حكومة رأس الخيمة
Government of Ras Al Khaimah

بلدية رأس الخيمة
Ras Al Khaimah Municipality

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لائحة شروط و مواصفات البناء
بإمارة رأس الخيمة

الاشتراطات الانشائيه

الإصدار (3)

حكومة رأس الخيمة

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Ras Al Khaimah Municipality

Ras Al Khaimah Municipality Structural Guidelines

RAKG-S-2021

Revision History

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Ras Al Khaimah Structural Guidelines-RAKG-S-2021.

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Contents

1. Introduction

1.1. Scope of Document

- This document is prepared to provide a sort of guidance for structural design engineers working on projects in Ras Al Khaimah. The main scope of this document is to provide main headings and important aspects which should be considered while processing the design of any project.
- The main objective of the structural guidelines is to ensure that all projects under the jurisdiction of Ras Al Khaimah Municipality follow a uniform approach for the design and construction of all structures. These guidelines seek to assist all structural engineers submitting project(s) to Ras Al Khaimah Municipality to better understand the minimum requirements for the design, review and checking the design of any structure with Ras Al Khaimah Municipality team during the approval process that will facilitate and ease the permits issuance. It is anticipated that the use of these guidelines will result in a unified form of design and construction of buildings throughout all types of structures.
- These Guidelines are intended to be used in conjunction with international, federal and local design codes, standards and other widely accepted references.
- In the case of any conflict between these guidelines and the mentioned design codes and standards, the requirements as outlined in the Ras Al Khaimah Municipality structural guidelines will prevail.

1.2. Disclaimer

- This document has been prepared only to provide some guidance for the design engineers and It shall be read in conjunction with all the applicable federal and local laws, codes, standards, regulations, circulars, manuals, policies and procedures as implemented by Ras Al Khaimah Municipality.
- All requirements indicated within this structural guideline may be amended whenever required and no prior notice required.
- The full responsibility and liability of the design and construction of any project is on the consultant and the contractor without any responsibility or liability on the municipality.
- Ras Al Khaimah Municipality is not liable for any defects, deficiencies, collapse or fatal mistakes in the design or execution of any project for which it has given approval.

2. General Requirements and Conditions

2.1. General Requirements

- Structural design for buildings and facilities shall be prepared by a qualified structural engineer licensed to practice the profession and approved by the Municipality.
- The structural calculations shall be prepared using recognized engineering software approved internationally.
- The structural package for the different structural elements shall be submitted by the approved consultant by Ras Al Khaimah Municipality.
- All buildings' parts and related building's materials shall have adequate safety and durability.
- Structures shall be designed to withstand the most critical straining actions resulting from the codified load combinations, provided that the effect of the maximum resultant loads shall not exceed the allowable stress limit of the construction material.
- Structures shall be designed to have sufficient stiffness to maintain any deformation due to vertical, horizontal loads and vibration within the allowable limits and without affecting the function of the structure.
- Structures shall be designed to ensure the overall stability and individual elements' stability under all loads' types and cyclic loads.
- All approved codes limits for strength, materials properties, durability and serviceability of structures are deemed to be satisfied wherever applicable.
- Concrete mix design should be satisfying specified codes requirements.
- Code minimum and maximum percentage of reinforcement related to different straining actions are deemed to be satisfied for all members.
- Reinforcement details, development lengths and splices should be according to specified codes requirements.

2.2. Third Party Requirements

- Third party review may be required for any of the following structures subjected to the pre-agreement with Ras Al Khaimah municipality:
  - Any building of height more than G+40 floors.
  - Irregular, complicated and un-usual structures.
- Whenever there is any doubt about the need for a third party reviewer for a project, it is the consultant responsibility to approach the Ras Al Khaimah Municipality to confirm the requirements for third party reviewer. The consultant shall raise an official letter to address the query.
- Ras Al Khaimah Municipality has the right to request a third party reviewer for any project if the consultant or specialist sub-contractor is found to be incompetent enough.
- The third party consultant shall be registered as a third part reviewer in any of the municipalities within United Arab Emirates, and shall be submitted to Ras Al Khaimah municipality for approval at the early stage of the design.
- Third party reviewer shall have similar experience in the project under review with proven track record of reviewing similar projects.
- Third party reviewer is required to adhere to Ras Al Khaimah municipality' design guidelines and circulars regularly.

2.3. Acceptable Software

The software approved by RAK Municipality as follows.

- CSI Software (ETABS, SAFE, SAP 2000 and CSI-Columns).
- MIDAS.
- STAAD.
- PROKON.
- SP COLUMN
- RAM CONCEPT.
- ADAPT.
- PLAXIS.

Any other internationally recognized software and regionally/locally standard software can be used for analysis and design subjected to pre-approval from the municipality.

2.4. Unit System

All structural calculations, analysis models' output, technical reports and drawings shall be presented in SI unit system.

The following table gives a guidance for the consistent SI units' system to be used:

Measurement item	Measurement unit
Levels	m
Dimensions	mm
Force	KN
Stresses	N/mm^2
Bending moment	KN.m
Bearing Pressure	KN/m^2
Temperature	C^o
Deformations/Deflection	mm

2.5. Building Life Time

Building life time shall be defined according to the code requirements, construction, regular maintenance and client requirements.

2.6. Fire Rating

- All structural elements and/or members shall have the following minimum fire rating unless otherwise noted by certified Fire and Life Safety specialist.
  - Two hours for horizontal elements.
  - Three hours for vertical elements and transfer elements.
- The proper fire rating for concrete elements shall be achieved by defining the proper element size/ concrete cover, and for steel elements shall be achieved by proper coating thickness of cementitious or intumescent materials.

3. Approved Codes and Standards

The following are the main codes and standards that shall be followed for the structural design along with the other American Concrete Institute (ACI) publications.

The defined version is the minimum approved publication version.

Publication Reference	Publication Title	Application of Publication
ASCE7-05	Minimum Design Loads for Buildings and Other Structures	Gravity loads, Wind loads and load combinations
UBC 97	Uniform Building Code	Seismic load
ACI318-11	Building Code Requirements for Structural Concrete	Concrete structural design
PCI 6th edition.	PCI Design Handbook - Precast and Pre-Stressed Concrete	Design of Pre-cast elements
ACI318-11	Building Code Requirements for Structural Concrete	Design of post tension elements
TR43 2nd edition	Post-Tensioned Concrete Floors Design Handbook (Second Edition)	
ACI 350-06	Code Requirements for Environmental Engineering Concrete Structure and commentary	Durability of concrete
ACI224R-01	Control of Cracking in Concrete Structures	
CIRIA 660-7	Early-age Thermal Crack Control in Concrete	
ACI562-19	Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings	Assessment and testing of existing structures
ACI364.1 R-94	Guide for Evaluation of Concrete Structures Prior to Rehabilitation	
AISC 360-05	Specification for Structural Steel Buildings	Steel structural design
AISC 341-10	Seismic Provisions for Structural Steel Buildings	
ACI 543R-12	Guide to Design, Manufacture, and Installation of Concrete Piles	Pile Design
	UAE Fire and Life Safety Code of Practice	Fire rating
IBC 2009	International Building Code	General

4. Materials

4.1. Concrete

- Minimum concrete grade for structural members is accepted as per code limits.
- Concrete grade is accepted up to f'c 70Mpa. Any concrete with higher grades cannot be used without prior approval from municipality.
- Modulus of elasticity has to be calculated in accordance with ACI 318 formula.

  $E_c = (4700 \sqrt{fc'})$ MPa.
- In case of using High Strength Concrete (HSC) with f'c more than 60MPa, the modulus of elasticity has to be calculated in accordance with Technical Report No.49's provided formula

  $E_c = (3320 \sqrt{fc'} + 6900) \times (Wc / 2346)1.5)$ MPa.
- Concrete grades input in design should be noted always as cylindrical compressive strength f'c.
- High strength concrete -if any- should be achieved via the addition of silica fume to the mix.
- The water/cement ratio in the concrete mix shall not exceed 0.40.
- A durable low heat of hydration concrete for sub structure elements (foundations, raft slabs and basement walls) can be achieved using a combination of OPC and GBBS in the concrete mix. GGBS percentage in the mix shall be within 36% to 65%.

4.2. Reinforcement

- Reinforcing steel shall be High Yield Strength deformed bars type 2 with minimum characteristic strength of fy =460 N/mm^2 unless otherwise justified by the designer.
- For shear design; the maximum yield strength to be used is fy=420 N/mm^2.
- All reinforcement shall conform to BS 4449 grade 460 or Equivalent ASTM specifications as a minimum.
- Welded wire mesh: Steel fabric reinforcement will comply with BS 4483 or Equivalent ASTM specifications.
- The preferred range of designated fabric types will be as per Table A.1 of BS 4483 or Equivalent ASTM specifications.

4.3. Structural Steel

- In accordance with procurement requirements typical in UAE, all steelwork shall adopt standard section dimensions as defined by British Standards. However, the material shall be procured to demonstrate compliance to ASTM standards and the design shall be in accordance with the provisions as defined herein in this report.

5. Loading Criteria

5.1. Loading Notations

The following loading notations are the recommended notations to be generally used in loading definitions such as load cases and load combinations in structural analysis software and calculations.

Load type	Notation
Self-weight	SW
Super imposed dead load	SDL
Live load-non reducible	LL
Live load-reducible	LLr
Mechanical load	Mech
Thermal load	T
Earthquake load	E
Wind load	W
Lateral earth pressure load	H
Water uplift load	F

5.2. Gravity Loads

5.2.1. Dead Loads

All Dead Loads are established based upon the self-weight of the structure and combined with the super imposed dead loads (finishes, partitions and other dead loads). The characteristic densities are listed under this section.

Self-weight of the primary structural elements shall be defined as a part of the material definition in the analysis software and not part of the applied superimposed dead load.

The following table illustrate the minimum density of the main materials to define the material self-weight.

Typical materials densities	
Item	**Density (KN/m^3)**
Reinforced Concrete; In-Situ Topping	25.0
Plain concrete	22.0
Normal weight screed (Typical finishes)	20.0
Plaster	20.0
Lightweight concrete fill U.N.O.	13.0
Glass	27.0
Steel	78.5
Landscaping / Retained wet soils	20.0
Dry soils	18.0

For Hollow block system (Hordi); the self-weight of the hordi blocks shall be considered in the analyses as per the actual weight of the blocks from the manufacturer data sheet.

5.2.1.1. Partitions

- As a general principle, the partitions' loads shall be applied as an equivalent uniform load. However, actual partition line load assignments shall be required in some instances. The blockwork type and density to be confirmed with architectural drawings and included in the submitted general notes drawings and calculation.
- The partition load shall be calculated in details as per the architectural layout.
- Minimum partition block density shall not be taken less than the following values unless proved otherwise by certified manufacture/supplier:

Typical block wall densities (unless otherwise provided from project supplier)	
Item	**Density (KN/m^3)**
Normal weight solid blocks	21.0
Normal weight hollow blocks (200mm thickness)	14.0
Normal weight hollow blocks (100mm thickness)	17.5
Light weight Aerated Autoclaved Concrete blocks (AAC)	6.0
Normal weight thermo blocks	15.0
Light weight thermo blocks	8.8

Uniform distributed load on plan due to partitions only shall not be taken less than the following minimum values.

Minimum partition distributed loads on plan	
Main Partitions Type	**Load (KN/m^2)**
Dry wall partitions	1.0
Light weight block partitions	2.5
Solid block work partitions	3.5

5.2.1.2. Finishes

The density of the finishes on the slab shall be 20 KN/m^3, and the actual thickness of the finishes shall be considered in the loading calculations.

Typical finishes distributed loads (unless otherwise calculated)	
Finish thickness (mm)	**Load (KN/m^2)**
50mm	1.0
75mm	1.5
100mm	2.0

5.2.1.3. Other Loads

A. Ceiling and services:

Load shall be 0.5 KN/m^2 as a minimum uniform load on plan to be considered unless more accurate calculation is available to justify lesser loads.

Moreover, the actual uniform load for the suspended services shall be calculated at the mechanical floors and parking floors' ceiling.

B. Façade load:

The actual façade load to be calculated and applied as a line load on the slab wherever applicable. In the case of having façade with more than one type of materials, equivalent line load to be calculated based on each material density and distribution.

In the absence of accurate façade load or justification from façade specialist; it shall be considered as 1.0 KN/m^2 (on elevation). This value is not applicable for the heavy façade system such as GRC, stone cladding, etc., it shall be calculated accurately.

C. Machines' plinth/base:

In the MEP areas, the equivalent load of the machine's support plinths to be calculated.

