



STRUCTURAL DBR

VOL – IV

**CONSTRUCTION OF PROPOSED CENTRE OF EXCELLENCE OF
FIRE TESTING TRAINING AND RESEARCH LABORATORY AT IIT,
PATNA**

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1. PROJECT BRIEF :

The proposed Construction of proposed centre of excellence of fire testing training and research laboratory at IIT Patna will be equipped to evaluate the fire safety performance of materials, structural assemblies, and building systems in accordance with **national (BIS/IS codes) and international standards (ASTM, ISO, Eurocode) (as per requirements)**. The facility will include **fire resistance test furnaces, reaction-to-fire testing equipment, smoke density measurement systems, and flame spread apparatus**, enabling comprehensive analysis of fire behaviour. The proposed G+2 building has been segregated into 3 parts :

S.N	Description for Centre of excellence of fire testing training and research laboratory at IIT Patna	Building Height	Building Area (Excluding the area of cavity , also area may vary during construction)
1	Live Fire Testing Building	G+2	452.94 Sqm
2	Fire Testing Laboratory	Ground	792 Sqm
3	Institute	G+1	588.0 Sqm
	Total Area		1832.94 Sqm

2. 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 which 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. 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 and functional integrity of overall structure in building.
- Desirable Structural performance under characteristic service design loadings
- Resistance to load due to natural phenomena i.e., wind and earthquakes.
- Structural durability and maintainability of the building.

The entire Structural Design and drawings has to be Vetted by an IIT. After getting Vetted from IIT the Structural Design shall also be approved by BCD before execution. All drawing/ soft drawings /fabrication drawings are to be vetted by IIT with their seal, signature date & forwarding letter. All structural models, analysis files with soft copies of all drawings (in both CD and Email) shall be shared with the CE (Design) office BCD, Patna. If required the structural consultant will have to visit the CE(Design) office for a brief discussion and explanations whenever required.

3. DESIGN PHILOSOPHY

The building is divided into 3 parts and each part is designed differently.

S.N.	Building Name	Description
1	Live Fire Testing Building	1. Design Considerations & Details are to be followed to make all buildings Earthquake Resistant as per zone 5 &

		<p>Importance factor 1.5 and fire rating consideration up to 4 hours as per NBC clause 4.1 (Fire assemblance of different fire rated material)</p> <ol style="list-style-type: none"> 2. The proposed structural system for the building comprises of RCC framed structure consisting of Beam, Slab and Column to resist static as well wind/seismic load for all building structure. To achieve complete utility of space, columns are spaced at strategic locations as per Architectural drawing. All the columns shall have isolated, raft or pile foundations based on the Soil investigation report, loads and relative locations of the columns. Safe Bearing Capacity shall be considered as per the soil investigation report. The proposed structure shall be designed as per the Fire Safety Norms and to withstand the high temperature up to 1000 degree Celsius up to 4 hours. 3. The proposed structure shall be a frame of refractory concrete finished with refractory brick, refractory mortars, fire rated glass door and windows are proposed in form of sandwich panel with an air gap as per the specification provided by the vendor, cavity wall wherever required with an air gap as mentioned in the architectural drawing and with proper ventilation as per the approval from the Engineer in Charge. 4. All internal surface of the building - wall, floor, ceiling, column, beam shall be finished with refractory bricks, with refractory mortar, refractory sealant and finished with intumescent paint (High temp. HR aluminium paint) to withstand fire by 4 hrs. 5. All electrical panel shall be placed on the external wall like – main panel, switch box etc, whereas electrical lighting fixtures which are inside shall be encased with the glass assemblies with rating of 4hrs. To electrical fixtures and equipment has to be fire rating up to 4 hrs as per the NBC clause 4.1. through fire rated material assemblies.
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2	Large scale Fire Testing Laboratory	<ol style="list-style-type: none"> 1. Design Considerations & Details are to be followed to make all buildings Earthquake Resistant as per zone 5 & Importance factor 1.2. 2. The proposed structural system for the building comprises of RCC frame consist of Beam, Slab and Column to resist static as well wind/seismic load for all building structure. To achieve complete utility of space column are spaced at strategic locations as per Architectural drawing. All the columns will have isolated, raft or pile foundations based on the Soil investigation report, loads and relative locations of the column. Safe Bearing Capacity shall be considered as per the soil investigation report. The proposed structure Shall be designed for carrying 10 tonne capacity overhead crane, firefighting equipment, wind load and load for polycarbonate sheet inclusive of load for persons needed during the time of cleaning of polycarbonate sheet. 3. This building will be designed as per the normal standard followed in IS standard code and NBC. But, high temperature material testing and simulation lab interior will be finished with refractory brick by refractory adhesive and sealant as per the NBC -IV and IS code and the surface (wall, floor, ceiling) will be painted with intumescent paint (High temp. HR aluminium paint) to withstand the temperature by 4 hrs. 4. The proposed truss and all steel members to be finished with intumescent paint (High temp. HR aluminium paint) to withstand the fire temperature by 4 hrs.
3	Institute	<ol style="list-style-type: none"> 1. Design Considerations & Details are to be followed to make all buildings Earthquake Resistant of the highest order as per zone 5 & Importance factor 1.2.

