRC
4. AISC/BS/EURO

4.0 LOADING PARAMETERS

a)Dead Loads

Self-weight of the structural members and finishing/filling materials will be calculated based on the following properties:

Material	Unit Weight	Reference Code
Reinforced Concrete	25.0 kN/cu.m	IS:875 (Part I)- Table 1
Plain Concrete	24.0 kN/cu.m	IS:875 (Part I)- Table 1
Steel/Structural Steel	78.5 kN/cu.m	IS: 800-2007, cl. No. 2.2.4
Floor Finishes / Plasters	20.0 kN/cu.m	IS:875 (Part I)- Table 1
Solid Block work with Plaster	22.0 kN/cu.m	IS:875 (Part I)- Table 1
Light weight block with plaster	10.0 kN/cu.m	IS:875 (Part I)- Table 1
Soil filling (Moist)	22.0 kN/cu.m	IS:875 (Part I)- Table 1
Soil Filling (Dry)	18.0 kN/cu.m	IS:875 (Part I)- Table 1

The material other than mentioned above shall be taken from respective reference code/vendor specifications, as applicable.

Other dead loads due to stationary building elements, which arise due to walls, filling in sunken areas etc. have been accounted for based on architectural drawings.

For all Structures Light Weight AAC Block with Plaster is considered.

Self-Weight of slab / beam / Columns will be as per the dimensions adopted in the respective drawings

b) Imposed Loads

Live loads considered in design are in accordance with table 1, IS:875 (Part II)-1987and IRS bridge rule.

Levels	Load Type	MEP Load (Kn/sqm)	SIDL (Kn/sqm)	Live Load (Kn/sqm)	Total Load (Kn/sqm)
Concourse	Departure Waiting Area	1	2	5	8
Concourse	Retail	1	3	4	8
Concourse	Private Lounge	1	2	5	8

Concourse	Food Court	1	2	5	8
Concourse	AFC Gates	1	2	5	8
Concourse	Departure Concourse	1	2	5	8
Concourse	Toilet	1	5	2	8
Concourse	Ticket Counter	1	2	5	8
Concourse	Staircase	-	2	5	7
Through Roof	Roof	0.25	0.5	0.75	1.5
FOB	Floor	1	2	5*	8
FOB	Roof	0.5	0	0.75	1.25
Cover Over Platform	Roof	0.5	0	0.75	1.25

- The above-mentioned loads are inclusive of light weight partition load.
- Service, equipment and façade cleaning system loads given by vendors will be adopted wherever applicable.
- (*) As per Cl. No. 2.3.2 of IRS Bridge Rule
- As per Clause no. 3.1.2 of IS 875 Part-2, maximal load of 1.5Kn/m2 shall be taken for light weight partition load.
- Apart from UDL live load, Suitable concentrated loads as per IS 875 Part-2 Table 1(iv) for assembly building shall be considered in analysis model.

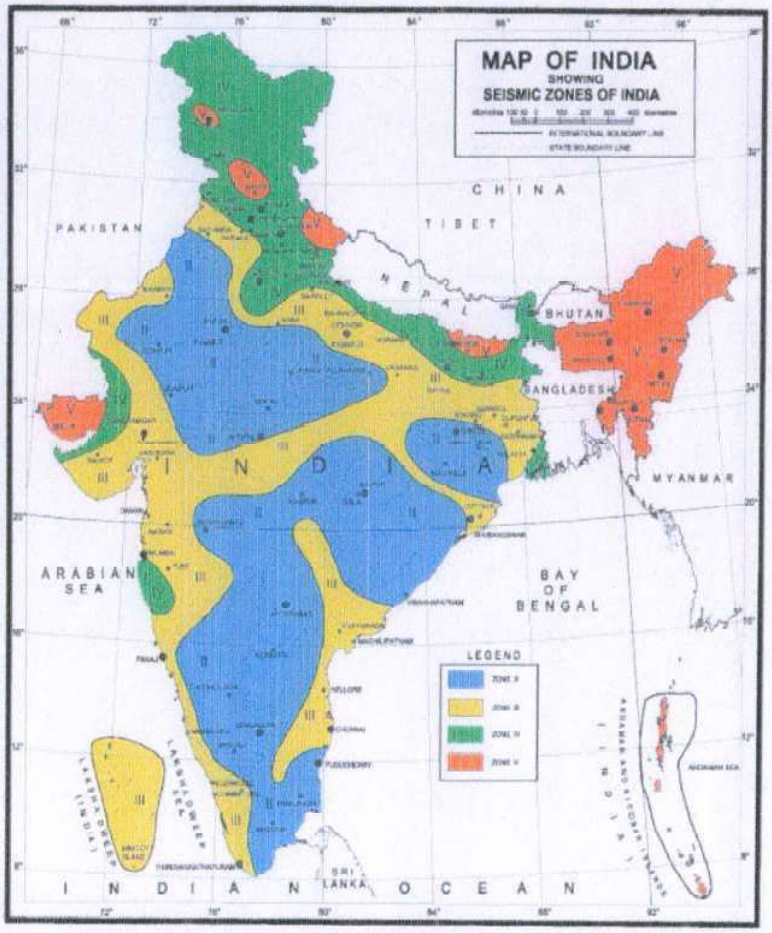
Collateral Loads: Wherever applicable, following Collateral loads are taken:

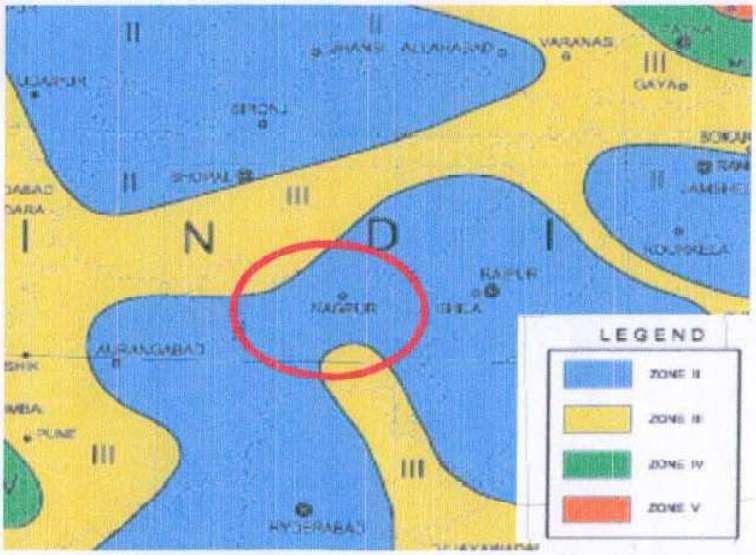
Solar Panel (or as per actual if higher)- 0.25KN/m2

Wall load- AAC blocks: Considering plaster of 12mm on one face and 12mm on other face.