5.2.2. Live loads

5.2.2.1. Reducible Live load

The live loads with a value that not exceeds 4.8 KN/m^2 considered as Reducible live load.

5.2.2.2. Non-Reducible Live load

The heavy Live load with value exceeds 4.8 KN/m^2, car parking load and public assembly occupancies shall be considered as non-reducible live load.

5.2.2.3. Permanent Live Load

The Mechanical and water tanks load shall be considered as permanent live load. The Load of Mechanical zones to be calculated as per the equipment manufacturer catalogue. However, the Mechanical load value shall not be less than the value in the minimum live load values shown in the following table.

5.2.2.4. Minimum Live Loads

The following table represents the minimum distributed live load which shall be considered in the design. Any other live loads not mentioned shall be referred from ASCE7-05.

Description of Live Load	Uniform Load (KN/m^2)
Residential (***)	2.0
Hotel rooms (***)	2.0
Balconies (up to 9.3m^2 area)	3.0
Balconies (more than 9.3m^2 area)	5.0
Corridors between apartments/rooms	2.0
Lobbies and public corridors	4.8
Staircases	4.8
Public Spaces	4.8
Retail Areas	4.8
Offices	2.5
General Plant rooms and MEP spaces (**)	7.5
Transformers and generators rooms	10.0
Car park	3.5
Loading Bay Areas (unless accurately justified)	15.0
Fire truck routes	20.0
Roofs *	2.0
Non-accessible steel roofs / Dooms /Folded roofs	0.6
Gym / Health club	5.0
Cinema	5.0
Water storage (to be calculated according to water height)	10xh

Notes:

- (*) Roof usage shall be confirmed with Architectural drawings, the loads on roof used for garden or assembly purposes shall be 4.8 KN/m^2 as a minimum. Any loads for MEP equipment or water tanks on roof shall be considered separately.
- (**) The mentioned MEP loads is the minimum applied value unless required more values based on actual equipment loads.
- (***) For the design of all flat slabs and post tensioned slabs, a minimum live load of 3KN/m^2 shall be considered.
- It is allowed to round up the live load of 4.8KN/m^2 to 5.0KN/m^2 for simplicity without changing any of the relevant code conditions.

5.3. Soil Lateral Loads

Soil pressure load and water load shall be calculated based on the soil investigation parameters.

As applicable, Soil lateral loads shall be determined using the equations for the at-rest earth pressure coefficient (K_O) for the case of basement retaining walls, while it is allowed to use (Ka) only for the case of cantilever retaining walls.

Soil properties to be used in case of backfilled soil behind basement walls:

Where new fill is placed behind the retaining walls, the following provisions for the fill material properties is to be attained as a minimum unless more accurate details are specified by certified geotechnical engineer and properly supervised in site.

Soil Density ($kN/m^{3)}$	Average Angel of Internal Friction	K_O	K_a	K_p
18-20	30°	0.50	0.33	3.0

Soil properties to be used in case of shoring behind basement walls:

Where there is an existing shoring placed or casted directly against the native soils behind the retaining basement walls; the soil properties provided in the soil report shall be used for basement wall design.

Surcharge loads

For all permanent retaining structures, the vertical surcharge loading on retaining structure shall be considered as per the following cases;

Case	Surcharge loads (KN/m^2)
Adjacent building at higher level (on shallow foundation)	Actual loads from the building at foundation level (located at higher level)
Adjacent roads	20
Construction site (current or future)	20
Minimum value	5

5.4. Uplift Load.

When considering the requirement for water uplift loads in design, the following should be taken into consideration by the consultant:

- For the purpose of analysis and design, the actual water table level shall be considered plus minimum seasonal variation of 1.0m.
- Dewatering effect of neighboring areas shall be considered.
- The effect of future developments (canal, water bodies, landscaping…. etc.) on the water table level shall be considered.
- Minimum factor of safety for overall stability against uplift shall not be less than 1.10 and considering the self-weight only during permanent cases and temporary cases (e.g discontinuity of dewatering activity).
- The consultant shall include clear notes in the structural general notes drawings stating clearly at which level of construction the dewatering will stop.

5.5. Thermal Effect due to Seasonal Variation and Self-Straining Actions

- The design shall account for the forces and movements resulting from an imposed thermal load due to seasonal variation, considering building enclosure conditions and continuous long spans.
- Thermal loads shall be considered for concrete structures if the building length is more than 50m.
- Thermal loads shall be applied to any steel structure regardless the building length.
- The thermal load due to seasonal variation shall be applied in the 2D and 3D analysis models considering positive/negative effects as per the following minimum values.

Location	Structural Element	Temperature (C^o)
Below Ground (Basement)	Retaining walls/columns/shear walls/Beams/slabs (excluding Ground slab)	+/- 10
Ground level and upper levels (Superstructure)	Columns/shear walls/Beams/slabs/	+/- 20
General	Steel structural elements	+/- 25

When incorporating the requirement for self-straining loads in a design, the following should be considered:

- Creep effect.
- Thermal effect.
- Shrinkage effect (early and long-term).

Late pour strip can be provided to reduce the effect of the early thermal cracking only and subjected to proper calculation for the consultant.

5.6. Seismic Loads

The following requirements along with the requirements of the applicable code (UBC97) should be referred to when considering the technical requirements for seismic load design.

Item	Description
Applicable standards	UBC97
Seismic Zone	Zone 2A For all buildings unless otherwise exempted in the following clause.
Mass Source	100% Dead loads, 100% permanent live loads and 25% of non-reducible live loads (LL).
Damping Ratio	5% for concrete and 2.5% for Steel.
Importance factor “I” and ductility factor “R”	To be considered as per recommendations of the applicable codes and standards.
Effects of Vertical Component of Earthquake Ground Motion	To be considered in the dead load component of seismic load combination according to the applicable codes and standards adopted for analysis and design. Where; $E_v=0.5C_aID$ as per UBC97.
Elements supporting discontinuous members of lateral load resisting systems	To be designed using the provisions of the applicable codes and standards, with special seismic load combinations and appropriate overstrength factor (Ω).
P-Delta effect.	To be considered according to the following combination; 1.2(Dead loads) +0.5(Reducible live load) +1.0(Non-reducible live load)
Dynamic Analysis	To be considered as per recommendations of the applicable codes and standards.
Minimum Scale Factor for Response Spectrum Analysis	g*I/R $g=9.81\ m/sec^2$
Soil Profile	According to the soil report recommendation. When the soil properties are not known in sufficient detail to determine the soil profile type, Type S_D shall be used.
Mass Participation Ratio	To be checked for a minimum of 90 %.
Torsional Irregularity	To be calculated as per applied code, and additional eccentricity to be applied if any.
Orthogonal Effect	To be considered either by the SRSS method or X/Y direction + 30% of Y/X direction.

Exemptions:

- Detached one and two family residential villas including the attached service blocks.
- Less than G+4 residential buildings (e.g. 4 suspended slabs).
- Single story shops with height not more than 6m and total area of complex not more than 500m^2.
- G+1 shop with total height not more than 8m and total area of complex not more than 500m^2.
- Up to G+1 motel (small hotels with limited number of rooms).
- Service buildings of mosques (such as ablution building, Imam house).

Commentary:

- The following typical buildings shall be designed for seismic loads regardless the number of stories or height:
  - Any building housing facilities required for emergency support.
  - Hospitals.
  - Fire and police stations.
  - Governmental and public buildings.
  - Schools and universities buildings.
  - Hotels.
  - Mosques and minarets.
  - Churches.
  - Shopping centers and hypermarkets.
  - Cinemas and theaters.
  - Multi-function halls (such as but not limited to ballrooms, sports' hall, etc.).
  - Commercial and office buildings.
  - Multi story car parks.
  - Airport's buildings and aviation control towers.
  - Buildings which have special structural systems (such as but not limited; irregular shape, long spans, etc.).
  - Industrial buildings.

- All the buildings (even if not designed for seismic) shall include proper lateral resisting system arrangement to resist minimum magnitude of potential lateral loads.

  For example; it shall include at least one of the following systems:
  - Set of minimum 2 clear framing system in each principle direction.
  - Shear walls in each principle direction.
  - Proper core wall.

5.6.1. Seismic Scaling

- Whenever dynamic analysis is adopted; dynamic seismic load shall not be less than 100% of equivalent static loads at the base level.
- Base level definition is the level of foundation or at which major change in stiffness occurs.
- It is allowed to ignore the seismic mass bellow the presumed base level while studying the structural elements above the scaling level.
- Seismic scaling down is not allowed (e.g. dynamic is more than static).

5.6.2. P-delta Effects

- P-delta effects should be considered for all the buildings following UBC97 for a proper columns' design including the slenderness effect.

5.6.3. Torsional Irregularity

- Torsional irregularity shall be considered to exist when the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts of the two ends of the structure.
- Where torsional irregularity exists, as defined in UBC97, the effects shall be accounted for by increasing the accidental torsion at each level by an amplification factor, Ax, determined from the following formula:

$$A_x = \left[\frac{\delta_{max}}{1.2\,\delta_{avg}}\right]^2$$

Where;

δ_{avg} = the average of the displacements at the extreme points of the structure at Level x.

δ_{max} = the maximum displacement at Level x.

The value of Ax need not exceed 3.0.

5.7. Wind Loads

The following requirements along with the requirements of the applicable code (ASCE7-05) should be referred to when considering the technical requirements for wind load design.

Item	Description
Applicable standards	ASCE7-05
Wind Speed	45 m/s, 3-second gust measured at 10 meters' height above ground level for 50 years return period (For ultimate design). 38 m/s, for 10 years return period (For serviceability check).
Exposure Category	To be considered as per recommendations of the applicable codes and standards.
Importance factor "I"	To be considered as per recommendations of the applicable codes and standards.
Directionality Factor "K_d"	0.85
Gust factor "G"	To be calculated as per recommendations of the applicable codes and standards. Minimum value = 0.85.

Commentary and Exemptions:

- Wind load is mandatory for all steel structure buildings' types.
- Wind load is mandatory for all reinforced concrete structure buildings more than G+15 stories.
- Wind load may be exempted for reinforced concrete structure buildings below G+15 stories subjected to the municipality's engineer judgment based on the building behavior (such as but not limited to; the slenderness, building irregularity, special structural system, wind load effect governing the design for any structural element).
- It is the consultant responsibility to investigate the requirement for wind load application on the building before submission to the municipality.

5.7.1. Wind Tunnel Test.

- Wind tunnel test shall be conducted in the following conditions.
  - Irregular, complicated, unusual structure. It shall be pre-agreed with Ras Al Khaimah Municipality.
  - Tall buildings more than 40 stories above ground.
- Wind base shear from wind tunnel test shall not be less than 80% of the calculated code wind base shear.
- Maximum damping ratio shall be 2% for ultimate design and 1.5% for serviceability checks.

5.8. Helipad Loads

For Helipad load, ASCE7-05 requirements shall be followed in addition to the following requirements:

- Minimum live load of 5 KN/m^2 to be applied.
- Concentrated loads to be applied separately with factor 1.5 to cover the impact load of the helicopter.

- The application of the helicopter concentrated load shall be studied as per the worst-case scenario in terms of load location with reference to the slab geometry.

5.9. Minimum Lateral Forces

Each structure shall be analyzed for the effects of static lateral forces applied independently in each of two orthogonal directions. In each direction, the static lateral forces at all levels shall be applied simultaneously. For purposes of analysis, the force at each level shall be determined using the following equation.

$$\mathbf{F_x = 0.01W_x}$$

where

F_x = the design lateral force applied at story x, and

W_x = the portion of the total dead load of the structure (SW & SDL) located or assigned to level x.

Structures explicitly designed for stability, including second-order effects, shall be deemed to comply with the requirements of this section.

5.10. Loading Combinations

- The Ultimate limit states shall be in accordance with ASCE7-05 Section 2.3.2. These Load Combinations shall be used in the design of all structural elements. The Load Combinations producing the most adverse load effects will be used in the design.
- The Serviceability limit states shall be in accordance with ASCE7-05 Section 2.4.1. These Load combinations shall be used in the analysis of foundation capacities and reactions, and all the serviceability checks such as crack width limitation. The Load Combinations producing the most adverse load effects will be used in the design.

6. Serviceability Requirements

Adequate provisions shall be adopted to limit the deflection of structural elements and eliminate risk of damage to non-structural elements due to vertical deflection and inter-story drift.

6.1. Control of Deflection in Concrete Elements

- Immediate and long-term deflections shall be within code accepted limits for all concrete slabs and beams.
- Non-linear cracked sections properties and effect of shrinkage and creep shall be considered in deflection calculations.
- Modulus of rupture should be considered as per ACI435R-95 code requirements.

