TL/PMC/PRYJ-STAN/LECPL/2023/531 **14th Dec. 2023**

To,
The Authorized Signatory
M/s Dinesh Chandra Evrascon JV
Radha Krishna Bhavan,
13/9A, Basant Vihar Colony,
Starchy Road, Civil Lines, Parayagraj (U.P.)

Sub: - "Project Management Services for Integrated Redevelopment of Prayagraj Railway Station through Engineering Procurement and Construction (EPC) Contract." **Approval of Design Basis Report (Structural) -Reg.**

Ref:-

1. PMC Contract Agreement No. 75-W/262/DY CE/C/PRYJ; Dated: 14.06.2023.
2. EPC Contractor Letter No. PRYJ/NCR/DRA/SITE/23-24/96; Dated: 27.05.2023.
3. Authority Engineer's Letter No. TL/PMC/PRYJ-STAN/LECPL/2023/41; Dated: 01.06.2023.
4. EPC Contractor Letter No. PRYJ/NCR/DRA/SITE/23-24/120; Dated: 09.06.2023.
5. Authority Engineer's Letter No. TL/PMC/PRYJ-STAN/LECPL/2023/72; Dated: 24.06.2023.
6. EPC Contractor Letter No. PRYJ/NCR/DRA/SITE/23-24/591; Dated: 08.12.2023.

Dear Sir,

Please refer to letter cited under reference no.6; vide which the EPC Contractor has submitted the Structural DBR in supersession of their submission vide letter cited under reference no.6.

Further, the submission has been reviewed in accordance with provisions as set forth in the EPC Agreement, BIS and found in order and hereby approved.

This is for your kind information and necessary action accordingly.

Thanking You,
For & on behalf of Lion Engineering Consultants Pvt. Ltd.

LION ENGINEERS CONSULTANTS PRIVATE LIMITED
SD
PRYJ

(SUBRATA SEN)
Team Leader
Encl: As stated.

Copy To:

(i) **CPM/C/PRYJ/NCR**, HQ Prayagraj - for kind information please.
(ii) **DY.CE/C-II/PRYJ/NCR**, Old GM Building, Prayagraj - for kind information and records please.

DESIGN BASIS REPORT

(STRUCTURE)

NORTH CENTRAL RAILWAY	LION ENGINEERING CONSULTANTS PVT LTD.	DINESHCHANDRA EVRASCON JV	CREATIVE GROUP LLP
AUTHORITY	AUTHORITY ENGINEER	CONTRACTOR	CONSULTANT

2.	Dec 8th, 2023	R1
1.	May 26th, 2023	R0
S. NO.	**SUBMISSION DATE**	**REVISION NO.**

LION ENGINEERING CONSULTANTS PVT. LTD.
"NO NO"

LION ENGINEERING CONSULTANTS PRIVATE LIMITED PRYJ

DINESHCHANDRA - EVRASCON JV

CONTENTS

List of Figures

List Of Tables

1. PROJECT BRIEF

Brief Description of Building:
Project consists of followings:

- Two station building blocks (Civil line side & City side) comprising of basement, G+9 floors & terrace.
- Two Concourse - Concourse 1&2 having top of floor @ 9.0m level with covering roof @ 25.00-meter top of roof over it.
- Skywalk Bridges
  - Two tier (double deck) bridge for connecting concourse 1 and concourse 2
  - Departure skywalk Connecting PF6 and station building
  - Arrival skywalk from Fobs (f2) to City side station building
- Arrival and RMS block: G+1 building
- Arrival and Parcel block: G+1 building with retail and commercial arcade
- Residential Quarters : G+7 RCC Framed building
- Basement and Public Plaza underground building with green cover over it
- Office block and parcel block at city side G+1 building
- Substation - For Entry Exit Blocks (station buildings):

Building Location:
Site for the proposed project of Prayagraj railway station is located at Prayagraj.

Structural System:
Concourse & FOBs:

The floor plan layout of the building is such that it is largely symmetrical (in plan) with respect to both axes. Steel-concrete composite systems have become quite popular in recent times because of their advantages against conventional construction. Composite construction has the biggest advantage of combined action of steel and concrete in structural design as well as construction. This system results in speedy construction with a possibility of working on parallel front.

The Foundation shall consist of pile cap sitting on a group of piles. RCC column shall be cast from top of pile cap to 3.00 meter above top of railway platform. Above 3.00-meter level, Structural steel prefabricated column shall be constructed. The Concourse beams shall be of prefabricated plate girders adequately stiffened. The lateral load resisting system shall be achieved by fixed supports at bottom of columns and braced columns at concourse level.

The concourse slab shall be built by casting RCC slab on trapezoidal profile composite steel deck sheeting for economy and fast construction.