		<p>2. The proposed structural system for the building comprises of RCC frame consist of Beam, Slab and Column to resist static as well wind/seismic load for all building structure. To achieve complete utility of space column are spaced at strategic locations as per Architectural drawing. All the columns will have isolated, raft or pile foundations based on the Soil investigation report, loads and relative locations of the column. Safe bearing capacity shall be considered as per the soil investigation report.</p> <p>3. The structure to be proposed as per the standard code of practice.</p>
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Proper soil investigation **including liquefaction analysis** shall be carried out very precisely. For liquefaction analysis, MASW test as per Annexure- F of IS 1893 test is recommended. If soil is found liquefiable, proper mitigation of liquefaction shall be done and test should be carried out post-mitigation of the treatment. Post mitigation test results shall be vetted by IIT and subsequently approved by CE (Design) BCD, Patna.

3-D Analysis of all the building structures Shall be carried out with dynamic analysis using STAAD.PRO/ETABS/SAFE software. The structural model along with the soft copies of AutoCAD drawings and analysis results (with calculations sheets of foundations and other structural members) must be shared with the office of CE design (in both CD and email). If required, the structural consultant shall have to visit the CE design office for a brief explanation of the project or its part. All designs shall strictly conform to the standards specified in clause.

Bricks shall be fly-ash brick for Large scale Fire Testing Laboratory and institute as per specification whereas as for live fire testing laboratory it will be refractory brick finished with refractory mortars.

Stability of non-structural members should be also checked as per relevant codal provision and BSDMA/ NDMA guidelines.

4. MATERIALS

The self-weight of the various elements is computed based on the unit weight of materials as given below: -

Material	Unit Weight (KN/m ³)
Steel	78.50
Plain Cement Concrete	24
Reinforced Cement Concrete	25
Refractory Cement Concrete	20-35
Refractory Mortars	22
Refractory Bricks	19.6
Cement Concrete Solid Block Work	20
Cement Concrete Aerated Block Work	10
Soil	20
Water	10
Aluminium	28
Glass	30
Density of Finishes	20
Cement Concrete Screed	24
Fire Rated Glass	30

4.1. Concrete

Concrete item	Grade(minimum)*	Max. size of Aggregate (mm)
Foundation	M30	20
Column	M30	20
Beams	M30	20
Slab	M30	20
Staircase	M30	20
Retaining walls	M30	20

Grade of concrete shall be as per approved design, suitable chemical admixture shall be used.

Foamed concrete wherever required shall be provided.

All the mix proportioning shall be done as per guidelines given in IS 10262:2019 and shall be carried out by any IIT.

4.2. Reinforcement

Steel reinforcement shall be of Grade Fe 550 D conforming to IS: 1786-1985.

Reinforcement bars shall be high strength deformed steel bars produced by thermo-mechanical treatment process of grade Fe550D, conforming requirement of IS 1786 (2008) and IS 9077-1979 (Reaffirmed 2018). Reinforcement binding should be done with galvanized iron binding wire. Galvanized iron binding wire thickness and material specification should as per IS 280 & others IS Code. Routine testing of reinforcement as per IS 1786 (latest revision) and binding wire should be done as per IS Code and direction of BCD

4.3. Structural Steel:

All structural steel used shall be confirmed to IS 2062. As per table 2 of IS 2062 (latest revision) steel grade E350 is used in design calculation of all members sizes with following properties.