  $f_{cr}=0.33\sqrt{fc'}$
- Only actual provided top and bottom reinforcement should be considered in deflection calculations.

Structural Concrete Component Description	Load Combination	Limit
Vertical deflection of floor elements not supporting brittle elements or facade	Total deflection (long term deflection under sustained loads plus immediate deflection under non-sustained loads)	L/240
	Live	L/360
Vertical deflection of floor elements supporting brittle elements or facade	Total deflection (long term deflection under sustained loads plus immediate deflection under non-sustained loads)	L/240
	Total deflection occurred after attachment of non-structural elements (excluding immediate deflection occurred before the attachment of non-structural component).	L/480
	Live	L/360
Vertical deflection of transfer elements (beam or slab) (**)	Total deflection (long term deflection under sustained loads plus immediate deflection under non-sustained loads)	L/750

Notes:

- (**) In case of excessive deflection regardless the limit is achieved; the vertical deflection shall be considered in the design of the floors above subjected to the engineering judgment.

6.2. Control of Deflection in Steel Elements

Structural Steelwork Component Description	Load Combination	Limit
Vertical deflection of floor elements not supporting brittle elements or facade	Dead + Live	L/240
	Live	L/360
Vertical deflection of floor elements supporting brittle elements or facade	Dead + Live	L/240
	Live	L/360
	Differential Live	L/500
Vertical deflection of flat roofs not supporting brittle elements or facade	Dead + Live	L/180
	Live	L/240
	Wind*	L/240
Vertical deflection of flat roofs supporting brittle elements or facade	Dead + Live	L/240
	Live	L/360
	Wind*	L/360
	Differential Live	L/500
Vertical deflection of flat roofs not supporting any elements	Dead + Live	L/120
	Live	L/180
	Wind*	L/180
Vertical deflection of transfer element (**)	Dead + Live	L/750

Notes:

- (*) Wind load shall be 0.7x"50-year return period wind load" or "10-year return period wind load".
- The above deflection limits do not consider pre-cambering. Pre-cambering may be used to reduce the total deflection as deemed necessary.
- (**) In case of excessive deflection regardless the limit is achieved; the vertical deflection shall be considered in the design of the floors above subjected to the engineering judgment.

6.3. Control of Lateral Drifts

6.3.1. Seismic Drift

Buildings' lateral drifts under seismic loads should be checked against UBC97 code specified limits.

Structural Component Description	Limit	
Inelastic inter-storey drift	Fundamental period ≥ 0.7 sec	Floor height (h) / 50
	Fundamental period < 0.7 sec	Floor height (h) / 40

- Load combination for seismic drift shall be as per ultimate load combinations including seismic load case.

6.3.2. Wind Drift

Buildings' lateral drifts under wind loads should be checked against ASCE7-05 code specified limits.

Structural Component Description	Limit
Inter-storey drift	Floor height (h) / 400
Overall building drift	Building height (H) /500

- Load combination for wind drift check is D+0.5L+0.7W, where wind load (W) is based on the 50-year return period.
- Wind Inter-story drift and overall building drift shall be limited to the standards limits (ASCE7-05) for all the building wherever wind load is applicable.
- Wind Inter-story drift shall be considered in the design of façade and cladding system in order to be protected as required.

6.4. Human Comfort and Vibration

6.4.1. Building Acceleration

Buildings should be designed and checked to meet human comfort of occupants as required.

Buildings accelerations shall be checked for high rise buildings for wind loads (10-year return period), and shall be less than the following limits.

Occupancy	Maximum acceleration limit
Residential and Hotels	15 mg
Offices	20 mg

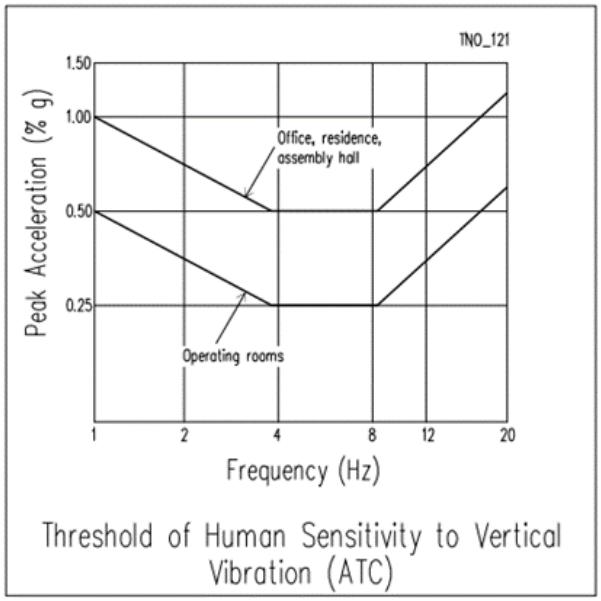
6.4.2. Vertical Vibration

Vibration check is mandatory for members subjected to dynamic loadings, all thin slabs (where span to thickness ratio is more than 42) and long cantilevers.

The susceptibility of floors to excessive vibrations due to walking excitation or equipment operation shall be assessed according to SCI Publication P354-“Design of Floors for vibrations” or DG11-“Floor Vibrations due to Human Activity”.

The following table provides the Vibration and Acceleration limits that shall be adopted in the design of the structures in terms of occupancy for the building facilities.

Occupancy	Acceleration Limit (%g)
Offices, Residential	0.5%
Dining, Dancing and Gym	1.5 to 2.5%
Aerobics, rhythmic activities only	4.0% to 7.0%
Shopping malls	1.5%



Alternative Approximated Approach

Vibration assessment based on the relation between natural frequency and deflection can be verified from the following formula.

$f = 18 / \sqrt{\delta_{(mm)}}$ for intermediate spans.

$f = 20 / \sqrt{\delta_{(mm)}}$ for cantilevers.

Where:

- δ is the maximum deflection due to loading in reference to the mass (m).

  It can be considered for 100% Dead loads and 10% Live loads.
- f is the natural frequency (1/T).
- Minimum natural frequency of 4 HZ can be used as a limit for a building of normal usage (e.g. residential, offices).

6.4.3. Other Considerations

- The consultant shall ensure for buildings with irregular façade shapes and where a potential noise expected to occur, the tonal noise generated as part of vortex shedding mechanism shall be properly addressed by wind specialist. The consultant is solely responsible to undertake the necessary study and to propose any effective remedial measures to resolve the problem (if any).

- Effects of axial long term shortening due to elastic, shrinkage and creep effects shall be investigated and accounted for in the design and construction. It is mandatory for buildings more than 40 stories.

  Deferential shortening between columns shall be limited to the minimum possible in order to minimize the impact on the horizontal elements design.

7. Structural Integrity

Buildings and other structures shall be designed to sustain local damage with the structural system as a whole remaining stable and not being damaged to an extent disproportionate to the original local damage. This shall be achieved through an arrangement of the structural elements that provides stability to the entire structural system by transferring loads from any locally damaged region to adjacent regions capable of resisting those loads without collapse. This shall be accomplished by providing sufficient continuity, redundancy, or energy-dissipating capacity (ductility), or a combination thereof, in the members of the structure.

7.1. Load Path Connections.

All parts of the structure between separation joints shall be interconnected to form a continuous path to the lateral force-resisting system, and the connections shall be capable of transmitting the lateral forces induced by the parts being connected. Any smaller portion of the structure shall be tied to the remainder of the structure with elements having the strength to resist a force of not less than 5% of the portion's weight.

8. Durability Requirements

8.1. Waterproofing Requirement

Waterproofing is mandatory for all members in contact with groundwater or soil.

Any waterproofing material specifications and methodology of application should be shown on the submitted structural drawings.

8.2. Control of Cracking

- Crack control for all parts of the structure should be satisfied following the requirements of ACI318, ACI 224R-01 and ACI_350 codes unless otherwise noted in this clause.
- Crack control requirements are not limited to structural members subjected to ground water.
- Early thermal and long-term cracking shall be verified for concrete structural elements according to CIRIA660-7.

Limiting cracks widths considered for different categories are presented in the following table.

Exposure condition	Limiting Crack Width (mm)
Structural elements exposed to humidity, moist air.	0.3
Structural element in contact with wet or dry soil (with or without ground water table). (e.g. Retaining wall's outer face, under-side of Raft).	0.2*
Water retaining structures. (e.g. Swimming Pool, Water Tanks).	0.1
Piles in contact with wet soil and under permanent tension stresses.	0.2

Note:

- (*) unless otherwise required for deep retaining walls and foundation below ground water table.

Maximum permissible crack width for deep retaining walls and foundation below ground water table should be defined as per the following chart.

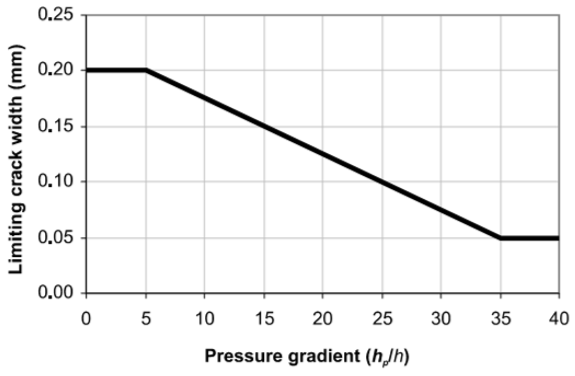


Figure 2.2 *Limiting crack width for self-healing related to pressure gradient across the section (EN1992- 3)*

Where:

- (h_f)is the depth of the water table till the soffit of the structural element.
- (h) is the structural element thickness.

8.3. Concrete Cover

The following clear concrete covers shall be provided as a minimum for different reinforced concrete elements unless otherwise required for fire rating and durability requirements.

Structural Element	Min. Clear Cover (mm)
Concrete for deep foundations (e.g. Piles)	75
Concrete permanently exposed to earth (e.g. Foundation and retaining wall's outer face)	75
Raft and basement retaining wall's internal face	50
Water tanks	50
Slabs	25
Beams	40
Ribs	25
Columns	40
Walls	30
Stairs	25
Transfer beams	50
Transfer slabs	45

8.4. Spacing Between Bars

The spacing between bars in different concrete elements shall be strictly followed as per ACI318, and considering all the conditions related to constructability (e.g. vibrator size and proper vibration for concrete compacting).

9. Concrete General Design Requirements

9.1. Cracking Stiffness Modifiers

All stiffness modifiers for ultimate limit state analysis should be as per ACI318 code provisions.

Element	Walls	Columns	Beams	Slabs	
			RC/PT	RC	PT
Required Cracked Properties	0.7Ig*	0.7Ig*	0.35Ig	0.25Ig	0.35Ig
Equivalent Stiffness Modifiers in 3D analysis (e.g. ETABS)	m_{11} =0.7 m_{22} =0.7 m_{12} =0.7 f_{11} =0.7 f_{22} =0.7 f_{12} =0.7	I_{33} =0.7 I_{22} =0.7 T =0.7	I_{33}=0.35 I_{22}=0.35 T =0.35***	m_{11} =0.25 m_{22} =0.25 m_{12} =0.25 f_{11} =0.25 f_{22} =0.25 f_{12} =0.25	m_{11} =0.35 m_{22} =0.35 m_{12} =0.35 f_{11} =0.35 f_{22} =0.35 f_{12} =0.35
Equivalent Stiffness Modifiers in 2D slab analysis (e.g. SAFE)	m_{11} =1.0 m_{22} =1.0 m_{12} =1.0 f_{11} =1.0 f_{22} =1.0 f_{12} =1.0	I_{33} =1.0 I_{22} =1.0 T =1.0	I_{33} =1.0 I_{22} =1.0 T =0.1	m_{11} =1.0 m_{22} =1.0 m_{12} =1.0 f_{11} =1.0** f_{22} =1.0** f_{12} =1.0**	N.A.

Notes:

- Where “m” is the flexural stiffness of shell elements, “f” is the membrane axial stiffness of shell elements, “I” is the inertia of frame elements and “T” is the torsional stiffness of frame elements.
- (*) Columns and walls cracking modifiers can be used 0.35 if proved by calculation that it is further cracked as per ACI318.
- Cracking modifiers of retaining walls can be reduced to f=m=0.35.
- (**) Membrane cracking modifiers in slab’s 2D model (f_{11},f_{22},f_{12}) during thermal analysis can be reduced to 0.25 for reinforced concrete slabs.
- (***) Torsional modifiers can be further reduced for compatibility torsion only. Beam should be designed to resist a minimum torsional moment equal to the code cracking torque (T_{cr}).
- Stiffness modifiers of transfer beams can be used as 1.0.

For service analysis models used for wind lateral drifts calculations, stiffness modifiers can be calculated by multiplying the ultimate reduced stiffnesses into 1.4 as per ACI318 code provisions.