- 200mm.thk. Wall = (0.2mx1mx1mx7.5KN/m3)+((0.012m+0.012m)x 1mx1m x20KN/m3)=1.98KN/m2
- 100mm.thk. Wall = (0.1mx1mx1mx7.5KN/m3)+((0.012m+0.012m)x 1mx1m x20KN/m3)=1.25 KN/m2

c) Seismic Loads



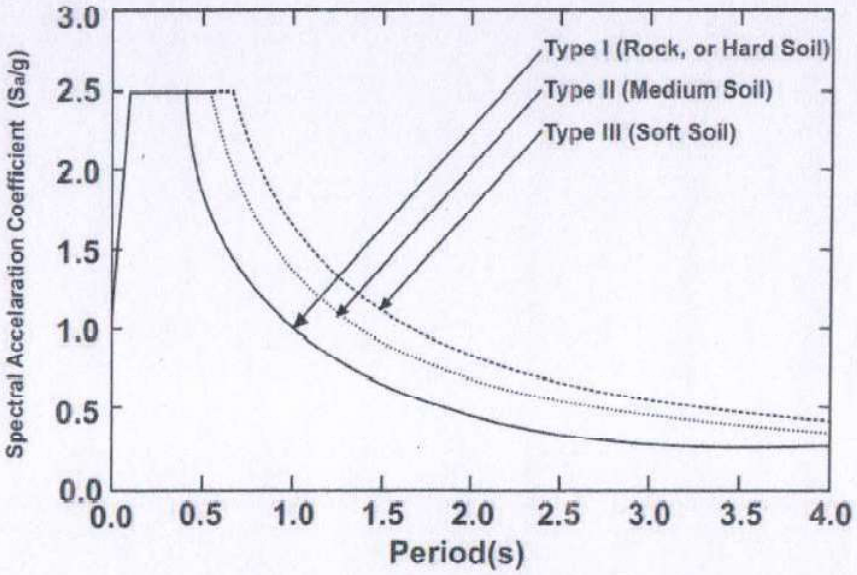


Seismic zone as per IS1893-part1: 2016

Soil Type

Types of soils are classified as Type I, Type II and Type III according to IS1893:2016 (Clause 6.4.2.1)based on thereference given in IRS Seismic Code Cl. No. 9.4.3. Type I, II and III soils refer to rock or hard soils, medium or stiff soils and soft soils respectively. It is necessary to determine the type of soil on which the structure will be placed in order to determine the correct spectrum to be used for estimating Sa/g.

A Ground Type I is assumed for this project. Annex C of IS 1893-Part 1: 2016 provides an indication of the range of geologies of India. Allowing for Volcanic/ Crystalline/ Metamorphic Rocks, Ground Type I has been assumed.



Design acceleration coefficient (Sa/g) as per IRS Seismic Code

Response reduction factor calculation

Depending upon lateral load resisting system of the structure, response reduction factor is given as per table below in compliance with Table 23 of IS800:2007, Table 9 of IS 1893: 2016 and Table 3 of IRS Seismic Code: 2020.

For super structure R=2, Substructure R=4/2.5 (R= 4 for RCC column with ductile detailing and R=2.5 for steel framed construction) andfoundation R= 2 shall be used.

Moment Resisting Frames

As the project lies in Zone 2, the buildings with ordinary moment resisting frames shall be designed and detailed as per IS 456 and IS 800, but not meeting the special detailing requirements for ductile behaviour as per IS 13920 or IS 800.

Time period calculation

The approximate fundamental translational natural period Ta of oscillation of structure will be calculated in accordance with clause 7.6.2 of IS 1893: 2016, based on the reference given in IRS Seismic Code Cl. No. 8.1.

Importance factor

The importance factor for various structures under consideration in this report is derived based on table 8 (Clause 7.2.3) of IS 1893: 2016 and Table-2 of IRS Seismic Code.

The following parameters will be used as per IS 1893 (Part 1) – 2016 and IRS Seismic Code:

Sr. No	Structure	Type	Time Period Calculation Formula	Response Reduction Factor	Importance Factor	Soil Type
1	72mt Wide Elevated Concourse	RC-Steel Ordinary Moment Resisting Frame System	Ta= 0.075 $h^{0.75}$ / Ta= 0.085 $h^{0.75}$	2 for Super structure. 4/2.5 for Substructure (Columns). 2 for Foundations.	1.5	1
2	18 mt Wide Central FOB	RC-Steel Ordinary Moment Resisting Frame System	Ta= 0.075 $h^{0.75}$ / Ta= 0.085 $h^{0.75}$		1.5	1
3	10 mt Wide North side (NGP) FOB	RC-Steel Ordinary Moment Resisting Frame System	Ta= 0.075 $h^{0.75}$ / Ta= 0.085 $h^{0.75}$		1.5	1
4	10 mt Wide South side (WR) FOB	RC-Steel Ordinary Moment Resisting Frame System	Ta= 0.075 $h^{0.75}$ / Ta= 0.085 $h^{0.75}$		1.5	1
5	Through Roof	RC-Steel Ordinary Moment Resisting Frame System	Ta= 0.075 $h^{0.75}$ / Ta= 0.085 $h^{0.75}$		1.5	1
6	Cover over Platform	RC-Steel Ordinary Moment Resisting Frame System	$T = 2\pi\sqrt{\frac{\delta}{g}}$	4	1.5	1

Where, h = Height of building considered from Ground Level to the terrace floor level

Design Horizontal Seismic Coefficient (A_h) = (Z/2) * (I/R) * (S_a /g)

Z (Zone factor) = 0.1 (Zone-2)

Seismic Weight

Clause No. 7.1 of IRS Seismic Code specifies to consider the live load on Railway bridges, to be considered as seismic mass, for calculations of earthquake loads in both horizontal and vertical direction, shall be taken as 50 percent of design live load (without impact). In Load combination also, only 50% of the Live load shall be combined with earthquake load along with Dead Loads.