Station buildings, Residential quarters and all other RCC buildings:

These buildings are RCC building with beams, slab, column and Shear wall. Therefore, SMRF (special moment resisting frame) system is used to design. All reinforcement detailing shall be as per IS: 13920.

Through Roof & Platform Cover:
Prefabricated structural steel columns shall be continued over the concourse columns after the concourse floor is constructed. The concourse roof shall consist of hollow section space frame with curvature for aesthetics. Precoated, profiled galvalume sheet with thermal insulation for through roof and corrugated color coated sheet for platform have been proposed.

LION ENGINEERS CONSULTANTS PRIVATE LIMITED PRYJ

DINESHCHANDRA - FIRASTA ARCHITECTS

Design Life:
All the structures of permanent works shall be designed for a design life of 70 years, hence for selection of materials for structural construction, guidelines of IS codes shall be followed.

2. Codes & Standards
The following Codes of Practice are shall be used and followed for design of structures

Calculation of Loads: -

- IS:875 -1987/2015 Code of Practice for design loads (other than earthquake) for Buildings and structure (All parts)
- IS: 1893-2016 Criteria for earthquake resistant design of structure.

Foundations: -

- IS:1080-1985(2016) Code of Practice for design and construction of shallow foundations on soils (other than raft, ring and shell)
- IS:1904-1986(2020) Code of Practice for design and construction of foundations in soils general requirement.
- IS:2911 (2010) (all parts) Code of Practice for design and construction of pile foundations
- IS:2950-1981(2013) Code of Practice for design and construction of raft foundations
- IS:2974-1998(2013/2015) Code of Practice for design and construction of machine foundations (All parts)
- IS:8009-1976/1980(2013/2015) Code of Practice for calculation of settlement of foundations (All parts)

RCC: -

- IS:456 -2000(2021) Code of Practice for plain and reinforced concrete.
- IS:458 -1988 Specification for precast concrete pipes.
- IS:3370-2021(Part i-iv) Code of Practice for concrete structures for the storage of liquids:(All parts).
- IS:4326-2013 (R2018) Code of Practice for earthquake resistant design and construction of buildings.
- IS:5525-1969(2013) Recommendation for detailing of reinforced concrete works.
- IS: 1786-2008 Specification for high strength deformed steel bars and wires for concrete reinforcement.
- IS:10262-2009 Recommended guidelines for concrete mix design.
- IS: 13920-2016 (R2021) ductile design & detailing of RC structures subjected to seismic forces.

Structural Steel & Composite Construction: -

- IS: 800 -2007(2012) Code of Practice for general construction in steel.
- IS:806 -1968(2013) Code of Practice for use of steel tubes in general building construction.
- IS:808 -1989 Dimensions for hot rolled steel beam, column channel and angle section.
- IS:816 -1998 Code of Practice for use of metal arc welding for general construction in mild steel

- IS:1161-1998 Steel tubes for structural purposes.
- IS:4000-1998 High Strength bolts in steel structures – Code of Practice.
- IS:7215 -1995 Tolerances for fabrication of steel structures.
- AISC:360-10 Specification for Structural Building (Only Chapter-I refer for composite beam and column design).

Miscellaneous: -

- IS: 432(part 2)-1995 Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement
- IS: 6313(part II) 2001 Standards for anti-termite treatment
- IS:1905-1998 Code of Practice for structural use of unreinforced masonry
- IS: 3067-1995 Code of Practice for general design details and preparatory works for damp proofing and water proofing of buildings.
- SP:6 -1998 Handbook for structural engineers (all parts)
- SP:7 -2016 National Building Code of India
- SP:16-1999 Design Aids for reinforced concrete to IS:456-1978
- SP:22-1982 Explanatory handbook on codes for earthquake engineering and IS:4326-1976
- SP:24-1983 Explanatory handbook on Indian Standard code of Practice for plain and reinforced concrete
- SP:34-1987 Handbook of concrete reinforcement and detailing (SCIP)

Material: -

- IS: 269 -2015 Specification for Ordinary, rapid hardening and low heat Portland cement.
- IS: 455 -1995 Specification for Portland blast furnace slag cement.
- IS: 1489-1991 Specification for Portland pozzolana cement
- IS: 4031-1991 Method of physical tests for Portland cement.
- IS: 383 - 2016 Specification for coarse and fine aggregates from natural sources for concrete.
- IS: 516 – 1999 Method of test for strength of concrete.
- IS: 1199-1999 Method of sampling and analysis of concrete.
- IS: 1566-2000 Specification for plain hard drawn steel wire fabric for concrete reinforcement.
- IS: 4990-1998 Specification for plywood for concrete shuttering works.
- IS: 2645-1999 Specification for integral cement water proofing compounds.