9.2. Columns and Walls

- Columns shall be detailed as per Intermediate moment resistance frame requirements.
- Columns and walls shall satisfy the slenderness requirements of compression members as per ACI318.
- Moment magnification factor (δ_{sn}) for columns and walls shall not exceed 1.4.
- Column minimum longitudinal reinforcement shall not be less than 1% of column's cross section.
- Column maximum longitudinal reinforcement shall not be more than 8% of column's cross section at splice location.
- Wall minimum longitudinal reinforcement shall not be less than 0.4% of wall's cross section.
- If columns and walls' longitudinal reinforcement ratio is more than 4% (at the location other than splices' locations) mechanical couplers shall be used at splice locations.
- Mechanical couplers shall be used if spliced bar size is more than T32.

9.3. Beams

- Beams shall be detailed as per Intermediate moment resistance frame requirements. This is not applicable for coupling beams, coupling beams need to follow requirements of ACI318-11, clause 21.9.
- For beams subjected to equilibrium torsion, no torsion redistribution is allowed.
- For beams subjected to compatibility torsion only. Beam should be designed to resist a minimum torsional moment equal to the code cracking torque (T_{cr}).
- Beams shall be checked for long-term deflection limits.
- Mechanical couplers shall be used if spliced bar size is more than T32.

9.4. Slabs

- Slabs shall be designed for combined effect of gravity and self-straining action loads where applicable.
- Slabs shall be designed for combined effect of gravity and lateral loads (seismic or wind) where applicable.
- Slabs shall be checked for punching shear stresses due to combined effect of shear and unbalanced moment together as applicable.
- Punching shear shall be checked so that the ratio between the applied shear (actual) and the allowable concrete shear (without shear links) is not more than 0.9 due to pure gravity load combination, and not more than 1.0 for other load cases.

  If the ratio exceeds the mentioned limits above but not more than the maximum allowable limit (concrete with shear links); shear links shall be provided.
- Slabs shall be checked for long-term deflection limits considering cracking non-linear analysis, defined modulus of rapture and reinforcement as per clause 6.1.
- For non-monolithically construction between slab and vertical elements; the consultant shall ensure that the slab is checked for shear friction resistance at the connections' location.
- Concrete grade (fc') of columns/walls shall not be more than 1.4 times the concrete grade of slab. Otherwise the precautions of ACI318 shall be followed.

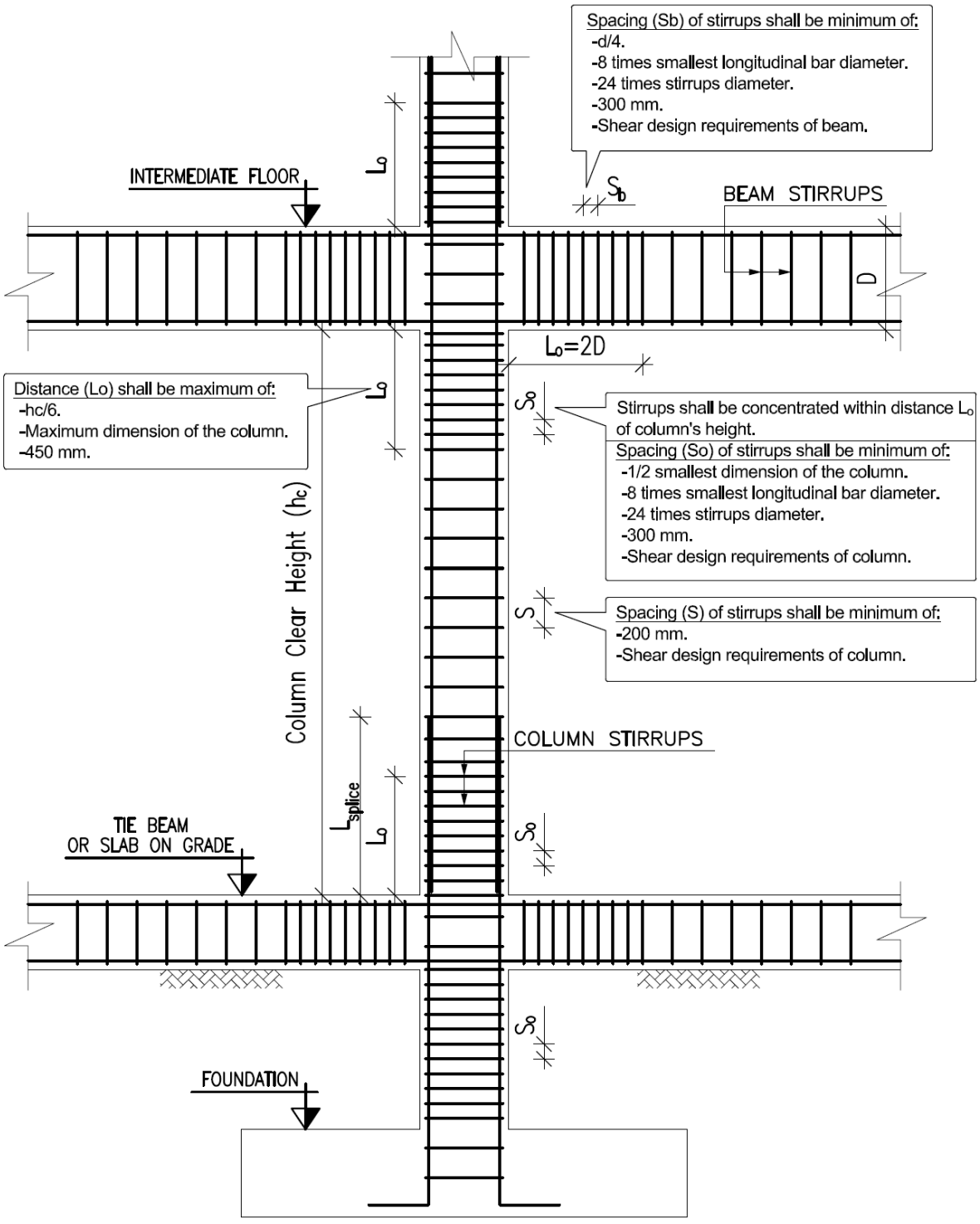


Figure 9-1: Column / Beam Connection Detail

9.5. Transfer Beams and Transfer Slabs

- Transfer beams are to be supported on at least two direct supports till the foundation.
- The eccentricity of the planted column axis relative to that of the longitudinal axis of the beam is not permitted unless properly calculated.
- The gravity load transferred through the planted column to the transfer element should not be less than the loads calculated by manual method (tributary area).
- Transfer element deflection shall be limited to the minimum possible to ensure minimum additional deflection impact on the slabs/beams above which are supported by planted column.
- Transfer elements and the element supporting them shall be designed for special seismic load combination including seismic over strength factor.
- Construction sequence analysis should be performed wherever deemed required.
- Reinforcement should be detailed to ensure robustness by means of provision of adequate peripheral, vertical and horizontal ties.

9.6. Structural Movement Joints

- In case thermal analysis is not taken into consideration for concrete structures; movement joints shall be provided between the parts of the concrete building with lengths exceeding 50m.
- These joints are designed and executed in the super structure of the building only and not allowed within the basement retaining walls and foundation.
- The width of the expansion joints shall be calculated between the two masses of the building according to UBC97 clause 1633.2.11.
- Expansion joints are used in fences at spacing not more than 15 m of fence length.

9.7. Additional Control Measures for Below Grade Construction

- Control of shrinkage and early age thermal stresses by applying limitations on the design and specification of the concrete mix, including minimization of Portland cement content and substitution by fly ash or blast-furnace slag and silica fume.
- Selection of coarse aggregate with a (verified) low coefficient of thermal expansion.
- Control of on peak concrete temperature and temperature difference across the section during placing and early age curing, including appropriate site monitoring.
- Design of shrinkage and temperature control reinforcement, determined by analysis of the type of concrete used, restraint conditions expected and effect of local geometrical constraints.
- Limitations on concrete pour sizes and timing between pours.
- Design for thermal loads and considering its impact on deferent structural elements
- Specification of infill strip joints (late pour strips) at agreed locations by the consultant and cast circa 45 days after the concrete structures either side.

10. Foundation

10.1. General Requirements

- The presence of soil investigation report is mandatory to execute the design of the foundation and to conclude all the relevant foundation recommendations.
- Soil investigation report shall be carried out by competent and accredited geotechnical specialist.
- Foundation type shall be as per the soil investigation report's recommendation.
- Foundation level should not be shallower than the geotechnical foundation level recommended by soil investigation report.
- Foundation level should be in compliance with the architectural levels and service requirements.
- The weight of foundations, soil filling weight above foundation shall be considered when calculating the design load. Soil filling can be only ignored if the specified allowable bearing pressure by soil investigation report is the net bearing pressure.
- The effect of uplifting in the sub-structure shall be considered in the design and stability checks of foundation.
- Raft of deep basements below ground water table shall be designed properly to resist the resultant hydrostatic pressure due to water uplift load.
- The foundations of buildings or boundary walls are not permitted outside the boundaries of the plot.
- Boundaries of the plot shall be shown in the Foundation, Basement, and Ground Floor plans.
- The foundation of the fences shall be designed and implemented from all sides as a strip foundation with at least 800 mm below ground level.
- The bases of columns/walls shall be simulated as per the following criteria unless further detailed scheme is studied to simulate the foundation/soil interaction.

Foundation type	Base simulation
Pile caps	Fixed
Raft (shallow / on piles)	Fixed
Isolated / combined footings	Hinged
Isolated / combined footings which are mandatory to be simulated as fixed base for the super structure' stability	Fixed

10.2. Shallow Foundation

- Shallow foundation shall be sized and designed according to the recommended allowable bearing pressure as per soil investigation report.
- Allowable bearing pressure shall correspond to maximum settlement of 25mm for isolated footings and 50mm for raft unless otherwise agreed before the design of the project.
- The foundations shall be constructed under the natural ground level sufficiently to achieve stability and shall be protected from soil erosion and moisture changes resulting from climatic and thermal conditions, provided that the foundation level shall not be less than 1000 mm below road level.
- Soil stiffness shall be simulated in the foundation Finite Element Analysis (FEA) model as area springs (based on specified subgrade modulus), the subgrade modulus shall be clearly defined in the soil investigation report.
- Shallow foundation shall satisfy both structural design including flexural, one-way shear, punching, and stability requirements (e.g. Overturning, Sliding, Uplift).
- Shallow foundations shall satisfy crack width requirements as required.
- Punching reinforcement is not allowed in isolated and combined footings.
- Raft occupying big area shall be checked for early thermal and long-term thermal cracking.

10.2.1. Foundations on/or adjacent to slopes

The placement of buildings and structures on or adjacent to slopes steeper than 1V:3H (33.3% slope) shall comply with the requirements of IBC2009, Sections 1808.7.1 through 1808.7.5.

10.2.1.1. Building clearance from ascending slopes

In general, buildings below slopes shall be set a sufficient distance from the slope to provide protection from slope drainage, erosion and shallow failures. Except as provided in Figure 10-1, the following criteria will be assumed to provide this protection. Where the existing slope is steeper than 1V:1H (100% slope), the toe of the slope shall be assumed to be at the intersection of a horizontal plane drawn from the top of the foundation and a plane drawn tangent to the slope at an angle of 45^{o} to the horizontal. Where a retaining wall is constructed at the toe of the slope, the height of the slope shall be measured from the top of the wall to the top of the slope.

10.2.1.2. Foundation setback from descending slope surface.

Foundations on or adjacent to slope surfaces shall be founded in firm material with an embedment and set back from the slope surface sufficient to provide vertical and lateral support for the foundation without detrimental settlement. Except as provided in the previous Section and Figure 10-1, the following setback is deemed adequate to meet the criteria. Where the slope is steeper than 1:1 (100-percent slope), the required setback shall be measured from an imaginary plane 45 degrees to the horizontal, projected upward from the toe of the slope.