Seismic Analysis Methods

Linear dynamic analysis shall be performed to obtain the design lateral forces (design seismic base shear, and its distribution to different levels along the along the height of the structure and to various lateral load resisting elements) for all FOB and Concourse structure.

Dynamic analysis will be performed by the Response Spectrum method as determined in IRS Seismic Code Cl. No. 9.4.

Damping Ratio

As specified in IRS Seismic Code Clause No. 9.4.3,the IS Code 1893:2016 will be referred to get information about damping ratio.According to clause 7.2.4 of IS1893:2016, irrespective of the material of construction, the value ofdamping shall be considered as 5% of critical damping for estimating horizontal seismic coefficient Ah.

Vertical Earthquake Effect

In compliance with clause 7.4 of IRS Seismic Code,

The vertical accelerations should be specially considered in bridges with large spans, those in which stability is the criteria of design and in situations where bridges are located in near field.

The seismic zone factor for vertical ground motions, when required may be taken as two-thirds of that for horizontal motions given in Table 2 of IS 1893 (Part 1). However, the time period for the superstructure has to be worked out separately using the characteristic of the superstructure for vertical motion, in order to estimate Sa/g for vertical acceleration. The natural time period of

superstructure can be estimated using appropriate modelling and free vibration analysis using computer.

$$A_v = \frac{\left(\frac{2}{3}\right)\left(\frac{Z}{2}\right)(2.5)}{\left(\frac{R}{I}\right)}$$ (cl. 6.4.6, IS1893:2016)

d)Wind loads

A basic wind speed of 44 m/s 3-second gust at 10 m height in open terrain will be adopted for the wind loading predictions for strength design. Wind forces based on the Gust wind calculation in accordance with IS 875:2015 shall be applied.

Design wind speed $V_Z = V_b \times k_1 \times k_2 \times k_3 \times k_4$

V_b ⟶ Basic wind velocity for Nagpur = 44 m/s

k_1 ⟶ Risk coefficient for a design life of 20 years (Service cond.) = 0.89

Risk coefficient for a design life of 100 years (Design cond.) = 1.07

k_2 ⟶ Terrain category 3 = varies

k_3 ⟶ Topography factor = 1.0

k_4 ⟶ Importance factor for the cyclonic region = 1.0

Wind pressure at height z, in N/m^2, Pz= $0.6\,Vz^2$

Design wind pressure $P_d = K_d \times K_c \times K_a \times P_z$

K_d ⟶ Wind directionality factor

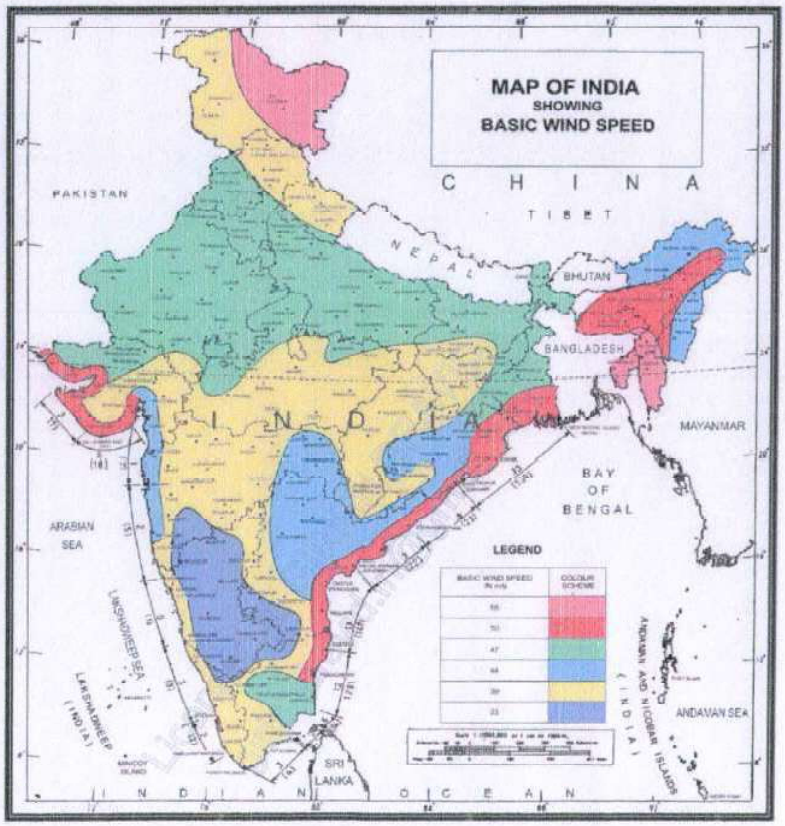
K_c ⟶ Area averaging factor

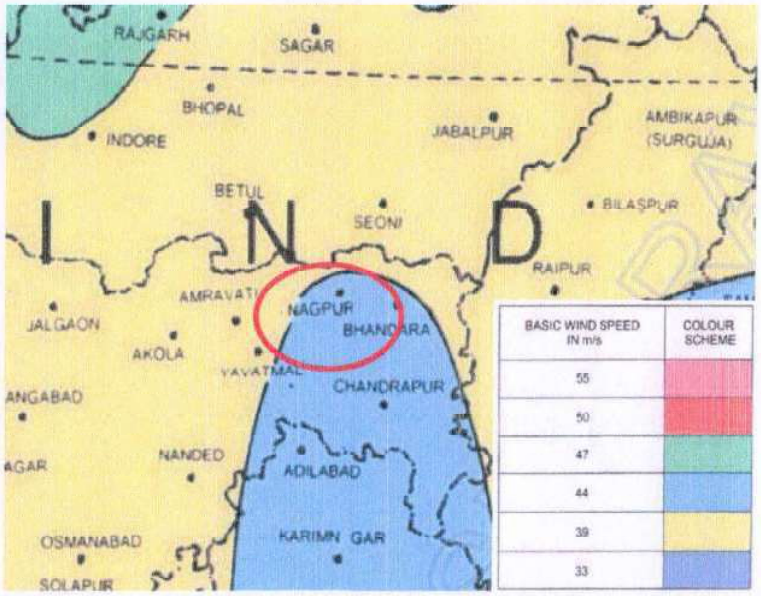
K_a ⟶ Combination factor

a) Design wind pressure to be calculated as per stipulations of Cl. 7.2 of IS 875 Part-3.

b) Wind load on individual members and structure as a whole should be estimated using Cl. 7.3 and 7.4 of IS 875 Part-3 respectively.

c) Interference effect, dynamic effect etc. should be taken care of as applicable as site condition.