Soil and Foundation: -

- IS: 8009:1976 Code of practice for calculation of settlements of foundation.

Welding standards: -

- AWS D1.1 - American Welding Society (AWS): Structural Welding (Steel).
- ASME Sec II –Part C Specifications for welding Rods, Electrodes and Filler Metals.

For design of strength of material, "Limit state method" shall be used. For design of serviceability limits of structure "Limit state of serviceability" method shall be used.
Many of above listed standards may not be directly used in detailed design, however, the comprehensive 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.

3. MATERIALS OF CONSTRUCTION

3.1 Reinforced Concrete:

The cement used for RCC work in the sub structure & super structure will be OPC (Grade 43 and 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 35% 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.

The following grades of Reinforced concrete shall be adopted:

Building more than 15.00-meter height

Description	Grade *[≥Min. grade as per cl. 6.1.2, table 5, IS 456:200]*	Max. Size of Aggregate (mm) *[Cl. 5.3.3 IS456:2000]*	Type of Cement used in Design Mix. *[Cl. 5.1 IS456:2000]*
Raft foundation/ Pile cap /pile	M 35	20	OPC
Isolated/ Combined footing	M 30	20	OPC
Shear Walls & Columns	M 35	12	OPC
Retaining Wall	M 35	20	OPC
Slab	M 35	20	OPC

Building less than 15.00-meter height

Description	Grade *[≥Min. grade as per cl. 6.1.2, table 5, IS 456:200]*	Max. Size of Aggregate (mm) *[Cl. 5.3.3 IS456:2000]*	Type of Cement used in Design Mix. *[Cl. 5.1 IS456:2000]*
Raft foundation	M 30	20	OPC
Isolated/ Combined footing	M 30	20	OPC
Shear Walls & Columns	M 30	12	OPC
Retaining Wall	M 30	20	OPC
Slab	M 30	20	OPC

Building less than 5.50-meter height

Description	Grade *[≥Min. grade as per cl. 6.1.2, table 5, IS 456:200]*	Max. Size of Aggregate (mm) *[Cl. 5.3.3 IS456:2000]*	Type of Cement used in Design Mix. *[Cl. 5.1 IS456:2000]*
Isolated/ Combined footing	M 25	20	OPC
Shear Walls & Columns	M 25	12	OPC
Slab	M 25	20	OPC

Concourse 1 and concourse-2

Description	Grade *[≥Min. grade as per cl. 6.1.2, table 5, IS 456:200]*	Max. Size of Aggregate (mm) *[Cl. 5.3.3 IS456:2000]*	Type of Cement used in Design Mix. *[Cl. 5.1 IS456:2000]*
Raft foundation/ Pile cap /Pile	M 35	20	OPC
Shear Walls & Columns	M 45	12	OPC
Retaining Wall	M 45	20	OPC
Composite Slab	M 45	20	OPC

Table 1 Grade of RCC elements

- All reinforcement steel to be used in the RCC shall be:
- High yield strength deformed bars of grade Fe 550 D with a minimum yield stress of 550 N/mm2, a minimum elongation of 14.5% and other specifications conforming to cl. 8.1, table 3 of IS: 1786 shall be adopted for 8mm to 32mm dia. bars.

3.2 Structural Steel:

- Rolled steel sections and plates for structural members and built up section shall be of high tensile steel of grade E450/E350 with yield stress of 450/350 MPa and all rolled sections shall be conforming to IS: 2062.

- Deck sheet shall be suitable profile and minimum thickness 1.00 mm, With yield stress of E350 MPa.

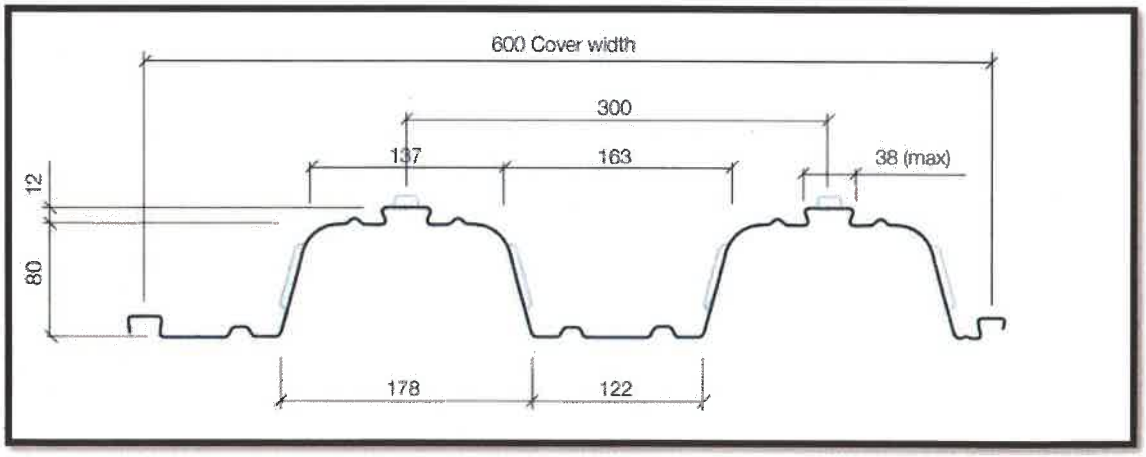

Fig. 1 Typical deck profile sheet (TR80)

- 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.