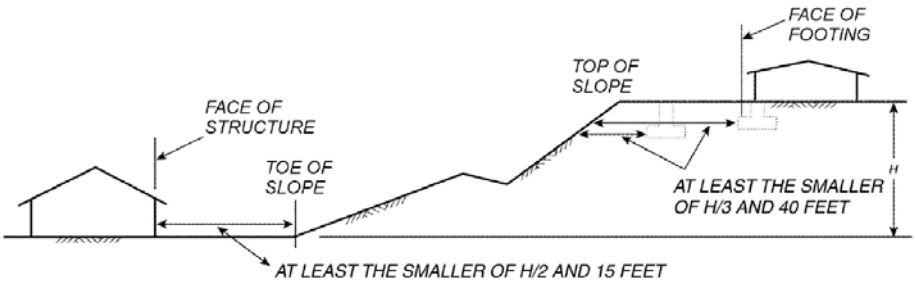


Figure10-1: Foundation Clearances from Slops

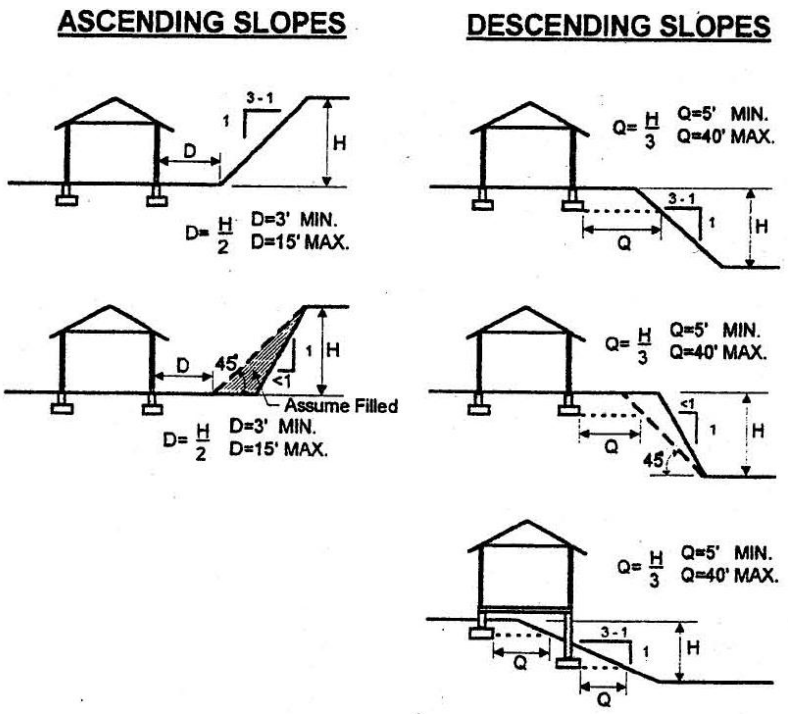


Figure 10-2: Explanatory figures for clause 10.2.1

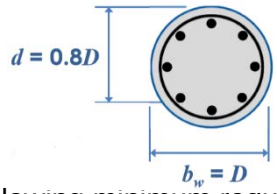
10.3. Retaining Walls

- The retaining walls shall be reinforced concrete, taking into account any recommendations of the reinforced concrete adjacent to the soil such as cement type, concrete cover, water proofing and crack width limitation.
- It is mandatory to have retaining wall structure when the difference in level between the plot and adjacent plots/ roads and sikas is 1.50m or more. Retaining wall may be required even if the difference in level is less than 1.5 meters if the municipality deems it necessary
- It is the responsibility of the consultant to investigate, collect and submit all the necessary information, the information shall include (but not limited to); affection plan and different level certificate which are mandatory for defining the requirements for retaining walls.
- The requirements for retaining walls shall be clearly defined at the early stage of the design and shall be properly coordinated with the main building foundation.
- Retaining walls shall be designed for the combination of lateral loads due to earth pressure, surcharge loads, ground water load, backfilled loads and gravity loads. Soil lateral loads shall follow clause 5.3.
- The retaining wall shall be designed to resist sliding and overturning with safety factors not less than (1.5). The bearing pressure below the retaining wall's foundation shall be within the allowable bearing pressure and considering the eccentric loading condition.
- The most critical loads' combination shall be considered in the stability checks of retaining walls (e.g. with/without surcharge loads).
- The thickness of the retaining wall shall be at least 250 mm, and the thickness at the bottom shall be sufficient to resist the resultant shear and flexural, as a result of the most critical loading case.
- Long retaining walls shall be checked for early thermal and long-term thermal cracking.

10.4. Deep Foundation (Piles)

10.4.1. General Requirements

- It is not permitted to use the (driven piles) method to execute the piles. If this method is used in the foundations, prior approval should be obtained from the municipality.
- Piles shall be sized and designed according to the recommended geotechnical piles' capacity as per soil investigation report.
- Piles should be designed to resist all loads (vertical and lateral) transferred from foundation element.
- Axial compressive working stresses on piles should not exceed 0.30.fc'.
- Design lateral shear force should be as per calculations, but not to be less than 5% of the vertical load on the pile.
- Curtailment of longitudinal pile's reinforcement shall follow the resultant ultimate bending moment profile along the pile.
- Shear reinforcement of piles shall be designed according to the ultimate resultant shear force profile along the pile.
- Shear design of the pile shall account for the effect of the corresponding axial force on the pile (e.g. tension).
- Circular section of pile shall be considered as an equivalent rectangular section for shear design purpose as follows:
  - Depth (d)=0.8xDiameter (D).
  - Width (b_w) = D.



- Pile's reinforcement shall follow the following minimum requirements.

Longitudinal Reinforcement Requirements	Minimum bar diameter	16mm	
	Minimum reinforcement	0.5% of pile's cross section area	
	Extend of reinforcements	Longitudinal reinforcing should continue at least with the minimum percentage for the full length of the pile.	
Ties Requirements	Minimum bar diameter of ties	10mm	
	Maximum spacing (S_{max}) of ties	Within distance L_o from foundation soffit. Where L_o = 3 times pile diameter.	8 times of longitudinal bar diameter, and not more than 150mm
		Outside distance L_o	12 times of longitudinal bar diameter, and not more than 200mm

- Piles stiffness shall be simulated in the foundation Finite Element Analysis (FEA) model as point springs (vertical and horizontal), the point springs shall be clearly defined in the soil investigation report. In the absence of horizontal pile stiffness information; it shall not be less than 10% of vertical pile stiffness.
- The pile diameter shall be selected to satisfy structural requirements of flexural and shear before executing the final pile design by piling specialist.
- Structural design of piles shall consider the following allowable tolerances' effects:
  - Moment due to allowable eccentricity of 75mm.
  - Lateral load due to allowable out of plumb 1:75.

- Design lateral load of the pile shall be the resultant of both X and Y directions of the same load case.
- Piles shall be designed structurally as fixed head piles as long as the pile cap is restrained in both directions.
- Spacing between center of piles shall not be less than 2.5 times pile diameter.
- For bored cast-in-situ piles, settlements of the order of 1% of the pile diameter is normally required to mobilize full skin friction whereas full bearing is developed at much higher settlements (usually at 10% of pile diameter). Therefore, it is highly recommended that the pile capacity shall be based on full skin friction and minimum partial end bearing.
- The contractor shall submit the as-built of piles after finishing piling construction to the consultant. The consultant is responsible to ensure that all the piles are executed within the allowable tolerance. if any of the piles are exceeding the tolerance, then it is the responsibility of the consultant to verify the impact of the deviated setting-out of piles on the foundation and/or piles design.

  It is the sole right of the municipality to request the as-built of the piles for verification whenever deemed required.

10.4.2. Pile tests

- The necessary tests for the endurance and quality of piles should be carried out.
- The tests shall be submitted to the inspection Engineer of the municipality prior to casting the foundations, results shall be verified to ensure that they conform to the technical specifications and standards.
- The following are minimum tests requirements for piling works approval.

Pile Test	Minimum percentage of piles
Integrity	100%
Dynamic load (load test magnitude 150% of working load)	5%
Static load (load test magnitude 150% of working load)	1% & Minimum one pile of each pile type
Sonic (recommended for dimeter more than 750mm)	10%

10.4.3. Piling Package by the Consultant

Piling package by the structural consultant shall present the following information in the piling package.

- Structural calculations and analysis models to demonstrate the piles loads.
- Preliminary structural drawings to demonstrate the overall structural feasibility and piles' loads.
- Piles' layout drawings showing piles' arrangement, setting-out and piles' types.
- Piles' general notes drawings covering but not limited to:
  - Piles' concrete and reinforcement grade.
  - Concrete cover.
  - Piles tests' types and failure criteria.
- Piles' schedule covering the following information:
  - Pile type (legend).
  - Pile diameter.
  - Number of piles within each type.
  - Pile cutoff level.
  - Pile tentative toe level (to be verified by piling specialist during the piling specialist submission).

- Pile's working loads
- Maximum Compression load and corresponding lateral loads from same load case.
- Maximum Tension load and corresponding lateral loads (if any).
- Number or percentage of tests for each pile's type.

Recommended sample for piling schedule:

Pile Type	Pile Legend	Number of piles	Pile Diameter (mm)	Cut off level (m)	Toe level (m)	Pile Working Loads (KN)				Piles Test Quantity			
						Case 1		Case 2		Working load test	Dynamic tests	Integrity tests	Sonic tests
						Maximum Compression	Lateral	Maximum Tension	Lateral				
P1	O	100	750	-1.00	-15.00	+3000	150	-500	100	1%	5%	100%	10%
P2													
P3													
Total Number													

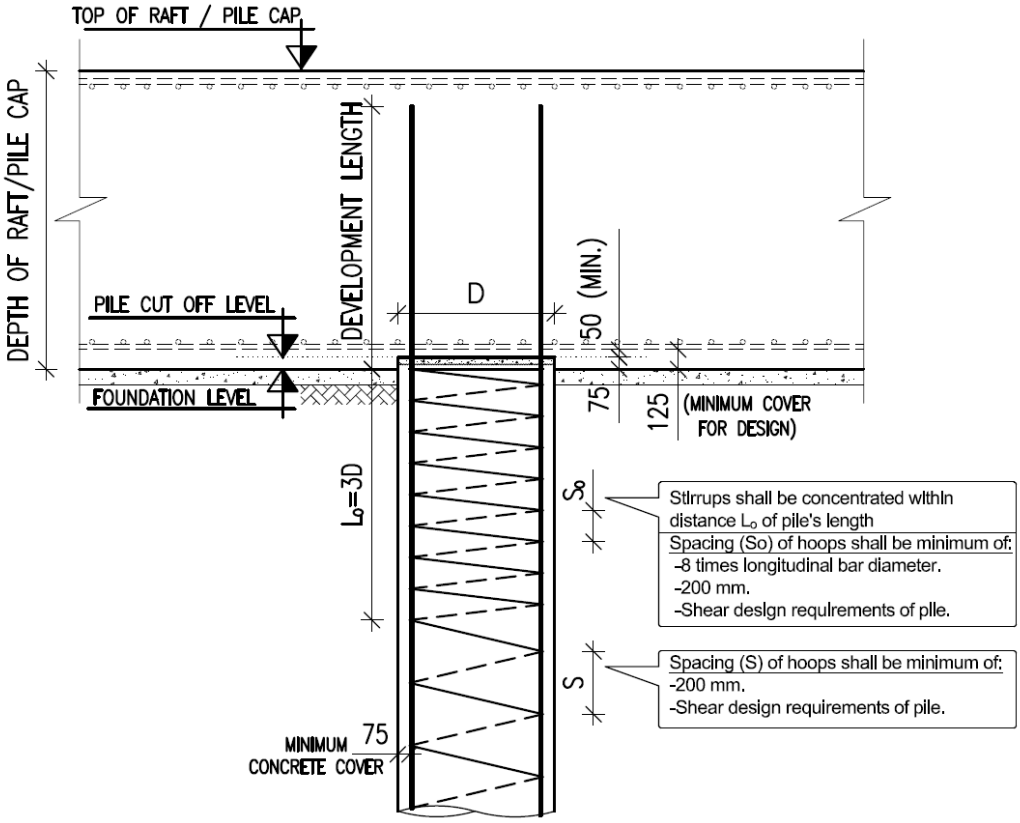
Note: The consultant can specify more load cases if deemed required.