BASIC WIND SPEED IN M/S

Increase in Allowable Soil Bearing Pressure:

When wind forces are resisted, then a 25% increase in the allowable soil bearing pressure is allowed (Note 6, clause 8.1, IS: 875 (Part 5) – 1987).

Return Period:

Inter-storey lateral drift computation	- 20 years	- IS 16700 2017 CL. NO.5.4.1 -A1
Acceleration computation	- 20 years	- IS 16700 2017 CL. NO.6.2.3
Design of building	- 100 years	- IS 875 P3- TABLE 1

e)Vibration loads

Walking vibrations:

Floors can be subjected to impulse loading due to a variety of sources in FOB and Concourse resulting in vibrations being felt by FOB and Concourse occupants. Typically, in FOB and Concourse, the most significant cause of floor vibrations is walking excitation, and levels must be kept within certain limits to ensure that adverse comments from FOB and Concourse occupants are kept to a minimum, walkingacceleration shall be less than $a_0/g=0.005$ and calculations shall be adopted direct from Etabs.

Vibrations due to train movement:

Vibrations due to movement of trains shall be checked and kept in accordance with the relevant sectionsof design national/international codes and relevant literature will be referred for adequate vibration-controlled floor design. Vibration study has commenced at site and the final report shall be attached as an annexure. The recommendation as per report shall be incorporated at the time of structure design.

f) Temperature loads

The temperature load has been applied in case length of structure is more than 45m for seasonal and diurnal variation and for shrinkage effects; it is converted into equivalent temperature for applying in ETABs model. Seasonal temperature variation for Ajni, Nagpur is considered with reference to IRC 6 -

2017, Annexure F. Worst Temperature load as per IRC 6, considering maximum temperature as 47.7° C and minimum as 3.9° C is considered in design of open terrace. Temperature load is not required for intermediate floors due to constant temperature load.

5.0 SEPARATION / EXPANSION JOINTS

Considering the difference in structure behaviour and current Structural Scheme, separation/expansion joints have been provided between East side building, concourse, and FOBs.

The separation/expansion joints will be governed by following formula:

Separation/expansion joint > Maximum horizontal deflection of East Building (Service Condition) + Horizontal Displacement in Concourse/FOB due to Wind/Seismic force + Horizontal Displacement in Concourse/FOB due to Temperature.The separation joint shall be calculated in line with cl. No. 4.1.8 of IRS Seismic Code and Cl. No. 7.11.3 of IS 1893 (2016).

As per IS 456:200 Clause No. 9.5.1 In ordinary buildings, such as lowrise dwellings whose lateral dimension do not exceed 45 m, the effects due to temperature fluctuations and shrinkage and creep can be ignored in design calculations. Although, the effects of temperature fluctuations, shrinkage and creep shall be considered while designing as applicable.

6.0 DURABILITY

By considering fire safety and durability aspects, cover to reinforcement for various structural members will be considered as maximum of the two values considered for durability and fire resistance criteria as follows. IS 456:2000 shall be referred for minimum concrete cover to the elements.

Structural Elements	Minimum Concrete Cover	Minimum Grade of Concrete	Fire Resistance
Footing/Raft/Pile	75 mm	M30	NA
Column / Shear Wall	40 mm	M25	2 Hr.
Beam	30 mm	M25	2 Hr.
Slab	30 mm	M25s	2 Hr.

7.0 MATERIALS OF CONSTRUCTION

Reinforced Concrete

The cement used for RCC work in the sub structure & super structure will be OPC (Grade 53) with FLYASH conforming to IS: 8112-1989 and 12269-1987. The Fly ash % will be meeting the design mix requirements and in line with stipulations of IS456 & IS1489 part1. Fly ash is a binder material. As per section 5, IS 1489, the amount of fly ash to be added shall not exceed 25% by mass of cement. Fly ash decreases the permeability of concrete which in turn is beneficial.

The use of fly ash reduces availability of free limes and permeability thus results in corrosion prevention. It improves the strength over time and thus, offers greater strength to the building.

All RCC works will be mechanically vibrated to produce dense, sound and durable concrete as per specifications. The water quality used in all stages of construction shall strictly confirm to IS: 456-2000. The grade of concrete in the location at beam/slab-column junction shall be kept matching with the column grade below. However, the extent of this concrete into the slab shall be limited to 1000mm surrounding the column outline.

Following grades are proposed for the project.