- Structural steel connection bolts shall of grade 8.8 as per IS: 1367.

- Anchor bolts shall be of grade 4.6 as per IS: 1367.

- 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.

The flooring and waterproofing is used as per specifications.

4. LOADINGS

4.1 Dead Loads:

Following unit weights of building materials have been considered in accordance with Cl. 2.1, table 1IS: 875 (Part I) -1987:

Description	Density of material
Reinforced cement concrete (up to 5% steel)	25 KN/m^3
Screed concrete floor	20 KN/m^3
Brick masonry including plaster (12mm plaster)	22 KN/m^3
Cement mortar / plaster	20 KN/m^3
Floor finish (stone/tile)	24 KN/m^3
Brick bat Cuba for terracing/waterproofing roof	20 KN/m^3
Glass	25.0 KN/m^3
Façade Load	2.5 KN/m/R/m height
Moist, sweet earth for filling of planters	20 KN/m^3
Foam Concrete	10 KN/m$^/$
AAC Block Masonry	10 KN/m^3
Thermos Col 25 kg/cum	0.25 KN/m^3
TR-60	0.111 KN/ m^2

Table 2 Unit weights of building materials

4.2 Super Imposed Dead Loads:

Following SIDL weights have been considered in accordance with unit weights given in Cl. 2.1, table 1IS: 875 (Part I) -1987:

LEVELS	LOAD TYPE	SIDL(Kn/m2)
Station Building		
Typical floor (75mm floor finish)	Floor Finish	1.5
Toilet (140mm floor finish)	Floor Finish	3.5
Air Concourse		
Floor (150mm floor finish)	Floor Finish	3.0
Platform		
Floor (50mm floor finish)	Floor Finish	1.0
FOBs		
Floor (75mm floor finish)	Floor Finish	1.5
Residential quarters		
Floor (50mm floor finish)	Floor Finish	1.0

Table 3 Superimposed Dead Loads

Live Loads: Live loads considered in design are in accordance with table 1, IS:875 (Part II)-1987 for type-Assembly Buildings. (Live loads used are ≥ those mentioned in code)

LEVELS	LOAD TYPE	LL(Kn/m2)
Station Building		
	Typical floor	5
	Toilet	2
	Electrical	7.5
	AHU	7.5
	Staircase	5
	Machine Room	10
Air Concourse		
	Typical floor	5
	Staircase	5
	Roof	0.75
Platform		
	Roof	0.75
FOBs (IRC6 Cl. 206.1)		
	Floor	5
Residential quarters		
	Typical floor	2
	Toilet	2
	Passage & stair case	3
	Terrace	1.5
	Water Tank	AS per actual

Table 4 Live load

Services Loads:
Services load of 0.5 KN/m^2 taken on all floors of Station buildings and 1 for Concourse. (Except staircase)

Partition Loads:
Partition load of 1.0 KN/m^2 taken on all floors of Station buildings and Concourse. (Except staircase)

Collateral Loads:
Wherever applicable, following Collateral loads are taken:
1. Solar Panel (or as per actual if higher)- 0.25KN/m^2

4.3 Wall Load- Fly ash blocks:
Considering plaster of 12mm on one face and 12mm on other face.
- 200mm.thk. Wall = (0.2mx1mx1mx10 KN/m^3) +((0.012m+0.012m) x20KN/m^3)=2.48 KN/m Ht

- 100mm.thk. Wall = (0.1mx1mx1mx10 KN/m^3) +((0.012m+0.012m) x20KN/m^3) =1.48 KN/m ht

4.4 Wind Loads:

Wind load design parameters shall be as per IS: 875 part-3 2015, (cl 4.2.2 NBC 2016 vol-1, part6) as listed below