10.4.4. Piling Package by the Piling Contractor

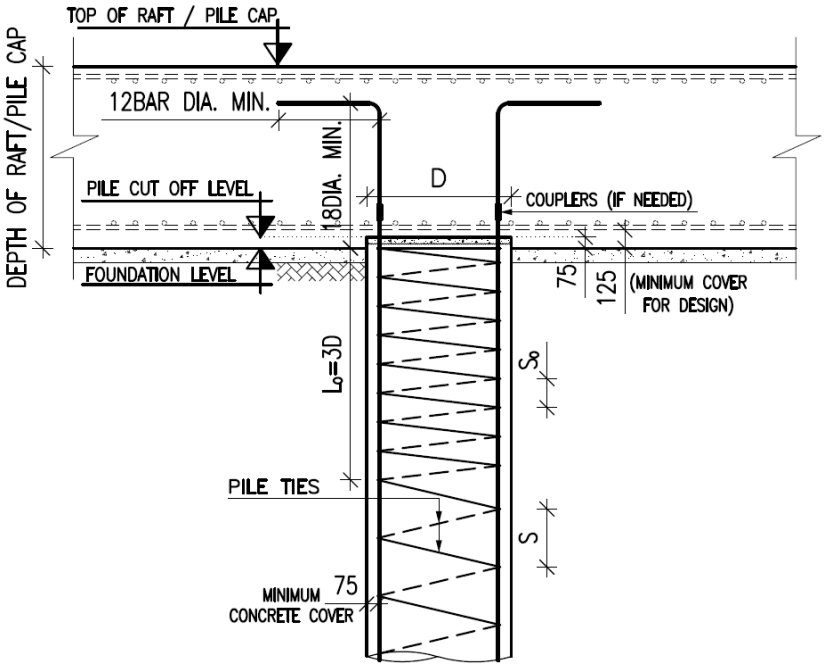
- Final piles' design shall be done by a licensed piling specialist. The design shall be based upon the piling reaction schedule prepared by the consultant and the soil investigation report information provided.
- Piling specialist shall present piles' information in a form of piles layout and schedule similar to the consultant presented information in addition to the followings;
  - Toe level confirmed based on the specialist's design and/or verification.
  - Piles' full reinforcement details.
- Geotechnical and structural design calculations of piles.
- Soil investigation report.

10.4.5. Pile Caps Requirements

- Pile cap shall satisfy structural design including flexural, one-way shear and punching.
  CRSI 2015 can be referred for one-way shear whenever deep action is satisfied.
- Punching reinforcement is not allowed in pile caps.
- Pile caps shall be restrained to ensure no moment transferred to the piles.
  - Single pile cap must be restrained in the two main directions.
  - Piles cap having two or more aligned piles must be restrained in the perpendicular direction to these piles.
- The pile cap restraining can be satisfied by tie beams or connecting slab.
- Minimum clear edge distance between face of pile and pile cap edge shall not be less than 250mm.
- The pile cap bottom cover to be considered in the ultimate design shall not be less than 125mm.
- The depth of pile cap shall be properly coordinated by the consultant to ensure the sufficient depth for the development detail of pile longitudinal reinforcement.



A. TYPICAL STRAIGHT DEVELOPMENT DETAIL



B. TYPICAL STANDARD HOOK DETAIL FOR SHALLOW PILE CAP

Figure 10-3: Pile reinforcement development details within pile cap

11. Pre-Stressed Concrete

- The current pre-stressed guidelines are relevant to the post tensioning bonded systems only, whereas the other pre-stressed systems shall be submitted for review and approval prior to work.
- The post tension structural elements shall be designed and executed by a specialized company in this field.
- The post tension elements shall be designed by a qualified engineer who is approved by the Competent Department.
- It is the consultant responsibility to communicate the approved loading criteria and loading plans to the post tension specialist.
- The structural calculation shall be submitted according to approved engineering software, in addition to the detailed drawings of the elements used, according to the international codes, with the stamp of the Consultant and the post tension specialist.
- All material shall be approved by the Consultant prior to commencement of execution and installation.
- Unless otherwise required by the design, the general requirements below shall be complied with according to the directions of the Ras Al Khaimah Municipality.

11.1. General Design Requirements

- The minimum thickness of the pre-stressed concrete slab shall be at least (Span/40) and not less than 200mm. For any further deviation from these limits; vibration shall be properly analyzed by the post tension specialist and verified by the consultant.
- Structural calculations shall verify both short term and long-term deflection, camber and vibration are within the permissible limits.
- Temperature and lateral loads analysis should be done using 3D building model, and the resultant forces shall be considered in addition to the gravity loads from the pre-stressed analysis.
- Cubic strength for the concrete used in pre-stressed slabs shall not be less than 40 N/mm^2.
- Concrete cover shall comply with durability or fire resistance requirements, whichever condition is the more onerous. The cover shall be measured to the outside surface of the duct; the minimum net cover for bonded system shall be 35 mm.
- The spacing between the ducts shall not exceed 1500mm. or 8 times the slab thickness whichever is less.
- All columns within flat slab system should be checked for punching shear as per the identified code.
- The uplift Force resulting from tension cables shall not exceed (0.6-0.9) of self-weight (according to ACI code recommendations). This limit can be waived considering that top reinforcement to be provided in the mid span as per code requirements.
- Tension shall be made from both sides if the length of the cable is greater than 35m.
- The ducts surrounding the cables shall be of a bonded duct, where the cables shall be covered with a certified grouting material.
- Rectangular spiral stirrups can be added in tension areas, not less than 6 laps of 12 mm diameter.
- Pan ducts for tension shall be performed if the cable track runs past the columns to prevent any extra non-considerable overshoots in the design of the columns.
- The cable routing shall be set by metal supports installed in the metal scaffolding, the dimension among them shall not exceed one meter.
- The locations of the cables shall be clearly indicated on the pre-stressed concrete slabs.

- The number of sample cubes taken for testing from casted concrete shall be at least 6 for each 50 cubic meters. Tests shall be scheduled according to the approved code.

11.2. Serviceability Requirements-Flexural Members

Design for serviceability requirements of members shall comply with ACI318 or Technical Report No.43-Euro Code.

11.3. Permissible Stresses in Pre-Stressing Steel

Case	Maximum limit
Jacking force for post tension elements	0.75 f_{pu}
Post-tensioning tendons immediately after tendon anchorage	0.70 f_{pu}

11.4. Pre-Compression Stresses

- For slabs with varying cross section along the slab span, either parallel or perpendicular to the tendon or tendon group, the minimum average effective pre-compression stresses of 0.9 MPa is required at every cross-section tributary to the tendon or tendon group along the span.

  Pre-compression of 0.9 MPa shall be used if the prestressing is used to address the punching shear of lightly reinforced slabs, otherwise, 0.7 MPa may be maintained as a minimum pre-compression.
- If the average pre-compression stresses exceed 3.0 MPa, the design engineer shall explicitly recognize and account for the consequence of shortening of the member in connection with the restraint of the member's supports.

11.5. Minimum Bonded Reinforcement

11.5.1. Bottom Reinforcement.

- Minimum area of bonded reinforcement shall be **$As=0.004A_{ct}$**.
- In positive moment areas, minimum length of bonded reinforcement shall be one-third the clear span length, ln, and centered in positive moment area.
- Bottom steel at columns and support locations should be not less than 30% of the top steel at the same location and not less than the requirements of lateral loads analysis.
- Moreover, the slab shall be provided with a bottom reinforcement mesh not less than T10-250.

11.5.2. Top Reinforcement.

- All support areas shall have the applicable code specified minimum reinforcement in the top for purpose of distributing the cracks and strength design requirements.
- Minimum area of bonded reinforcement in the negative moment zone at column supports shall be $As=0.00075A_{cf}$.

  Where A_{cf} is the larger gross cross-sectional area of the slab-beam strips in two orthogonal equivalent frames intersecting at a column in a two-way slab.
- In negative moment areas, bonded reinforcement shall extend one-sixth the clear span on each side of support.
- The slab shall be provided with a top reinforcement mesh not less than T10-250 for slab thickness more than or equal 300mm.

- Moreover; the slab reinforcement shall be provided wherever deemed required for lateral and different thermal effects.

11.6. Reinforcement Detailing

11.6.1. Edge Reinforcement

- Un-tensioned reinforcement should be placed along edges of all slabs. This should include U-bars laced with at least two longitudinal bars top and bottom.

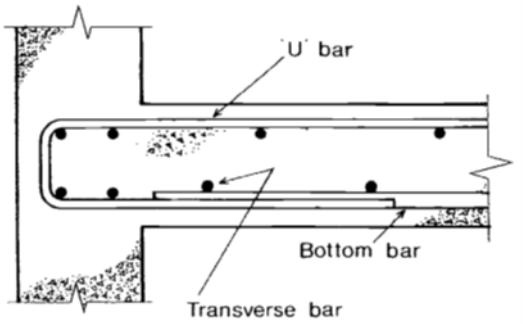


Fig.: Reinforcement layout at the edge of a slab.

11.6.2. Reinforcement Between Tendon Anchorages

- The slab zone between tendon anchorages requires reinforcement to span the unstressed zones. Any prestressed tendons that pass through this zone, parallel to the slab edge, may be included with the relevant reinforcement, provided it is in the local tension zone.
- The area of tension reinforcement (and/or prestressed tendons) provided parallel to the slab edge should resist bending moments from the ultimate vertical loads calculated for a continuous slab spanning l_a. This reinforcement should be evenly distributed across a width equal to $0.7l_a$, and should be continuous along the edge.
- The area of reinforcement placed perpendicular to the slab edge should be the greater of 0.13% bh, or a quarter of the reinforcement provided parallel to the edge. It should be placed evenly between anchorages, and extend the greater of la or 0.7la plus a full anchorage length into the slab.

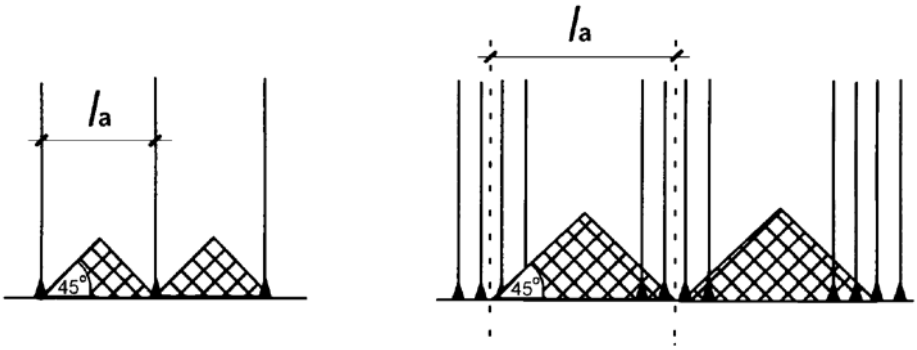


Fig.: Unstressed areas of slab edges between tendons requiring reinforcement

- For situations where it is not practically possible to place the prestressing tendons within 0.5h from the column, reinforcement should be placed to bridge the vertical force from the adjacent tendon to the columns as shown. The reinforcement should:
  - Be placed under the prestressing tendon.
  - Have sufficient area to transmit the vertical component of prestressing for that tendon to the column extend a full anchorage length beyond the tendon lie within 0.5h of the column and at least one bar should pass over the column.

    Where “h” is section depth.

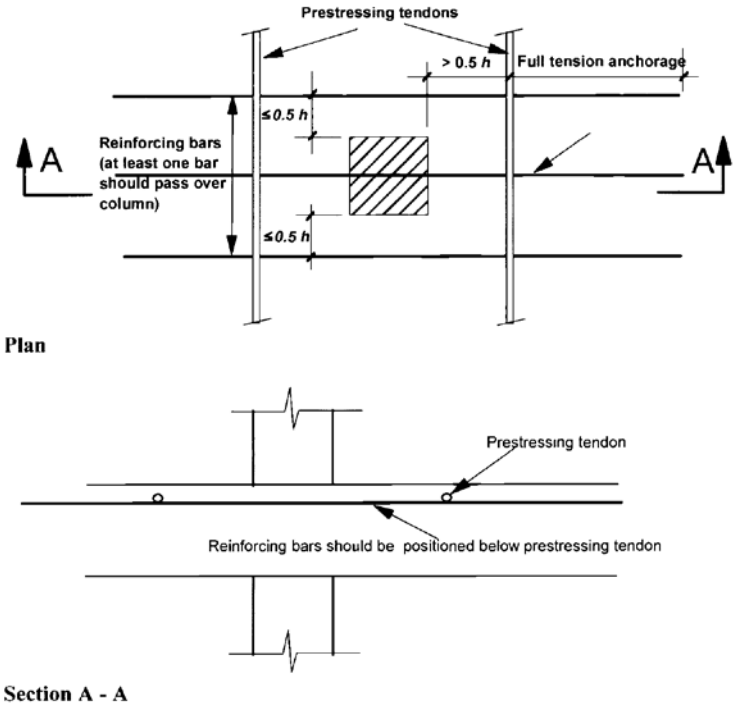


Fig.: Additional reinforcement required where tendons are not within 0.5h from the column

12. Steel Structures

12.1. General requirements

- Steel structure buildings shall be designed by a specialist in terms of design and execution experience.
- The structural design of steel buildings shall be prepared by a qualified structural engineer licensed to practice the profession and approved by the municipality.
- The detailed design calculations shall be submitted using approved analysis software in addition to the detailed shop drawing for the various steel elements, with the stamp of the consultant and the steel contractor.
- Maximum capacity ratio of all steel elements under the maximum effect of design load and its combination should not exceed 95%.
- All the requirements and limitations of both ultimate and service limit status should be satisfied according to the design code.
- Design shall include all limit states in addition to the limit states of strength and serviceability as follows:
  - Strength limit states including general yielding, rupture, yielding, buckling and transformation into a mechanism.
  - Serviceability limit states
  - Stability against overturning & sway.
  - Fracture due to fatigue and brittle fracture.
  - Corrosion and durability.
- In order to ensure the durability of the structure under conditions relevant both to its intended use and to its intended life, the following factors should be considered in design:
  - Environment around the structure and the degree of exposure.
  - Shape of the members and structural detailing.
  - Protective coatings.
  - Whether inspection and maintenance are possible.
- All steelwork exposed to the external environment shall be either hot dipped galvanized or will have a suitable paint system to protect against corrosion in compliance with minimum client requirements.
- The proper fire rating for steel elements shall be achieved by proper coating thickness of cementitious or intumescent materials.