Element	Levels	Characteristic Cube strength (N/mm^2)
Foundation	-	30/35/40
Beams & Slabs	All Levels	30/35/45/50
Columns/Shear Walls	All Levels	30/35/45/50
Retaining walls	All Levels	30/35/40

Grade	E Value as per code(N/mm^2)
M15	19365
M20	22361
M25	25000
M30	27386
M35	29580
M40	31623
M45	33541

M50	35355

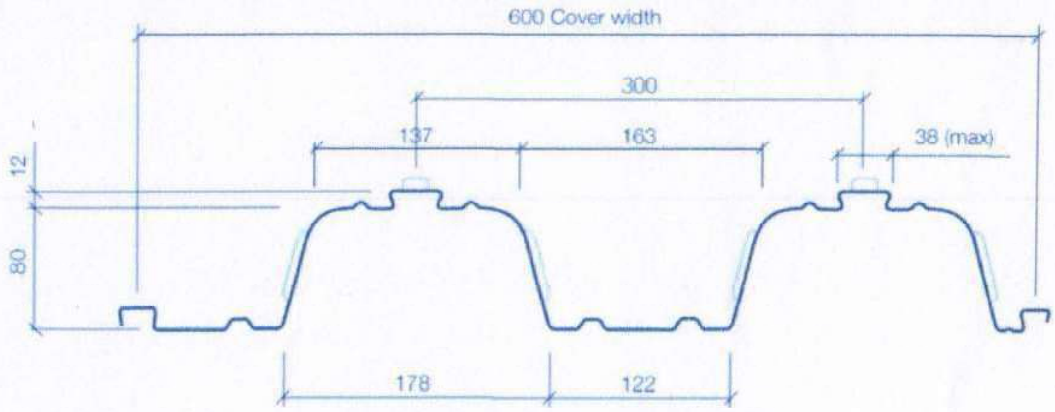
E value = 5000√Fck as per Cl. 6.2.3.1 of IS 456 2000 has been considered in the design.

Structural Steel

Structural steel encased column shall be built up in high tensile steel with a yield stress of E250/E350/ E450 MPa conforming to IS: 2062 (Table 50 – EPC Agreement). Structural steel for Pre-Engineered building used as per EPC Agreement.

Structural steel beam shall be Rolled/built up section high tensile steel with yield stress of E250/E350/E450 MPa and UB rolled section shall be E250/E350/E450 MPa conforming to IS: 2062. (Table 50 – EPC Agreement)

Deck sheet shall be TR-60/TR-80 of 0.8-1.2mm thick. With yield stress of E350 MPa with minimum 275 gsm galvanization of TATA steel/Lloyds/JSW make



Typical deck profile sheet (TR80)

Shear studs shall have yield stress of E350 MPa. Dia. of 19/22/25mm shall be used based on the modular requirements of beam spans / spacing/ forces etc.

Bolts of grade 8.8 as per IS: 4000 to be used which after torque application will develop friction grip. Anchor rods/bolts shall be E250 MPa conforming to IS standard.

Welding electrodes shall be E8018 conforming to AWS D1.1. Welding procedure, specification sheet (WPSS) and Welding Procedure specification Record (WPSR) as per stipulation as per AWS D 1.1 should be approved from the competent authority of the field before start of the execution of work.

Quality assurance plan (QAP) covering the various stage of fabrication materials and related aspect should be approved from competent Authority before start of fabrication work.

Fabrication of structural steel shall be done based on IRS B1 and IRS welded bridge code.

Reinforcement Steel

All reinforcement used in this work will confirm to I.S.1786 with Fy = 550 N/sq.mm provided % elongation should be more than 14.5% and will be in the form of deformed bars. Use of Fe415 grade may be specified wherever applicable.

Reinforcement after being placed in position shall be maintained in a clean condition until completely embedded in concrete. Special care shall be exercised to prevent any displacement of reinforcement in concrete already placed. To protect reinforcement from corrosion, concrete cover shall be provided as indicated on the drawings. All bars protruding from concrete and to which other bars are to be spliced and which are likely to be exposed for an indefinite period shall be protected by a thick coat of neat cement grout.

8.0 EXPOSURE CONDITION

All structural element will be designed to prevent excessive cracking due to flexural, early age thermal shrinkage as recommended in IS 456:2000, the clear cover and minimum dimension of elements shall be based on the exposure conditions.

As mention below:

SR. No.	Structural member	Clear cover (mm)	Min Dimension (mm)	Durability Exposure Condition	Max Crack width (mm)	Fire resistance
1	Foundation / Pile / Pile Cap	75	-	Moderate	0.2	NA

2	Columns	40	200	Moderate	0.3	2.0-hour
3	Shear walls	40	160	Moderate	0.3	2.0-hour
4	Beams, PT Beams	30	200	Moderate	0.3	2.0-hour
5	Slabs, PT Slabs	30	125	Moderate	0.3	2.0-hour
6.	RCC Retaining wall	40 (Soil face)	-	Moderate	0.2	NA
		30 (Inside face)	-	Moderate	0.3	NA
7.	Water tank walls	40 (Soil/water face)	-	Moderate	0.2	NA
		30 (Inside face)	-	Moderate	0.3	NA
8.	STP tank walls	40 (Soil/water face)	-	Moderate	0.2	NA
		30 (Other face)	-	Moderate	0.3	NA
9.	Staircase Waist slab	30	125	Moderate	0.3	2.0-hour

Provision of clause no 35.3.2. of IS 456:2000 has been followed in the design of structural elements, while deciding the maximum Crack Width.

9.0 ANALYTICAL APPROACH

By looking through the Architectural perspective and functional needs of the building, having higher loads and larger spans of column grids, feasibility of various structural framing systems will be examined and appropriate decision will be taken.

After preliminary sizing of various structural members, 3D computer model of the entire building structure will be generated to carry out structural analysis by considering all the effects of vertical and lateral loads (i.e., Gravity, Wind and Earthquake).

The 3D Model will be analysed by using the "ETABS Nonlinear Version18.1.1" and "StaadPro" software. ETABS Nonlinear Version 18.1.1 and StaadPro software has been thoroughly tested, validated and recognized internationally by several organizations and is well suited for the analysis of building systems.

Geometrical dimensions, member properties and member-node connectivity, including eccentricities will be modelled as per actual. Variation in material grades, if present, will also be considered.

Seismic and Wind forces will be generated by the software based on parameters, coefficients and factors assigned to the model in accordance with the relevant codes.

The permissible values of the load factors and stresses are utilized within the purview of the Indian Standards.