Unit mass	7850 kg/m ³
E	200000 N/mm ²
Ultimate tensile strength	570N/mm ²
Yield stress	450N/mm ² for thickness less than 20 mm
	430N/mm ² for thickness between 20 to 40 mm
Percentage Elongation	20% (minimum)
Charpy V- notch energy	E>20J at RT

- **intumescent** paint shall be mechanically sprayed on all structural steel members. Intumescent paint shall be in conformity with IS code – 17044.

4.4. *Intumescent paint*

Fire-retardant (intumescent) coatings as per **IS 17044:2018** .These paints are designed to **swell under high temperatures**, forming an insulating char layer that protects the substrate and can provide **fire resistance ratings up to 240 minutes (4 hours)**. The specification covers **performance requirements, physical properties, durability tests, and fire exposure evaluations**.

5. LOADING PARAMETERS

5.1. *Imposed dead loads*

Apart from the superimposed live load, other dead due to stationary building elements are also mentioned here under, which arise due to walls, floor finishes, services, false ceilings, filling in sunken areas etc.

The imposed loads that are envisaged to act permanently (wherever applicable) are as following:

<u>Items</u>	<u>Minimum Intensity in kN/m² of plan area</u>
Weatherproof course & thermal insulation	4.0 or Depends on the thickness; slope and kind of material to be used for Weather proofing.
Floor Screed**25thk	0.5
Floor finish***	1.5 (or as per density of flooring)
Sunken portion in toilet with brick jelly concrete (200 thick)	4.0 (or as per density of filling material)

Above imposed load may be revised as per architectural and structural requirements.

In fire testing laboratory actual equipment loads shall be calculated and maximum value to be considered.

In toilet area the actual partition loads shall be calculated and maximum value considered.

** Floor screed of 25 mm thick shall be considered for the entire floor except roof.

***Floor finishes Load due to tile and bedding mortar.

5.2. Imposed Live loads

The superimposed load or otherwise live load assessed based on the occupancy classifications as per IS: 875 (Part 2) 1987 to be followed.

The concentrated loads are considered to be applied in position, which produce maximum stresses and where deflection is the main criteria.

5.3. Wind loads

Since building is B+2 floor structure, the impact of these loads is considered on structural design. The wind pressure shall be calculated on the provisions laid in IS: 875 (Part 3) – 2015.

Design wind speed= $V_z = V_b * k_1 * k_2 * k_3 * k_4$

V_b	Basic wind speed for Patna	= 47 m/s
k_1	Risk coefficient for all general buildings	As per clause 6.3.1 and table 1 of IS 875 (Part-III)
	(For a design life of 50 years)	
k_2	Terrain category 2	=1.0
k_3	Topography factor	=1.0 □ □
Based on the above, Design Wind Speed		

Design wind pressure (P_z) = $0.6 \times (V_z)^2$

Further to Design Wind Pressure (P_z) appropriate pressure coefficient will be used as applicable.

Wind loads on cladding/glazing:

For designing the cladding / glazing supports, the wind load will govern the design, for which Local wind intensity as per IS 875 (Part 3) will be considered.

Detail calculations for wind load analysis must be shared with the vetting institution as well as CE design office. The structure shall be assessed for Dynamic effects of wind as per clause 9.1. of IS:875/part 32015.

Z	Zone Factor for (Zone V)	0.36
I	Importance Factor	1.5
R	Response Reduction Factor (SMRF)	5.0

5.4. Seismic Loads

Demand of seismic forces must be assessed as per IS 1893:2016 and accordingly capacity of structure must be designed. In case of irregularity, the analysis must follow as per guidelines given in IS 1893:2016.

The loading due to earthquake is assessed based on the provisions of IS: 1893-2016 Part I. For seismic load calculations and analysis dynamic method as per Cl.7.7 of IS 1893:2016.

Part-I should be considered.

The seismic weight shall be calculated as per 7.4.1 of IS-1893:2016 with appropriate consideration of imposed load as per clause 7.3 of IS :1893:2016(Part – 1).

The number of mode shape shall be considered in such a way that mass participation factor in both direction is achieved upto 90%. Also it should satisfy table no-06 of IS-1893 Part-1. The combination of result for various mode is adopted using complete Quadratic Combination (CQC).The design base shear (V_b) shall be compared with a base shear (V_{bt}) calculated using fundamental period. In case V_b is less than V_{bt} , all response quantities.