12.2. Structural Integrity

- All buildings shall be effectively tied together at each principal floor level.
- Each column shall be effectively held in position by means of horizontal ties in two directions, approximately at right angles, at each principal floor level supported by that column.
- Horizontal ties shall be provided at roof level, except where the steelwork only supports cladding that weighs not more than 0.7 KN/m^2 and that carries only imposed roof loads and wind loads.
- Continuous lines of ties should be arranged as close as practicable to the edges of the floor or roof and to each column line. Ties designed and provided as shown in following figures are acceptable.
- All horizontal ties, and all other horizontal members, should be capable of resisting a factored tensile load, which should not be considered as additive to other loads, of not less than 75 KN.

- Each portion of a building between expansion joints shall be treated as a separate building.
- For special buildings where it is stipulated to be designed to avoid disproportionate collapse, all requirements with regard to tying of columns, continuity of columns, resistance to horizontal forces, notional removal of column, accidental loading and key element design etc. shall be carefully studied and designed as required by the relevant sections of codes.

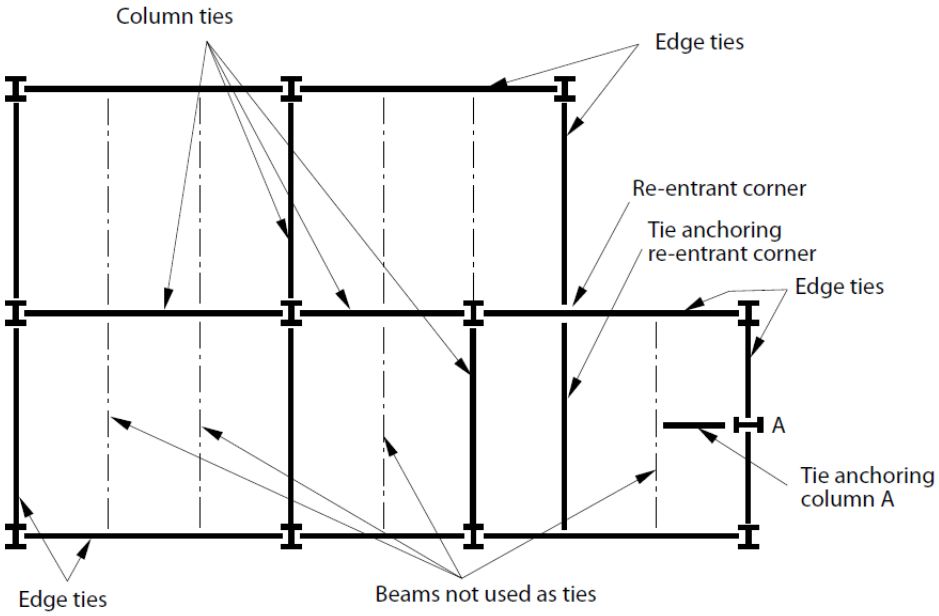


Fig.: Tying of columns

13. Geotechnical and Soil Investigation

13.1. Boreholes and Site Testing

13.1.1. Boreholes Number

- For single small plot of less than 1600m2; it shall be minimum 2 boreholes.
- For moderate plots; it can be one borehole for each 750-1000m^2 and not less than 3 boreholes.
- For plots of large area; the exploration points may be placed in a grid. The mutual distance between the boreholes points that considered an appropriate for structures should normally be 30-50 m.
- Where a certain project consists of a number of adjacent units, one exploration point per unit may suffice if the data of the boreholes have shown a uniform soil formation.
- In uniform soil conditions, the borings or excavation pits may be partially replaced by penetration tests or geophysical survey. (B.S.5930-1999).
- For structures which have main core walls as part of the structural system; at least single borehole shall be located below the core.

13.1.2. Boreholes Depth

- The boreholes, penetration tests or other site tests should normally be performed to explore the ground conditions to such depth to ensure the design certainty of foundation, and should be undertaken below all layers that may be unsuitable for foundations purposes (e.g. made ground and weak compressible soils, including weak strata overlaid by a layer of higher bearing capacity). If rock is found, a penetration of at least 3.00 m in more than one borehole may be required to establish whether bedrock or a boulder has been encountered.
- For shallow foundation; the depth of boreholes below the anticipated foundation level shall be 2-3 times the width of the foundation element.
- For deep foundation; the depth of the borehole shall be taken below the anticipated pile toe level as 5 times the pile diameter or 5m whichever is greater.
- Minimum depth of borehole shall not be less than 8m.
- The greater the natural variability of the soil condition, the greater the extent of the ground investigation required to obtain a confident indication of the soil characteristics to establish the overall foundation design.
- The data from boreholes should be recorded and analyzed by qualified and experienced geotechnical engineer.
- Boreholes should be carefully backfilled, concreted or grouted up. Trial pits should be outside the proposed foundation areas.

13.1.3. Soil Investigation Report

- Soil investigation tests is required for all types of buildings without exception, and a special report by a licensed soil testing laboratory in Ras Al Khaimah should be conducted exclusively.
- All laboratories employed for soil investigation purposes must be licensed, approved and accredited by Ras Al Khaimah Municipality. Certified laboratories from other emirates might be allowed subjected to advance approval of Ras Al Khaimah Municipality.

  The appointed laboratory shall conduct soil investigations in strict adherence to the procedures and recommendations as illustrated in the international codes and Ras Al Khaimah Municipality guidelines during the soil investigation operation, with proper sampling and extraction materials.
- All soil reports shall be stamped and signed by a professional geotechnical engineer.
- Soil investigation report shall be mainly based upon specific location with specified coordinates as per affection plan and geographical maps from the concerned authority. It shall also relevant to the information about magnitude of superimposed loads, number of floors, land use history, surface topography, geological features and surface drainage.

13.1.4. Information to be Included in the Soil Investigation Report

The soil investigation report shall include (but not limited to) the following information. However; geotechnical specialist is responsible to provide any further information deemed required based on the site and project condition.

- Overall site description and location.
- Plan showing boreholes' location and levels referred to site map.
- Laboratory testing results.
- Sub surface condition profile, based on boring and showing a cross-sectional view of all boreholes.
- Water table levels.
- Presence of cavities.
- Liquefaction risk study (if applicable).
- Complete borehole logs showing detailed records of soil strata, soil classification, ground water level, SPT, RQD, TCR and SCR values at different levels.
- Filed tests results such as;
  - Standard penetration test (SPT) results.
  - In-situ Permeability test results.
  - Pressuremeter test results.
  - Cone penetration test (CPT) results.
  - Down Hole test Report.
  - Groundwater readings from Installed standpipe piezometers.
- Laboratory tests results such as;
  - Physical / Mechanical and Index properties results.
  - Compaction related test results.
  - Chemical testing results.
  - Shear Strength test results.
  - Uniaxial compressive strength (UCS) test results.
  - Direct shear test results.
  - Permeability of the soil for different layers.
- Photographs of cores' samples.

13.1.5. Recommendation to be Included in the Soil Investigation Report

The soil investigation report shall include (but not limited to) the following recommendations. However; geotechnical specialist is responsible to provide any further recommendation deemed required based on the site and project condition.

- Shallow foundation recommendation including allowable bearing pressure (stating clearly if gross or net) and subgrade modulus and foundation level.

  Noting that the safety factor for soil bearing capacity shall be at least 3.0 for permanent structures, and 2.0 for temporary structures.
- Deep foundation recommendation including piles geotechnical capacities in compression and tension, and pile point stiffness (vertical and lateral).

  Noting that the safety factor for piles shall be at least 2.5 for both compression and tension.
- Open excavation recommendations including but not limited to allowable slopes' recommendations.
- Shoring recommendations for deep excavation including soil parameters required for shoring design such as average bulk density, angle of shearing resistance, cohesion, coefficient of active, passive and at-rest pressure for different layers of soil profile.
- Dewatering recommendations if ground water table is encountered including the permeability of the different soil layers.
- Soil seismic classification based on top 30m of soil strata and matching with UBC97 classification.
- Recommendation on the earth work, excavation, filling and compaction.
- Recommendations for suitability of site material to be used as fill material.
- Cement recommendation based on the chemical results of soil and ground water.
- Soil improvement recommendations and methodology (if applicable).
- Liquefaction risk study recommendation (if applicable).
- Any recommendation regarding problematic soil (if applicable).

14. Enabling Works

14.1. Open Excavation

- Angle of inclination for all open excavations should be as reported in soil investigation report but not more than 30 degrees. In some cases where high ground water table is encountered, a lower angle might be required to maintain safety of slopes.
- In case of high ground water table above target excavation level, dewatering shall be executed before starting excavation and dewatered level shall be at least 1.0 m below the target excavation level.
- Open cut excavations are not allowed along the plot boundaries unless a No Objection Certificate is encountered from the municipality and/or adjacent plot owner.
- All precautions should be considered for ensuring stability and safety of slopes for any open excavation.
- All existing utilities shall be protected at all times during excavation and construction.

14.2. Backfill Materials and Compaction

- The material used for backfilling purpose shall be of selected fill composed of sand/granular mixture free from organic materials or other deteriorates substances. The geotechnical specialist must state whether the material available in site could be used for general backfilling or not after performing the necessary analysis.
- The backfill materials shall be placed in layers of thickness 150mm to 250 mm and to be compacted to not less than 95% of the maximum dry density.
- Sand cone test may be carried out to determine the degree of compaction.
- The plate load test (as per ASTM D1195/D1195M– 09) also is an acceptable test where the allowable bearing capacity corresponds to the allowable settlement will be confirmed.

14.3. Shoring

- Shoring systems are allowed to be used as a temporary retaining structure to retain soil at construction sites peripheries.
- Shoring system is mandatory for any sharp excavation deeper than 1.50 meters.
- Shoring system is not allowed to be extended outside the plot boundaries.
- Ground tie back anchors should be avoided in neighboring plots unless a Non-Objection Certificate (NOC) is encountered from the municipality and adjacent plot owner.
- Ground tie back anchors in public properties (roads, sikkas, etc.…) is subject to the approval of authorities (municipality, electricity company, telephone company and water company).
- Shoring system should be designed according to height of retained soil and all different construction cases conditions.
- Shoring system should be designed assuming extra unplanned excavation of minimum depth 0.50m.
- Shoring system shall take into consideration the ground water level and the water tightness requirement during excavation. In the presence of ground water table above excavation level; It shall be proper water tight shoring system (such as secant piles, diaphragm wall or sheet piles).
- All shoring works shall be continuously monitored by the contractor and consultant. If any corrective action required during construction shall be approved by the municipality prior to execution.

- Surcharge loads should be considered with minimum value of 20KN/m^2.
  In case of adjacent structures, the resulting lateral and vertical reactions of the neighboring structure should be considered if found more than the specified minimum surcharge.
- Cantilever soldier piles shoring system (steel beams with precast panels) is allowed up to 5m deep excavation only. Any other requirements shall be approved in advance by the municipality.
- All existing utilities shall be protected at all times during excavation and construction.
- Shoring zone shall consider proper allowance between the shoring and the basement retaining wall to account for water proofing, construction tolerance and allowable deflection.
- The allowable maximum deflection of shoring shall not be more than 30mm adjacent to roads.

14.4. Submission Methods for Excavation and Shoring Permit

The consultant may apply for the excavation and shoring permit through one of the following two methods:

14.4.1. Method A

Applying for excavation and shoring permit before obtaining a building permit as follows:

The shoring permit can be independent from the building permit submission or can part of excavation and site preparation permit of the project. The permit shall be handed to the shoring contractor after the approval of the shoring drawings submitted by him, and obtain preliminary approval of the submitted drawings and enclose the necessary commitments.

14.4.2. Method B

The shoring permit can be submitted as a part of building permit submission at the final stage of the project, where the shoring drawings are submitted along with the final structural drawings and the consultant undertakes to make the necessary modifications to the project's drawings according to the conditional approval and final requirements of the NOCs. The permit issuing will be conditional in this case till the appointment of the shoring contractor, and the issuing of the final construction drawings for the project.