The stiffness modifiers of the concrete elements in the analytical models are to be adjusted to comply with the cracking level under service and ultimate loads, accordingly two separate models will be run, i.e., SLS model Serviceability design check and ULS for Strength design. Following table shows the values of Property modifiers to be adopted for respective cases: -

Service Condition: *IS 456: 2000,* IS 1670: 2017 *and IS 1893: 2016 shall be referred for property modifiers of concrete elements*

FOR BEAMS		FOR COLUMNS	
Cross section (axial) Area	1	Cross section (axial) Area	1
Shear area in 2 direction	1	Shear area in 2 direction	1
Shear area in 3 direction	1	Shear area in 3 direction	1
Torsional Constant	0.01	Torsional Constant	0.9
Moment of inertia about 2 axis	0.7	Moment of inertia about 2 axis	0.9
Moment of inertia about 3 axis	0.7	Moment of inertia about 3 axis	0.9
Mass	1	Mass	1
Weight	1	Weight	1
FOR SLABS (shell slabs only)		**FOR SHEAR WALLS**	
Bending m11 Modifier	0.35	Membrane f11 Modifier	1
Bending m22 Modifier	0.35	Membrane f22 Modifier	0.9
Bending m12 Modifier	0.35	Membrane f12 Modifier	0.9
		Bending m11 Modifier	0.9
		Bending m22 Modifier	0.9
		Bending m12 Modifier	0.9

Ultimate Condition: *IS 456: 2000,* IS 1670: 2017 *and IS 1893: 2016 shall be referred for property modifiers of concrete elements*

FOR BEAMS		FOR COLUMNS	
Cross section (axial) Area	1	Cross section (axial) Area	1
Shear area in 2 direction	1	Shear area in 2 direction	1
Shear area in 3 direction	1	Shear area in 3 direction	1
Torsional Constant	0.01	Torsional Constant	0.7
Moment of inertia about 2 axis	0.35	Moment of inertia about 2 axis	0.7
Moment of inertia about 3 axis	0.35	Moment of inertia about 3 axis	0.7

Mass	1	Mass	1
Weight	1	Weight	1
FOR SLABS (shell slabs only)		**FOR SHEAR WALLS**	
Bending m11 Modifier	0.25	Membrane f11 Modifier	1
Bending m22 Modifier	0.25	Membrane f22 Modifier	0.7
Bending m12 Modifier	0.25	Membrane f12 Modifier	0.7
		Bending m11 Modifier	0.7
		Bending m22 Modifier	0.7
		Bending m12 Modifier	0.7

The computer analysis will evaluate individual internal member forces and the reactions at foundation level.

Global deformation and drift patterns of the entire structure as well as deflection and sway of individual members and joints will also be evaluated by the 3D model analysis.

This data will then be used to verify adequacy of the member sizes adopted.

A sufficient number of iterations will be done to achieve the most appropriate and optimized structural member sizes.

Considerations adopted for 3D model,

1. Fixed supports are considered at base level.
2. Rigid diaphragm assigned to the floor and Flat plate Slab are modelled as Shell thin elements.
3. Design eccentricity is considered as per cl 7.8.2 of IS 1893: 2016.
4. Appropriate moment releases are assigned for the elements wherever required.
5. Foundation analysis and design shall be performed using SAFE 2016 and RCDC.

Design of structure during various construction stage considering sequence of construction/ erection and launching along with applicable construction loads need to be done apart from design of final structure considering serviceability and ultimate limit state.

10.0 LATERAL LOAD AND SERVICEABILITY LIMITS

Story displacement and drifts under lateral loads (seismic and wind) will be checked from 3D-ETABS/STAAD model. The displacement response due to seismic forces (Δs) obtained from the analytical model represents building elastic response. However, seismic codes account for the inelastic response by magnifying the obtained elastic displacements with correction factor.

Items	Deflection limit	Code of References
Deflection for Wind	H/500	IS 16700: 2017 and IS 456: 2000
Deflection for Seismic force	H/250	IS 16700: 2017 and IS 1893: 2016
Inter Storey drift	h/250	IS 16700: 2017 and IS 1893: 2016
Immediate deflection (DL + LL)	Span/350	IS 456: 2000
Long term deflection	Span/250	IS 456: 2000
Deflection for Wind/Live (Purlin)	Span/150	IS 800: 2007
Deflection for Wind/Live (Rafter)	Span/180	IS 800: 2007
Deflection of Steel Girder for Live Load	Span/240	IS 800: 2007
Air Concourse Girder	Span/325	IRS Steel Bridge Code

The following serviceability criteria will be applied are as follows.

11.0 LOAD COMBINATIONS

Service load combinations for SLS model:

Followings IS codes are referred for load and load combinations

1. IS 456: 2000 Table No. 18

2. IS 1893: 2016 Clause No.6.3

3. IS 875: 2015 Part-5 Clause No. 8.1.

SR. NO.	LOAD COMBINATIONS	LOAD FACTORS							
		D.L	L.L	ALG_X / ACG_X	ALG_Y / ACG_Y	$SPEC_X$	$SPEC_Y$	$SPEC_z$	TEMP
1.	DL+LL	1.00	1.00	-	-	-	-	-	
2.	$DL \pm SPEC_X \pm 0.3SPEC_z$	1.00	-	-	-	±1.00	-	±0.30	
3.	$DL \pm 0.3SPEC_X \pm SPEC_z$	1.00	-	-	-	±0.30	-	±1.00	
4.	$DL \pm SPEC_Y \pm 0.3SPEC_z$	1.00	-	-	-	-	±1.00	±0.30	
5.	$DL \pm 0.3SPEC_Y \pm SPEC_z$	1.00	-	-	-	-	±0.30	±1.00	
6.	$DL+LL \pm SPEC_x \pm 0.3SPEC_z$	1.00	0.80	-	-	±0.80	-	±0.24	
7.	$DL+LL \pm 0.3SPEC_x \pm SPEC_z$	1.00	0.80	-	-	±0.24	-	±0.80	
8.	$DL+LL \pm SPEC_Y \pm 0.3SPEC_z$	1.00	0.80	-	-	-	±0.80	±0.24	
9.	$DL+LL \pm 0.3SPEC_Y \pm SPEC_z$	1.00	0.80	-	-	-	±0.24	±0.80	
10.	$DL + LL \pm ALG_X/ACG_X$	1.00	0.80	±0.80	-	-	-	-	
11.	$DL + LL \pm ALG_Y/ACG_Y$	1.00	0.80	-	±0.80	-	-	-	
12.	$DL \pm ALG_X/ACG_X$	1.00	-	±1.00	-	-	-	-	
13.	$DL \pm ALG_Y/ACG_Y$	1.00	-	-	±1.00	-	-	-	