All horizontal and vertical projections must satisfy requirements of Cl.7.12.2 of IS 1893:2016 Part I

Design of Compound walls must satisfy requirements of Cl.7.12.3 of IS 1893:2016 Part I

Design of footings must satisfy requirements of Cl.7.12.1 of IS 1893:2016 Part I

RCC Design and Detailing of members shall be done as per IS456:2000 and IS 13920: 2016.

The design horizontal seismic co-efficient (A_h) shall be determined by the following method.

$$=Z/2 \cdot I/R \cdot S_a/g$$

Where,

Medium soil will be considered as per soil report and Damping 5%.

Analysis should be done as per IS 1893 2016 and detailing should be done as per IS 13920 2016.

Since it is a very important building so it is advisable to check the analysis by performing non-linear dynamic analysis (time history analysis taking ground motion equivalent to 1934 earth quake of Bihar- Nepal).

5.5. Expansion joints & Seismic gaps

Live fire testing and training and High temperature material testing and simulation is separated with expansion joint. Structures with different structural behaviour and irregular geometrical shapes shall also be provided with expansion joints. Also, seismic gap should be maintained as per codal provisions/requirements. The construction of the joints should be made through specialised agency having well experience of SITC of seismic joints.

Seismic gap must be designed as per storey drift calculated (as per clause 7.11.3 of IS 1893:2016 Part I). Gap shall be made waterproof and to be filled with fireproof sealant without compromising seismic and fire safety clauses as per IS codes.

5.6. Soil Loads

i. Prevailing sub soil conditions

Soil Investigation is to be carried out by the EPC Contractor. Isolated/combined piled pile cap/raft foundations is to be designed as per soil investigation report.

ii. Soil loads on retaining walls

For the purpose of design of retaining structures such as STP, underground water tank retaining wall to sustain level differences, the following parameter will be considered.

iii. Assumed soil properties

Angle of shearing resistance $[\theta] = 30$ (Assumed) (should be used as per the soil investigation report).

iv. Load on soil

General surcharge on the soil retained $=q = 12 \text{ kN/sq.m}$ (should be used as per the soil investigation report).

v. Sub-soil water level

Partial submergence will be considered of evaluating pressure on the underground structures, thereby exerting saturated soil pressure on the retaining structures.

vi. Shrinkage Effect

Depending on the approved general arrangement of the structure, appropriate sequence could be recommended.

vii. Geo Technical Investigation

Geo technical investigation has to be done in connection of the said construction by the EPC contractor. Adequate bore holes for each structure to be done to get a representative report of the area of construction.

viii. Foundation system

Isolated Raft foundation/ Pile foundation shall be adopted as per the geo-technical report. with approval of CE (Design), BCD.

In case of pile foundation, suitable number of piles shall be tested for Initial Test/Routine Load Test/ Pile Integrity test as per IS 2911 as per codal provision.

6. NOMINAL COVER FOR REINFORCEMENT

From Durability requirement, exposure condition is assumed as '**Moderate**' for Structural elements below ground floor level.

The nominal cover to reinforcement to meet Durability requirement shall be as follows: -

Moderate - 30 mm

The nominal cover to main reinforcement shall be as follow

Column- 40 mm or dia. of longitudinal Reinforcement whichever is greater.

Raft foundation - 75mm

For Two-hour fire resistance requirement, the nominal cover to reinforcement shall be as follow: -

Slab - 35 mm for simply supported

25 mm for continuous

Beams - 40 mm for simply supported

30 mm for continuous

For any other element not specified above, clear cover shall be as per the clause 26.4 of IS:456-2016. Cover of concrete element should be given as per 2 hours fire rating. Refer NBC 2016 & IS: 456: 2000 for details.

7. PROPOSED APPROACH OF STRUCTURAL ANALYSIS

The building is an R.C.C. frame structure. After preliminary sizing of various structural members, a computer model of the structural frame of the building shall be generated for carrying out computer analysis for the effect of vertical and lateral load that are likely to be imposed on the structure.

The building model as prepared shall be analysed using Licensed STAAD.PRO/ETABS/ software for all possible load combinations as per IS Codes The most unfavourable effect of loads shall be chosen for design of structural members.

Floor analysis of typical floor – for vertical load with building space frame or plain frames in transverse / longitudinal directions or substitution frame in transverse / longitudinal directions.