DESCRIPTION	FOR	VALUE	REFERENCES
Basic Wind speed	V_z	$V_z=V_b.k1.k2.k3.k4$	IS:875 (Part 3), Cl. 6.3
Risk Coeff. Factor	k1	1.07	Table 1 of IS:875 (Part 3), Cl. 6.3.1, Sl. IV
Terrain roughness and height factor	k2	1.06	Table 2 of IS:875 (Part 3), Cl. 6.3.2.2, Sl. IV(30m), Terrain cat. 3
Topography Factor	k3	1.0	IS:875 (Part 3), Cl. 6.3.3, Upwind Slope θ=0
Importance factor for cyclonic region	k4	1.0	IS:875 (Part 3), Cl. 6.3.4, All other structures, No coastal area
Design wind speed at height z	V_z	47x1.07x1.06x1.0x1.0 =53.30	calculated by IS:875 (Part 3), Cl. 6.3
Design wind pressure at height z	Pz	$0.6xV_z^2=0.6x53.30^2$ =1705 N/m^2	IS:875 (Part 3), Cl. 7.2
Design wind pressure	Pd	Kd.Ka.kc,Pz	IS:875 (Part 3), Cl. 7.2
Wind directionality Factor	Kd	0.9	IS:875 (Part 3), Cl. 7.2.1
Area averaging factor	Ka	0.9	Table 4 of IS:875 (Part 3), Cl. 7.2.2, Sl. III(>25m)
Combination factor	Kc	0.9	IS:875 (Part 3), Cl. 7.3.3.13
Design wind pressure	Pd	0.9x0.9x0.9x1705 =1243 N/m^2	IS:875 (Part 3), Cl. 7.2
Internal pressure coefficient	Pi	+0.2 or -0.2	IS:875 (Part 3), Cl. 7.3.2.1, opening less than 5 %
		+0.5 or -0.5	IS:875 (Part 3), Cl. 7.3.2.2, opening 5 % to 20 %
		+0.7 or -0.7	IS:875 (Part 3), Cl. 7.3.2.2, opening more than 20 %

Table 5 Wind parameters

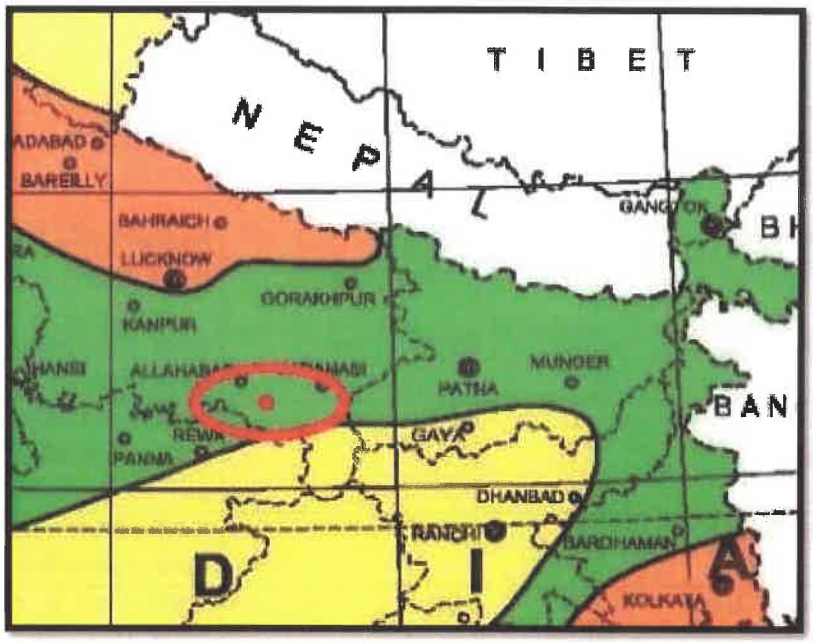

Fig. 2(a) & 2(b) Wind speed as per NBC 2016

Basic Wind speed up to 10m height is 47m/s as per per cl 4.2.2 NBC 2016 vol-1, part6, section1 Annex-C.

4.5 Seismic Loads:

Seismic load parameters shall be considered as follows

DESCRIPTION	FOR	VALUE	REFERENCES
Seismic Zone Coefficient	- ZONE -III	0.16	Table 3 of IS:1893 (Part 1), Cl. 6.4.2
Response reduction factor	R		Table 8
Importance Factor	I		Table 7
Rock or soil sites factor	Medium soil	2.0	Table 4 of IS:1893 (Part 1), Cl. 6.4.2.1
Damping Ratio	(For all structures)	5.00 %	IS:1893 (Part 1), Cl. 7.2.4
Time period of the structure			To be calculated as per building geometry and type of construction.

The importance factor for various structures under consideration in this report is derived based on table 8 (Clause 7.2.3).