14.	DL+LL+TEMP	1.00	1.00						0.6

Ultimate load combinations for ULS model:

Followings IS codes are referred for load and load combinations

1. IS 456: 2000 Table No. 18

2. IS 1893: 2016 Clause No.6.3

3. IS 875: 2015 Part-5 Clause No. 8.1.

SR. NO.	LOAD COMBINATIONS	LOAD FACTORS							
		D.L	L.L	ALG_X / ACG_X	ALG_Y / ACG_Y	$SPEC_X$	$SPEC_Y$	$SPEC_z$	TEMP
1.	DL+LL	1.50	1.50	-	-	-	-		
2.	DL+LL ±$SPEC_X$ ± 0.3$SPEC_Z$	1.20	1.20	-	-	±1.20	-	±0.36	
3.	DL+LL ± 0.3$SPEC_X$ ± $SPEC_Z$	1.20	1.20	-	-	±0.36	-	±1.20	
4.	DL+LL ±$SPEC_Y$ ± 0.3$SPEC_Z$	1.20	1.20	-	-	-	±1.20	±0.36	
5.	DL+LL ± 0.3$SPEC_Y$ ± 0.3$SPEC_Z$	1.20	1.20	-	-	-	±0.36	±1.20	
6.	DL ±$SPEC_X$± 0.3$SPEC_Z$	1.50	-	-	-	±1.50	-	±0.45	
7.	DL ±0.3$SPEC_X$± $SPEC_Z$	1.50	-	-	-	±0.45	-	±1.50	
8.	DL ±$SPEC_Y$± 0.3$SPEC_Z$	1.50	-	-	-	-	±1.50	±0.45	
9.	DL ±0.3$SPEC_Y$± $SPEC_Z$	1.50	-	-	-	-	±0.45	±1.50	
10.	DL ±$SPEC_X$± 0.3$SPEC_Z$	0.90	-	-	-	±1.50	-	±0.45	
11.	DL ±0.3$SPEC_X$± $SPEC_Z$	0.90	-	-	-	±0.45	-	±1.50	
12.	DL ±$SPEC_Y$± 0.3$SPEC_Z$	0.90	-	-	-	-	±1.50	±0.45	
13.	DL ±0.3$SPEC_Y$± $SPEC_Z$	0.90	-	-	-	-	±0.45	±1.50	
14.	DL + LL ± ALG_X/ACG_X	1.20	1.20	±1.20	-	-	-	-	
15.	DL + LL ± ALG_Y/ACG_Y	1.20	1.20	-	±1.20	-	-	-	

16.	$DL \pm ALG_X/ACG_X$	1.50	-	±1.50	-	-	-	-	
17.	$DL \pm ALG_Y/ACG_Y$	1.50	-	-	±1.50	-	-	-	
18.	$DL \pm ALG_X/ALG_X$	0.90	-	±1.50	-	-	-	-	
19.	$DL \pm ALG_Y/ACG_Y$	0.90	-	-	±1.50	-	-	-	
20.	DL+LL+TEMP	1.35	1.15						1.5

Suffixes x, y and z in the above table indicate the direction in which the force is applied.

All members will be designed for the largest value of the design forces obtained due to positive as well as negative values of reversible forces (Wind and Earthquake).

The Bi- directional combinations will be applied only when applicable.

12.0 STEEL STRUCTURES

Structural steel / composite structure will be used mainly for Concourse, FOBs, Roof and any other additional architectural feature.

The Design of steel structures shall be done by Limit/working State method, in accordance with the provisions of IS: 800-2007, other relevant IS codes, AISC and BS-Euro Codes, as applicable to specific structures. All structures will beMS Truss Type Frame System/ Simply Supported framed structure. Basic consideration for structural framing will be stability, rigidity, building usage, ease of fabrication / erection and overall economy. Additional bracings / moment connections will be used to assure stability of structures. Structure will be designed such that the surfaces of all parts will be accessible for inspection, cleaning, painting and maintenance. The load combinations for steel design shall be as per IS: 800-2007.

13.0 STABILITY OF STRUCTURES

For the purpose of stability of the structure against overturning, the restoring moment shall not be less than 1.2 times the maximum overturning moments due to dead load plus 1.4 times the maximum overturning moments due to imposed loads.

In case where dead load provides the restoring moments only 0.9 times in dead load shall be considered. The restoring moments due to imposed loads shall be ignored.

The factor of safety against sliding shall not be less than1.40.

Factor of safety against buoyancy shall be not less than 1.20 ignoring the superimposed loading.

Factor of safety against overturning and sliding are in line with the code IS 456: 2000 and factor of safety against buoyancy is as per IS 3370 Part-1.

14.0 STRUCTURAL SOFTWARE USED

3D Structural analysis for entire building will be carried out on ETABS (Version 18.1.1) software.

And following software will be engaged for reinforcement designs of different structural element.

Beams : RCDC Connect Edition 11.03.01.10

Columns/Walls : RCDC Connect Edition 11.03.01.10

Floor Plate analysis/ Foundation : SAFE Version 16.0.2

Structural Steel : STAAD/ ETABS/ Idea Statica

Drawings : AutoCAD & Revit

15.0 ERECTION METHODOLOGY

The erection methodology for structures above track shall be prepared separately considering the type of structure, its location and practical restraints. It shall be ensured that the adjacent structures shall be designed for the weight of all temporary and permanent materials together with all other forces and effects which can operate on any part of structure during erection. Allowances shall be made in the permanent design for any locked in stresses caused in any member during erection.

Detailed erection methodology along with drawings will be submitted after consultation with vendor.