14.5. Required Documents for Excavation and Shoring Permit

- The general site plan of the plot with complete details of the surroundings in terms of buildings and its heights, distance from plot boundaries, adjacent foundations' type and number of basements (if any).
- The type of the structural system of the shoring and the design of the system to ensure its safety and feasibility.
- Structural sections through the shoring showing the followings;
  - Excavation depth from natural ground level and the adjacent roads,
  - Any other nearby facilities.
  - Level of additional local excavation due to water tanks, lift pits or any other facilities below the basement level.
  - Gap allowance between shoring inner face and basement wall face for construction tolerance and water proofing allowance.
  - Ground water table level.
- Full details of strutting system and/or anchoring system.
- In all case, "No Objection Certificates" shall be obtained from the department of Sewage, Electricity, Water and Telecommunication or any other authorities with the commitment to comply with their requirements and attach it in the documents.
- Full coordination shall be carried on between relevant architectural, structural and shoring drawings.
- The shoring contractor shall provide a valid license to carry out the required activity before assigning the work to him.
- Soil investigation report and shoring design calculations shall be submitted as a part of enabling package.
- Shoring contractor shall provide an under taken letter covering the responsibility of any damage or cracks in the adjacent buildings or roads as a result of shoring and excavation works.
- The consultant shall review and approve the shoring drawings and design prepare by the shoring contractor before submitting to the municipality.

15. Items to Be Included in Structural Submission

The following items shall be included and properly covered in the structural submissions:

- Soil investigation report.
- Detailed design calculations and design basis report.
- Analysis models (e.g. ETABS, SAFE, PROKON, etc.).
- Different levels certificate and/or levels difference confirmation by the consultant.
- General notes and standard details for structural elements including the following minimum information.
  - Concrete grade (Cube/Cylinder).
  - Reinforcement grade.
  - Allowable soil bearing pressure.
  - Foundation level.
  - Ground water level (if any).
  - Dewatering information (if any).
  - Waterproofing types.
  - Type of used partitions.
  - Reference datum level (e.g. Gate level, etc…).
  - Concrete cover of different elements; foundation, slabs, beams, ribs, columns.
  - Standard details of beams and foundation.
- Structural Drawings
  - Shoring plans and details; in case of deep excavation.
  - Loading plans.
  - Raft foundation plans showing general arrangement (GA) and reinforcement details. Location and dimensions of lift pits/sump pits to be shown clearly on GA drawings.
  - Isolated/combined footing plans and schedules. Foundation plan shall show the dimensions of strap beams (if existing).
  - In case of deep foundation (piles), piles layout and general notes drawings shall be submitted for piles showing the different piles types and the required tests to be done on piles.
  - Retaining wall details including plans, setting out and reinforcement details sections.
  - Column layouts plan showing clear setting out of columns.
  - Schedule of columns including reinforcement, sizes and detailed sections.
  - Floor plans showing general arrangement, concrete sizes of all the elements and setting out (such as slab thickness, beam sizes, opening sizes) and reinforcement details.
  - Schedule of beams, with reinforcement and sizes, including typical beam elevation and sections for different beam types.
  - Detailed sectional plans and elevations for shear walls showing all dimensions, openings and reinforcement.
  - Plans, sections and details of swimming pools, reinforced concrete water tanks, level differences and significant architectural features.
  - Plan & section for staircases showing all dimensions and reinforcement.

- The name of all the structural floor plans shall be labelled similar to architectural floors plans. Refer to the following figure for further explanation.

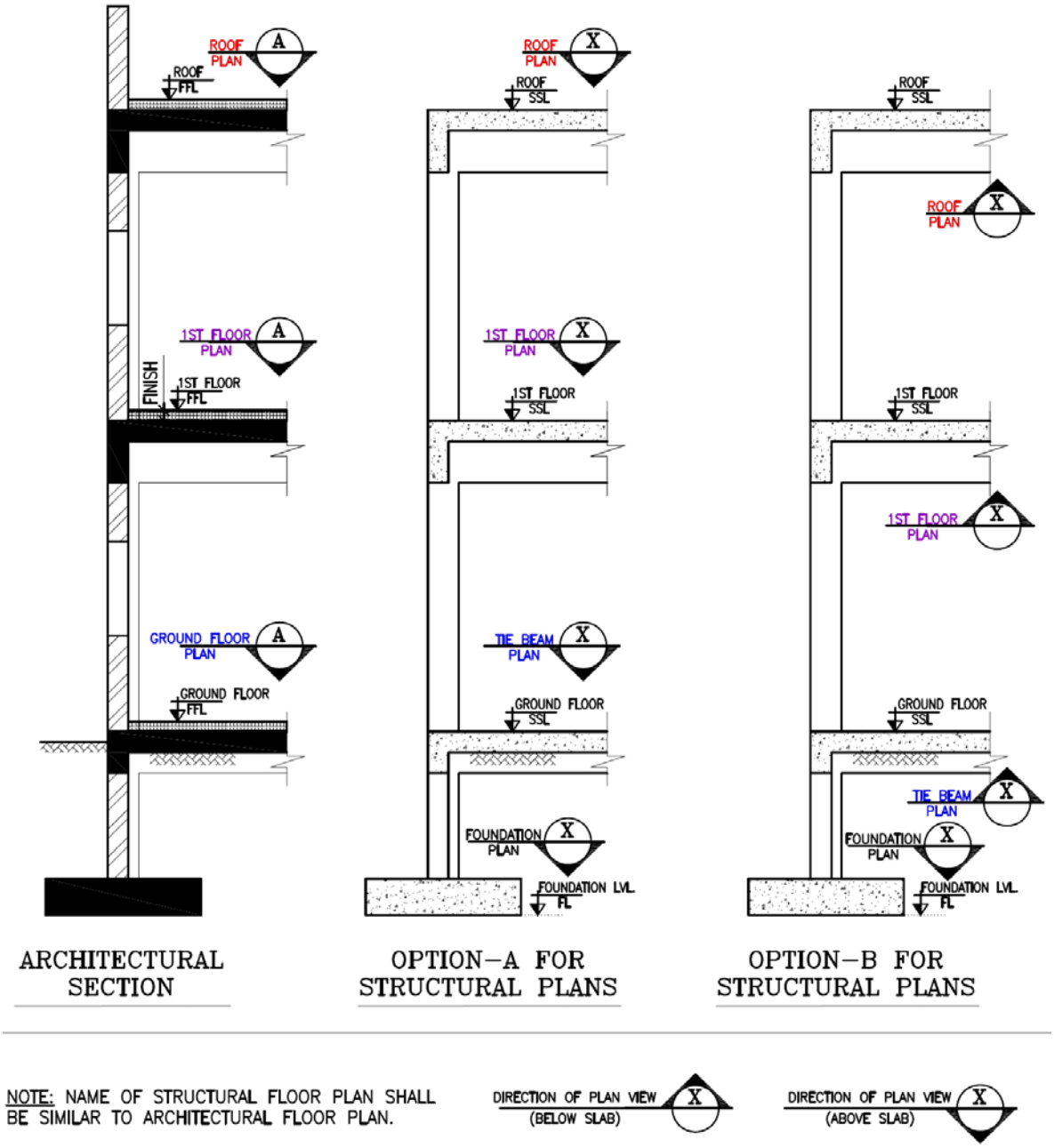


Figure 15-1: Structural Floor Plans Labeling System

16. Extension and Modification of Existing Buildings

16.1. General Requirements

- The study of the building shall be carried on by a specialized consultant approved by Ras Al Khaimah Municipality who shall study the status of the building, its structural age and determine the possibility of modification, addition and defining all the necessary precautions.
- The Structural elements that are included in the extension and/or modifications, shall be strengthened and enhanced in order to accommodate the additional design loads or geometric changes according to the applicable design methods and applicable standards.
- All strengthening works in site shall be carried by approved specialist with proven track record.

16.2. Building Classification

Buildings subjected to modification and additions shall be classified according to their structural age as follows:

16.2.1. Buildings with a Structural Age Over 15 Years

- Any structural modification or additional loads to those buildings are allowed only subjected to proper and detailed study performed by specialized approved consultant.

16.2.2. Buildings with a Structural Age of 10 to 15 Years

- The structural analysis of the building shall be carried out using one of the approved structural software, the tests for the buildings under execution or parts of it. It shall be carried out when there are reasons to doubt the performance of the building or any part thereof to resist the expected loads or doubt in its validity for use.
- All or some of the following tests might be required according to the directions of the municipality:
  - Core test.
  - Ultrasonic pulse velocity.
  - Schmidt Hummer.
  - Load tests.
  - Check of specific parts of the foundations as required.
  - Soil Report for the added parts (if any).
- Load tests shall be carried out in such a way to ensure the safety of individuals and property, and shall not affect the test itself or its results.

16.2.3. Buildings with a Structural Age Less Than 10 Years

- The Municipality has the right to request any tests or structural analysis deemed necessary to take the appropriate decision regarding the acceptance or rejection of the required modification.

16.3. Soil Testing Procedures

- In order to expedite obtaining the license for modification or addition to an inhibited building; where it is difficult to carry out soil tests; it is possible to postpone the necessary soil testing until the start of execution. The results shall be presented to the Licensing Structural Engineers after being studied

and modified by the consultant, and based on this; he shall submit modified drawings for final approval (if necessary).

16.4. Decisions and Procedures

- If the building does not meet the satisfactory criteria for the different construction materials or the proper structural analysis according to the previous provisions; the Municipality has the right to take one of the following actions:
  - Reform and rehabilitation.
  - Allow the use of the building under reduced loads based on the results of analysis or load tests.
  - Rejection of the modifications or additions.
  - Demolition of the building.

17. Inspection of Buildings Construction

Inspection of construction works shall be carried out according to the approved manual's requirements of buildings construction and considering the followings:

17.1. Inspection of concrete works

- Inspection shall include the reinforced concrete, pre-stressed concrete and pre-cast concrete works to ensure that they conform to the approved drawings. (Plain concrete works and non-structural elements are excluded).
- The inspection shall include (but not limited to) reinforcement bars, its locations, quantities, arrangements, overall lengths, development lengths, and lap splices.
- Inspection shall include the results of concrete cubes tests of different structural elements.
- The inspection shall include the results of the piling tests during the inspection of pile caps and raft on piles.
- Pre-stressed concrete, pre-cast concrete and special works shall be delivered by the designated engineer from the executing company for those works.
- The Consultant and the Competent Engineer shall ensure the availability of all approved documents and drawings in the construction site.

17.2. Inspection of Structural Steel Works

- Inspection shall include steel elements and sections of steel structures, high-strength bolts, nuts, sealing rings, welding and measuring work, and joints with bolts or welds and their arrangements according to the approved drawings.
- The steel works shall be delivered by the designated Engineer of the executing company for those works.
- The Consultant and the Competent Engineer shall ensure the availability of all approved documents and drawings in the construction site.

17.3. Inspection of Founding Soil

- The inspection shall include the founding soil below any type of foundation.
- The inspection shall include all earthworks in site including excavation, backfilling, compaction, dewatering and shoring works.

18. Approval of New Structural Systems

Any new structural system or material (non-conventional) shall be submitted in advance to Ras Al Khaimah Municipality for approval before implementing by the consultant in the design, even if the system is approved in any other emirate.

18.1. General requirements

- Company profile, including the company classification in Ras Al Khaimah municipality or any other municipality within UAE.
- Copy from factory and trade licenses, indicating the particular activities in production of the new structural system.
- Full set of drawings for a project executed by means of the new structural system, including architectural and structural drawings.
- List of previous projects with photos and copy of building completion certificates (BCC).
- Approval of the new system from all relevant authorities such as (but not limited) civil defense.

18.2. Technical requirements

- Full set of general structural notes and details, including sections, materials specifications, connection details, and data sheets.
- Used materials specifications for galvanized coating, steel, concrete, bolts, screws, insulation system, etc.….; including factory data sheets, warranties, related tests and sources.
- Design codes and applicable software; including gravity and wind loads definition, analysis method, serviceability and strength criteria.
- Specific test results such as (but not limited) acoustic test, fire resistance test, insulation test and strength tests.
- Special treatment for cutting edges and holes against corrosion and rustiness.
- Specific arrangement to control the cracks caused between two different materials.
- Water tightness specifications of the system: gaps in cladding and walls, condensation, wetted area, water leakage, coats and finishing, wall and roof insulation.
- Proposed system durability and warranty in years.
- Supplementary evidences indicate that the new system is compliant with international standards and codes (BSI & ASTM).
- Substructure system details and specification (foundation level, ground floor slab, and tie beams).