Structure	Importance factor	Lateral load resisting system
Air concourse	1.5	Important service & community buildings or structures
Station Building	1.5	Important service & community buildings or structures
Parcel/Arrival/Office Building	1.5	Important service & community buildings or structures
Residential Tower Building	1.2	>15.00 meter high buildings
Through roof	1.5	All other buildings
Cover on platform	1	All other buildings
Foot over bridges	1.2	IRC - 6 Cl. 219.5.1.1

Table 7 Importance factor (Table 8 of IS:1893 (Part 1), Cl. 7.2.3)

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 IS800:2007:

Structure	Response reduction factor	Lateral load resisting system
Air concourse	5	Special Moment Resisting Frame (SMRF)
Station Building	5	Special Moment Resisting Frame (SMRF)
All other buildings	5	Special Moment Resisting Frame (SMRF)
Residential Building	5	Special Moment Resisting Frame (SMRF)
Through roof	5	Special Moment Resisting Frame (SMRF)
Cover on platform	5	Special Moment Resisting Frame (SMRF)
Foot over bridges	1	IRC - 6 Cl. 219.5

Table 8 Response reduction factor (Table 9 of IS:1893 (Part 1), Cl. 7.2.6)

According to note 1 of Table-9 of IS1893:2016, RC and steel structures in Seismic Zones III, IV and V shall be designed to be ductile and hence, OMRF (ordinary moment resisting frames) are not allowed in those seismic zones.

- Fixed column bases and their anchor bolts should be designed to withstand a moment of 1.2 times the full plastic moment capacity of the column section
- Both fixed and hinged column bases shall be designed to withstand the higher of full shear under any load case or 1.2 times the shear capacity of the column section.

Soil Type

Types of soils are classified as Type I, Type II and Type III according to IS1893:2016 (Clause 6.4.2.1). 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.

Based on the type of foundation and soil, the net bearing pressure in soils can be increased as per Table 1 and Table 2 of IS1893:2016.

A Ground Type II is assumed for this project (As per Doc no. 75-W-258-NCRPRJ-G-001), and. Annex C of IS 1893-Part 1: 2016 provides an indication of the range of geologies of India.

Allowing for superficial weathered rocks and superficial deposits such as alluvium, which is shown to be extensive in northern India, Ground Type II has been assumed. This applies to medium stiff ground profiles and also assumes that the ground is not susceptible to liquefaction or cyclic softening under the design earthquakes.

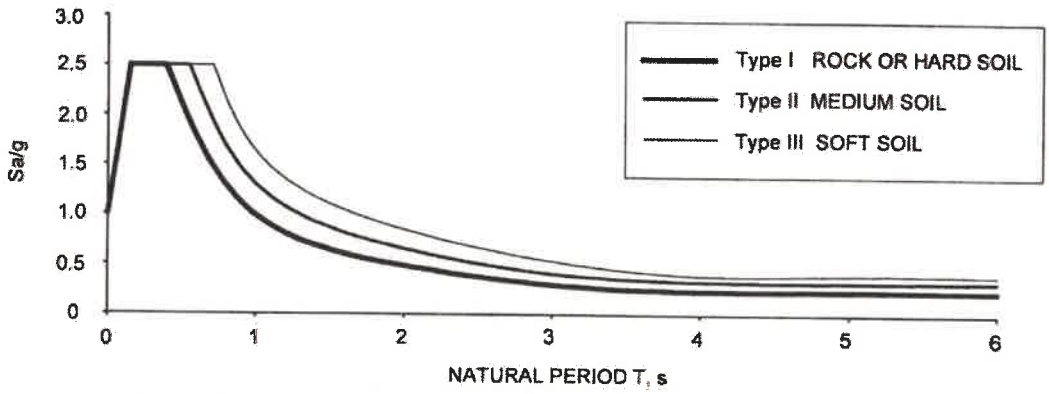

Fig. 4 Design acceleration coefficient (Sa/g) as per IS1893-part1: 2016

SEISMIC WEIGHT

Clause 7.3 of IS 1893 specifies to consider full dead plus percentage of imposed load for estimating design seismic force. In compliance with clause 7.3.2, imposed load on roof except equipment and permanently fixed facilities need not be considered. Hence, for through roofs and cover on platforms no imposed load is assumed to contribute to the seismic weight of the structure.
However, for air concourse, where imposed load is above 3 kN/m^2, 50% of total imposed load shall be considered in calculation of seismic weight (table-10, clause 7.3.1).

Seismic Analysis Methods

Response spectrum method of dynamic analysis shall be employed for all type of structures, including foot over bridges.

Damping Ratio
According to clause 7.2.4 of IS1893:2016, irrespective of the material of construction, the value of damping shall be considered as 5% of critical damping for estimating horizontal seismic coefficient Ah.