16.0 FOUNDATION

Foundation shall be designed accordance to IS 456: 2000(2016). Analysis and design of raft/ combined/ isolated/Piled foundation shall be done by safe and design of isolated footing, retaining wall will be prepared in excel sheet and provided in pdf format. As per soil investigation report maximum allowed settlement is 50 mm for Isolated footing and Code (IS 1904) Table 1 is also taken in consideration for differential settlement. The recommended safe bearing capacities as per reports is as follows:

Test Locations	Depth (m) from EGL.	Recommended Allowable Bearing Capacity-T/m² for B-Width of Foundations				
		B=2m	B=3m	B=4m	B=5m	B=6m
BH-4 (Central FOB)	1.5	-----	-----	-----	-----	-----
	2.0*	15.00*	12.00*	12.00*	12.00*	11.00*
	3.0*	13.00*	11.50*	11.00*	11.00*	10.50*
	4.5	13.00	11.50	11.00	11.00	10.50
	6.0	52.00	48.00	45.00	44.00	43.00
	7.5	52.00	48.00	45.00	44.00	43.00
BH-5 (Central FOB)	1.5	-----	-----	-----	-----	-----
	3.0	12.50*	11.50*	11.00*	10.50*	10.50*
	4.50	12.50	11.50	11.00	10.50	10.50

* Recommended Allowable Bearing Capacities at upper depths considering weathered rock stratification.

Test Locations	Depth (m) from EGL.	Recommended Allowable Bearing Capacity-T/m² for B-Width of Foundations				
		B-2m	B-3m	B-4m	B-5m	B-6m
BH-7 (North FOB)	1.5*	10.50*	9.50*	9.50*	9.00*	9.00*
	3.0*	10.50*	9.50*	9.50*	9.00*	9.00*
	4.0	10.50	9.50	9.50	9.00	9.00
	5.0-7.5	52.00	48.00	45.00	44.00	43.00
BH-9 (North FOB)	3.0	12.50*	11.00*	10.50*	10.50*	10.50*
	4.5	12.50	11.00	10.50	10.50	10.50
	6.0-7.5	52.00	48.00	45.00	44.00	43.00

* Recommended Allowable Bearing Capacity considering weakness in stratification encountered at lower depth.

Test Locations	Depth (m) from EGL.	Recommended Allowable Bearing Capacity-T/m² for B-Width of Foundations				
		B=2m	B=3m	B=4m	B=5m	B=6m
BH-8 (South FOB)	3.0*	27.50*	25.00*	24.00*	23.00*	22.00*
	4.5*	27.50*	25.00*	24.00*	23.00*	22.00*
	6.0-7.5	52.00	48.00	45.00	44.00	43.00
BH-10 (South FOB)	1.5	13.00	12.00	11.50	11.00	10.50
	2.0*	13.00*	12.00*	11.50*	11.00*	10.50*
	3.0*	13.00*	12.00*	11.50*	11.00*	10.50*
	4.5*	13.00*	12.00*	11.50*	11.00*	10.50*
	6.0	15.00	13.50	12.50	12.00	11.50
	7.5	52.00	48.00	45.00	44.00	43.00

* Recommended Allowable Bearing Capacity considering weakness in stratification encountered at Lower depth.

Test Locations	Depth (m) from EGL.	Recommended Allowable Bearing Capacity-T/m² for B-Width of Foundations				
		B-2m	B-3m	B-4m	B-5m	B-6m
BH-13 & BH-14 (72m Wide Elevated Concourse)	3.0*	14.00*	12.50*	12.00*	12.00*	11.50*
	4.5*	14.00*	12.50*	12.00*	12.00*	11.50*
	6.0	41.50	35.50	34.00	33.00	32.00
	7.5	52.00	48.00	45.00	44.00	43.00

* Recommended Allowable Bearing Capacity considering weakness in stratification encountered at lower depth.

Test Locations	Depth (m) from EGL.	Recommended Allowable Bearing Capacity-T/m² for B-Width of Foundations				
		B-2m	B-3m	B-4m	B-5m	B-6m
BH-15 (North FOB Metro Connectivity)	3.0	9.00	8.50	8.50	8.00	8.00
	4.5*	17.00*	16.00*	15.00*	14.50*	14.00*
	6.0	17.00	16.00	15.00	14.50	14.00
	7.5	52.00	48.00	45.00	44.00	43.00

* Recommended Allowable Bearing Capacity considering weakness in stratification encountered at Lower depth.

** Soil report attached in Annexure A, B, C, D&E

The Geotechnical Report and Data provided from the geotechnical report shall be verified by the field unit.

17.0 EQUIPMENT (DG SET & OTHERS)

DG set- this is kept clear from the main framing by way of suitable separation gap so that the possibility of vibration transmission does not arise.

Other equipment- which is either static or those with insignificant vibrations such as cooling towers will be kept directly on the floors by way of vibration isolation pads.

18.0 FACADE CLEANING SYSTEM

Structure support system for Façade cleaning at terrace shall be provided as per vender requirement.

19.0 STRUCTURAL MAINTENANCE

Periodical inspection of the structure should be done to identify repair work and take necessary action accordingly. Maintenance should be done in accordance with IRS Bridge manual. Some of the common maintenance works have been listed below:

For Structural Steel:

1. Paintwork:

- Periodical Thorough Paint: The entire steel work should be painted at regular intervals which vary from six years in arid zones to one year in highly corrosive areas. The chief engineer shall prescribe the periodicity of painting.
- Patch Paint: When small area of paint show pronounced deterioration, which requires immediate remedy, it is not desirable to wait for the girder or the member as a whole becoming due for periodic painting. The affected areas must be patch painted.
- Paint schedule & methodology to be followed as per IRS Bridge Manual.

2. Bolts:

- Loose bolts should be identified and fixed.
- If a bolt is found to be cracked, cause of crack should be identified and bolt should be replaced immediately.
- For HSFG bolts, painting schedules and methodologies to be followed as specified in IRS bridge manual for the girder as a whole.

3. For RCC:

- The areas around bearings shall be kept free of ballast, debris dust, oil / grease etc.
- Drainage system shall be thoroughly cleaned and repaired as necessary before the onset of monsoon.
- Protective surface coat, where provided, shall be maintained
- Superstructure and bearings shall be maintained as per the design requirements and any deficiencies/defects noticed during inspection shall be attended to.

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20.0 OTHER DATA

Specific requirements of floor and wall cutouts for services, sinking of floors in services, kitchen and toilet areas, porch and external architectural features will be provided as required by Architects and Service Consultants. The relevant information will be obtained from them in the form of drawings.

Girish Dravid

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