Space frame analysis of the structure – for wind / earthquake load. Geometrical dimensions, member properties and member-node connectivity, including eccentricities will be modelled in the analysis problem. Wind / earthquake load derivations will be carried out using coefficients / factors in accordance with the relevant codes. The permissible values of the load factors and stresses will be utilized within the purview of the Indian Standards.

The computer analysis will produce individual member forces, reactions at foundation level and deflection pattern of the entire structure as well as individual member sizes and arrive at the most appropriate design of the structural members. Some re-runs of the analysis programmer might be required for arriving at the optimum structural space frame characteristics that satisfy the strength and stability criteria in all respects.

8. STRUCTURAL DESIGN METHODOLOGY

- All R.C. C members will be designed according to the limit state method as specified in IS: 456: 2000. Steel structures will be designed as per IS: 800 2007. Detailing of RCC members shall be done as per IS 13920 :2016 and IS 18168 :2023 for Steel members. Exposed steel members shall be painted with fire resistant material/ paint with 2 hours' fire rating.

Materials of construction will be predominantly concrete with consideration for strength and durability Minimum grade of concrete to be used shall be M30 Grade.

High yield strength Deformed bars conforming to IS: 1786 with $F_y = 500$ MPa will be used as reinforcement.

Cover to reinforcement shall be in accordance with IS 456 corresponding to moderate exposure conditions and to satisfy fire rating of 2 hrs.

- For steel truss / members:
SP – 38(1987) BIS

9. FOUNDATION SYSTEM

9.1. Foundations for Building

Isolated/ Raft foundation/ Pile foundation shall be adopted as per the geo-technical report with approval of CE (Design), BCD. The design of foundation shall suitably be carried either via manual calculations or through licensed software. Soft copies of foundation calculations and models must be submitted to the vetting institution and CE design office.

10. STABILITY OF STRUCTURES

For the purpose of stability of the structure as a whole against overturning, the restoring moment shall not be less than 1.2 times overturning movement.

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 dead load shall be ignored.

The factor of safety against sliding shall not be less than 1.4

Factor of safety against buoyancy shall be not less than 1.2 ignoring the superimposed loading.

10.1. Other Data

Fire testing Equipment loads, Lift loads and lifts machine room equipment and cut out layouts will be obtained from the concerned manufacturers. An impact factor of 100% will be considered in the supporting structures.

10.2. DESIGN STANDARDS

In the analysis, design and detailing of the building, the following relevant Indian Standard Codes shall be used.

1.	IS-875 (Part 1)-1987	Code of Practice for Design Loads (other than Earthquake) for buildings and structures – Unit Weights of buildings materials and stored material.
2.	IS-875(Part-2) - 1987	Code of Practice for Design Loads (other than Earthquake) for buildings and structures-Imposed loads.
3.	IS-875(Part-3) - 2015	Code of Practice for Design Loads (other than Earthquake) for buildings and structures-Wind loads.
4.	IS-875 (Part 5) - 1987	Code of Practice for Design Loads (other than Earthquake) for buildings and structures – Special loads and load combinations.
5.	IS: 456 - 2016	Code of Practice for Plain and Reinforced Concrete.
6.	IS 1893:2016	Criteria for earthquake resistance design of structures
7.	IS 13920: 2016	Ductile Detailing of Reinforced Concrete Structures
8.	IS: 1786 - 1985	Specification for High Strength Deformed Steel Bars and Wires for Concrete Reinforcement.
9.	IS: 432(Part 2) - 1982	Specification for Mild Steel and Medium Tensile Steel Bars and Hard Drawn Steel Wire for Concrete Reinforcement Hard Drawn Steel Wire.
10.	IS: 1904 – 1986	Indian Standard Code of Practice for Design & Construction Foundations in Soil: General Requirements.
11.	IS: 2062 – 1999	Steel for General Structural Purposes. Specification.
12.	IS: 1161 - 1998	Specification for Steel tubes for Structural Purposes.
13.	IS: 800 - 2007	Code of Practice for General Construction & design for Steel.
14.	IS: 4326 - 2013	Code of Practice for Masonry work.
15.	SP-34	Handbook on Concrete Reinforcement & detailing.