Vertical Earthquake Effect
In compliance with clause 6.3.3.1 of IS1893:2016, when the structure is
(i) Located in seismic zone IV or V or
(ii) Having vertical or plan irregularities or
(iii) Rested on soft soil or
(iv) A bridge or
(v) Having long spans or
(vi) Having large horizontal overhangs of structural members or subsystems
The effects due to vertical earthquake shaking shall be considered. Therefore, due to the length of span vertical effects shall be considered for both the Zone III and Zone IV case.
The design seismic acceleration spectral value Av shall be calculated as:

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

With reference to Table 5 (v), buildings undergo complex earthquake behaviors and hence damage, when they do not have lateral force resisting systems oriented along two plan directions that are orthogonal to each other. Hence, in compliance with clause 6.3.2.2 and 6.3.4.1 of IS1893:2016, such building systems shall be designed for earthquake load combinations listed below. Seismic vibration in the longitudinal, transverse and vertical directions shall be combined following the rule:

$$r1 \pm 0.3\ r2 \pm 0.3r3$$

(IS1893:2016 cl. 6.3.4.1, IRC: SP: 114-2018, cl.4.2.2)

where r1 is the leading seismic direction and r2, r3 are the remaining seismic directions.

4.6 Temperature & Shrinkage Loads:

The temperature load shall be applied in case length of structure is more than 45m for seasonal and diurnal variation and for shrinkage effects; it is to be converted into equivalent temperature for applying in analysis model. In view of maximum and minimum peak temperature data available, temperature load of 40° C will be considered in design of open terrace and shrinkage load of -5° C shall be applied on every floor. Temperature load is not required for intermediate floor due to constant temperature load.

5. Method of Design

Design Methodology:
The design of Composite Columns & beam shall be done using AISC: 360-2010 -LRFD method.
RCC structures shall be designed as per IS456-2000 and SP-16.
Limit state method shall be followed as per IS 800-2007 for design of steel structures and connection designs.
The considerations for the design of structure should be as follows:
(a) Structure safety and stability.
(b) To meet the demands of aesthetics conceived by the Architect.
(c) Availability of material, equipment and expertise.
(d) Constructability and ease of maintenance.

(e) Durability.
(f) All RCC structural members shall conform to provisions of IS 13920.

LOAD COMBINATIONS:
Serviceability load combinations and Limit state of collapse load combinations shall be used for analysis and design as per table 18 of IS 456:2000, cl. 6.3.4.1 of IS 1893(part1):2016 and table 4 of IS 800:2007.

Load combinations Used for Strength, Serviceability are tabulated below:
For the purpose of computing stresses and deformations, the following minimum load types and consequential effects shall be considered as applicable.

Dead Load	DL + SDL
Live loads	LL
Non-Reducible Live Load	NRLL
Seismic Loads in X-Dir	Eqx
Seismic Loads in Y-Dir	Eqy
Wind Load in X-Dir	WLx
Wind Load in Y-Dir	WLy
TEMP Raise	TR*
TEMP Fall	TF*
Scaled Seismic Loads in X-Dir	Rx
Scaled Seismic Loads in Y-Dir	Ry

Table 9 Load Types and notation

Serviceability load combinations and Ultimate load combinations used for analysis and design as per IS 456 and IS 1893 is as follows:

Load Combination	Dead Load (DL)	Live Load (LL)	Seismic Load (EQ)	Wind Load (WL)	Temp Load (TR/TF)
DL + Live/Temp	1.0	1.0	-	-	1.0
DL + EQ	1.0	-	1.0	-	
DL + Wind	1.0	-	-	1.0	
DL + live + EQ/Wind	1.0	0.8	0.8	0.8	

Table 10 Limit State of Serviceability Load Combinations

Load Combination	Dead Load (DL)	Live Load (IL)	Seismic Load (EQ)	Wind Load (WL)	Temp Load (TR/TF)
DL + Live/Temp	1.5	1.5	-	-	1.4
DL + EQ	1.5 or 0.9	-	1.5	-	
DL + Wind	1.5 or 0.9	-	-	1.5	
DL + live + EQ/Wind	1.2	1.2	1.2	1.2	
DL + live + Temp	1.05	1.275	-		1.05

Table 11 Limit State of Collapse Load Combinations

1) $1.2\,[DL + IL \pm (EL_X \pm 0.3\,EL_Y)]$ and
$1.2\,[DL + IL \pm (EL_Y \pm 0.3\,EL_X)]$;

2) $1.5\,[DL \pm (EL_X \pm 0.3\,EL_Y)]$ and
$1.5\,[DL \pm (EL_Y \pm 0.3\,EL_X)]$; and

3) $0.9\,DL \pm 1.5\,(EL_X \pm 0.3\,EL_Y)$ and
$0.9\,DL \pm 1.5\,(EL_Y \pm 0.3\,EL_X)$.