16.	SP-16	Reinforcement design of RC members.
17.	IS:3370-2009 part 1/2/3/4	Concrete structure for storage of liquid
18.	IS 16051	Fire Retardant Coatings — Method of Test
19.	IS 2042	Asbestos Cement Building Boards – Specification
20.	IS 1528	Methods of Tests for Solid Clay Building Bricks
21.	IS 195	<i>Methods for Fire Tests of Building Materials</i>
22.	IS 3809	<i>Fire Resistance Test for Electric Cables</i>
23.	IS 1641/42/43	<i>Code of Practice for Fire Safety of Buildings (General): General Principles of Fire Grading and Classification</i>
24.	IS 10570	<i>Specification for Calcium Silicate Building Boards</i>
25.	IS 17044	<i>Specification for Fire Retardant Coatings</i>
26.	IS 16947	<i>Cables for Power, Control and Instrumentation – Fire Survival Test</i>
27.	IS 6 / 8	Specification requirement for moderate heat duty fire clay refractories.
28.	SP 20	<i>Handbook on Masonry Design and Construction</i>
29.	IS-6042	<i>Code of practice for construction of light weight concrete block masonry</i>
30.	NBC PART IV	Fire and Life safety
In addition to this other Indian / British /European Codes to be followed as per Engineer in Charge Direction.		

EPC Contractor shall provide chairs at 1 chair/sqm minimum for foundation and also suitable cover blocks of grade same as RCC (M30).

Foundation shall be typically with 150mm local sand layer with 75mm brick flat soling with 100mm thick levelling course (PCC) over it.

Technical data sheet shall be made available to Design Wing, CE (Design) for checking and record purposes in soft copies and also in hard copies.

Wherever required NDT test shall be carried out by EPC Contractor.

11. LIST OF REFERRED IS CODES

Field Investigation

- i. IS: 1948-1970 Classification and identification of soils for general engineering purposes (first revision) Amendment 2.
- ii. IS: 1892-1979 Code of practice for sub surface investigations for foundations.
- iii. IS: 2132-1986 Code of practice for thin walled tube sampling of soils
- iv. IS: 6935: 1973 Method for determination of water level
- v. IS: 3043-1987 Practice For Earthing.

Laboratory tests

- i. IS: 2720-1983 (Part 1) Methods of tests for soils: Preparation of dry soil samples for various tests (second revision)
- ii. IS: 2720-1980 (Part-2) Methods of test for soils: Determination of water content (2nd revision) Amendment 1
- iii. IS: 2720-1980 (Part-3/Sec 1) Method of test for soil: Determination of specific gravity: Fine grained soils.
- iv. IS: 2720-1980 (Part-3/Sec 2) Method of test for soil: Determination of specific gravity: Fine, medium & coarse grained soils. (First revision) IS: 2720-1985 (Part-4) Methods of test for soils: Grain size.
- v. Analysis (Second revision) IS: 2720-1985 (Part-5) Methods of test for soils: Determination of liquid and plastic limit (Second revision).
- vi. IS: 2720 (Part-8) Determination of water content- dry density relation using heavy compaction. (First revision).
- vii. IS: 2720 (Part-10) Methods of test for soils: Determination of Shear strength Parameter using triaxial apparatus.
- viii. IS: 1498-1970 Classification and identification of soils for general engineering purposes.
- ix. IS: 3015-1987 Methods of Sampling and Test (Physical and Chemical) For Water and Wastewater.

Foundation Construction-

- i. IS: 1080-1986 Code of Practice for design and construction of shallow foundation on soils (other than raft, ring and shall) (Second revision).

- ii. IS: 1904-1986 Code of Practice for design and construction of foundation in soils: 1st Revision (Amendment 1).
- iii. IS: 6403-1981 Code of Practice for determination of bearing capacity of shallow foundation: First revision (Amendment 1).
- iv. IS: 2911 (part-III) Code of Practice for Design and Construction of Pile Foundations.
- v. IS: 2720 (part 16)-1987 Laboratory Determination of CBR IS: 8009 (part 2)-1980 Settlement for shallow & deep foundations.
- vi. IS: 1893 (Part-1) Criteria for Earthquake Resistant Design of Structures.
- vii. IS: 2950-1 (Part-1) Practice for design and construction of raft foundations.

12. LOAD COMBINATIONS

The various load shall be combined in according with the stipulations in IS: 875 (Part 5) – 1987. Whichever combination produces the most unfavourable effect in the building, foundation or structural member concerned shall be adopted.

Following load combinations of the member forces will be considered for arriving at the design forces.