Table 11a Orthogonal Seismic Load Combinations

Notes:
- Earthquake and wind loads are reversible
- Wind load and earthquake loads are considered for both x & y directions. Whenever imposed load is combined with earthquake load, the appropriate part of imposed load as specified in IS: 1893-2016 / Clause 7.3.3 of seismic code will be used both for evaluating earthquake effect and for combined load effects used in such combination.
- Serviceability loads combinations with suitable live load reduction factor as per IS: 875 (Part-2) will be used for foundation design.
- For construction stage loading, 1 DL + LL of 100kg/m^2 to be considered.

Connections design
The connections should have the required capacity considered after redistribution of moments. There is no possibility of brittle failure since the ductile connections will permit rotation at the joint resulting in no possibility of sudden failure.

Stability:
Stability of structure against overturning and sliding as per Clause 20.0 of IS: 456-2000 is followed in the design and listed as below:
- Factor of safety against overturning:
  Restoring moment to be at least 1.2 times the maximum overturning moment due to the characteristic dead load and 1.4 times the maximum overturning moment due to the characteristic imposed loads.
- Factor of safety against sliding: 1.4
  In both the above cases, 0.9 times of characteristic dead load only to be considered in the design.

Serviceability Requirement:
This is given with following limitations:

- For Vertical deflections (Total load deflections) =Span/250 for Serviceability.
- Span/360 for material susceptible to braking.
- Lateral displacement of Structure=Height/ 500.
- Drift shall be 0.4% of story height.
- For Cracking-

For all RCC elements shall be cracked section and limiting crack width to 0.2 mm.

Drift- The maximum horizontal relative displacement due to earthquake forces between two successive floors shall not exceed 0.004 times the difference in level between these floors.

Floor vibrations
Floors can be subjected to impulse loading due to a variety of sources in buildings resulting in vibrations being felt by building occupants. Typically, in buildings, the most significant cause of floor vibrations is walking excitation, and levels must be kept within certain limits to ensure that adverse comments from building occupants are kept to a minimum, walking acceleration shall be less than $\frac{a0}{g} = 0.005$ and calculation shall be adopted direct from Etab.

Property Modifier for RCC framed building:
Cracked RC section properties shall be modified separately for serviceability limit state (SLS)and ultimate limit state(ULS) design as per the Table-6 of clause 7.2.C of IS 16700-2017 or as per clause 6.4.3.1 of IS1893-2016

S.No.	Structural Element	For SLS Condition		For ULS Condition	
		Area	Moment of Inertia	Area	Moment of Inertia
1	Slabs	1.0 Ag	0.35 Ig	1.0 Ag	0.25 Ig
2	Beams	1.0 Ag	0.70 Ig	1.0 Ag	0.35 Ig
3	Columns	1.0 Ag	0.90 Ig	1.0 Ag	0.70 Ig
4	Shear Walls	1.0 Ag	0.90 Ig	1.0 Ag	0.70 Ig

Table 12 Property modifiers used

Where

- Ag Represent gross area of member
- Ig Represent gross moment of Inertia of member

6. Analysis methodology and software used

The buildings shall be analyzed by 3d analysis and design software considering the relevant Indian Standard Codes. Applicable Dead, Live, Wind and Seismic Loads along with appropriate load combinations shall be considered. Software like ETABS, STAAD, and SAFE shall be used for analysis and design.

For concourse, the floors comprise of RCC slabs over deck sheet, which is supported over structural beams (plate girders) in a composite manner. This mechanism will ensure that the in-plane stiffness is so large that no two nodes can move relatively to each other. That is, they all translate or deform together as well as there is no elongation/strain developed. Therefore, a Rigid Diaphragm action shall be assumed in the 3d analysis so that the transfer of load to frames and shear walls is facilitated depending on their flexibility and their location in the structure.

For design of individual elements suitable excel spreadsheets are to be used.

Additional Considerations To Design Method

Expansion Joint:
Expansion joints are recommended when structure exceeds 45m length. The width of the joints shall be calculated as per IS-1893-2016, clause7.11.3.

7. Concrete Cover

Nominal concrete Clear Cover to All Reinforcement Including Links (As per Clause26.4 of IS: 456-2000) considering Environment condition is Moderate & fire resistance of 2 hrs.

Structural Element	Face	Nominal Cover
Foundation	All sides	50 mm
Column	All sides	40 mm
Shear Wall	All sides	30 mm
Beams	For Continuous For Simply Supported	30 mm 40 mm
Slabs	Continuous floor Simply supported floor	25 mm 35 mm
Retaining wall	Earth side Inside Water Side (Water Tank) STP wall Liquid face	30 mm 30 mm 30 mm
Deck Slab	Top side Bottom side	30 mm 50 mm

Table 13 Concrete Cover