The following abbreviations are used in specifying different load combinations:

- 1. DLF = Dead Load of floors
- 2. DLW = Dead Load of walls
- 3. DL = Dead Load (sum of DLF and DLW)
- 4. LL = Live Load
- 5. EQX = Earthquake Load in X direction
- 6. EQZ = Earthquake Load in Z direction
- 7. WLX = Wind Load in X direction
- 8. WLZ = Wind Load in Z direction
- 9. Where, X and Z are two principal axes.
- 10. DLF
- 11. DLW
- 12. DLF + DLW
- 13. LL
- 14. EQX

15. EQZ
16. WLX
17. WLZ
18. DL + LL
19. 1.5 (DL + LL)
20. 1.5(DL+EQX)
21. 1.5(DL-EQX)
22. 1.5(DL+EQZ)
23. 1.5(DL-EQZ)
24. 0.9DL+1.5EQX
25. 0.9DL-1.5EQX
26. 0.9DL+1.5EQZ
27. 0.9DL-1.5EQZ
28. 1.2(DL+LL+EQX)
29. 1.2(DL+LL-EQX)
30. 1.2(DL+LL+EQZ)
31. 1.2(DL+LL-EQZ)
32. 1.5(DL+WLX)
33. 1.5(DL-WLX)
34. 1.5 (DL +WLZ)
35. 1.5 (DL -WLZ)
36. 0.9DL+1.5WLX
37. 0.9DL-1.5WLX
38. 0.9DL+1.5WLZ
39. 0.9DL-1.5WLZ
40. 1.2(DL+LL+ WLX)
41. 1.2(DL+LL- WLX)
42. 1.2(DL+LL+ WLZ)
43. 1.2(DL+LL- WLZ)

For non-orthogonal Columns, the following additional load combinations shall be used in the design.

1. $1.2(DL+LL+EQX+0.3EQZ)$
2. $1.2(DL+LL - EQX- 0.3EQZ)$
3. $1.2(DL+LL+EQZ+ 0.3EQX)$
4. $1.2(DL+LL - EQZ-0.3EQX)$
5. $1.5(DL+EQX+0.3EQZ)$
6. $1.5(DL+EQX-0.3EQZ)$
7. $1.5(DL - EQX+0.3EQZ)$
8. $1.5(DL - EQX-0.3EQZ)$
9. $1.5(DL+EQZ+0.3EQX)$
10. $1.5(DL+EQZ-0.3EQX)$
11. $1.5(DL - EQZ+0.3EQX)$
12. $1.5(DL - EQZ-0.3EQX)$
13. $0.9DL+1.5(+EQX+0.3EQZ)$
14. $0.9DL+1.5(+EQX-0.3EQZ)$
15. $0.9DL+1.5(-EQX+0.3EQZ)$
16. $0.9DL+1.5(-EQX-0.3EQZ)$
17. $0.9DL+1.5(+EQZ+0.3EQX)$
18. $0.9DL+1.5(+EQZ-0.3EQX)$
19. $0.9DL+1.5(-EQZ+0.3EQX)$
20. $0.9DL+1.5(-EQZ-0.3EQX)$

13. GENERAL NOTES

General Notes for RCC / steel / other members shall be duly mentioned in all drawing and have to supplied along with working drawings. The following are included in the notes:

- a. Notes on reinforcement.
- b. Development length and lap length of reinforcement based on grade of steel and grade of concrete.
- c. Cover to reinforcement.
- d. Wherever required NDT test shall be carried out by EPC Contractor as instructed by BCD & no extra payment is payable to EPC Contractor for that.
- e. Exposed steel members shall be painted with fire resistant material/ paint with 2 hours' fire rating.
- f. Foamed concrete shall to be used as per the direction of engineer in charge wherever required/suggested by primary consultant and duly approved by BCD.
- g. If any re-baring of bars to be done; then pull out test confirm to strength shall be done as the frequency specified in the Indian Standard or International standard & no extra payment is payable to EPC Contractor for that.
- h. Any structural member shall be executed as per approved structural drawing duly vetted.
- i. Geo- technical Investigation has to be done by the EPC Contractor. Adequate no. of bore holes must be drilled so that the entire campus is covered. The soil investigation report must include the liquefaction analysis report.
- j. If the foundation system as recommended is by the consultant consist of Piles, the pile load test (initial/ routine/ integrity) shall have to be carried out by the EPC Contractor as per IS 2911 (Part 4): 2013. The foundation system as suggested shall have to be checked for uplift pressure and differential settlement.