

**EARTHQUAKE RECONSTRUCTION AND REHABILITATION  
AUTHORITY (ERRA)**

**INTERIM GUIDELINES  
FOR  
DESIGN AND CONSTRUCTION OF BUILDINGS  
IN EARTHQUAKE AFFECTED AREAS**

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# **EARTHQUAKE RECONSTRUCTION AND REHABILITATION AUTHORITY**

## **INTERIM GUIDELINES**

### **FOR**

#### **CONSTRUCTION OF BUILDINGS IN EARTHQUAKE AFFECTED AREAS**

## **1 GENERAL**

These guidelines describe general design requirements applicable to the structural design of all building elements including foundation to ensure adequate strength for the whole structure and all parts thereof for safe support of all loads in addition to the seismic loads.

All structures and their components shall be analysed for all phases of construction for a high degree of structural competence, reliability and ease of construction, as per the various standards & codes described hereunder:

## **2 DESIGN LOADS**

### **2.1 DEAD LOADS**

2.1.1 Dead loads are the vertical loads due to the weight of all permanent structural and non- structural components of a building, such as walls, built-in & moveable partitions, floors, roofs, and finishes including all other permanent construction.

2.1.2 Dead loads also include the weight of all fixed services equipments, such as piping, heating & air-conditioning equipments, elevators and the weights of all other fixed equipments.

2.1.3 The vertical and lateral pressures of liquids are also treated as dead loads.

2.1.4 Dead loads shall be calculated from the unit weights given in ANSI/UBC or from the actual known weights of the materials used. (Table -1)

2.1.5 To provide for partitions where their positions are not known on the plans, the beams & the floor slabs (where these are capable of effective lateral distribution of the loads) shall be designed to carry, in addition to other loads, a uniformly distributed load per sqft of not less than one third of the weight per foot of the finished partition but not less than 20 lb/ft<sup>2</sup> (1 KPa), if the floor is to be used for office purposes.

### **2.2 LIVE LOADS**

2.2.1 Live loads are the loads superimposed by the use and occupancy of the building not including the wind, seismic and temperature loads or dead loads.

- 2.2.2 Live loads include loads due to intended use and occupancy of an area, personnel, moveable equipments, lateral earth pressures, vehicle and impact loadings.
- 2.2.3 Floor live loads as per occupancy and intended use requirements, are as given in Table -2. Unit live loads given in the table, are the minimum live loads for the design of the listed areas. For any area not listed, minimum design live loads shall be in accordance with ANSI or UBC.
- 2.2.4 For elevators and other moving loads, equipment manufacturer information shall be used for wheel loads, equipment loads, and weights of moving parts. If not otherwise specified by the equipment manufacturer, impact and lateral forces shall be in accordance with UBC.
- 2.2.5 The floor area live load may be omitted from areas occupied by equipment whose weight is specifically included in dead load. Live load is not omitted under equipment where access is provided.
- 2.2.6 PARAPETS & BALUSTRADES

Parapets and balustrade shall be designed for the minimum loads given in Table 11.4 of Building Code of Pakistan, expressed as horizontal forces acting at top of handrail or coping level.

### **2.3 DYNAMIC / VIBRATIONS LOADS**

Dynamic effects caused by vibrating loads of equipment and machinery such as pumps, fans, screens, and compressors shall be determined by established analytical methods or design data from suppliers. It is intended to minimize the vibration effects as far as possible by the provision of shock absorbing materials in accordance with supplier's recommendations.

### **2.4 WIND LOAD**

- 2.4.1 All loads due to the effect of wind pressure or suction shall be considered as wind loads. The wind loads on the structure shall be calculated in accordance with ANSI/ASCE 7 using the following formula:

$$q_z = 0.00256 k_z (IV)^2$$

Where

V = Basic wind speed = 100 miles/hour

K<sub>z</sub> = Velocity pressure Exposure coefficient

I = Importance factor

q<sub>z</sub> = Velocity Pressure at height 'Z' in pounds per square foot.

$$q_z = 0.613 k_z (IV)^2$$

Where

V = Basic wind speed = 45 meter/sec

K<sub>z</sub> = Velocity pressure Exposure coefficient

I = Importance factor

q<sub>z</sub> = Velocity Pressure at height 'Z' in N/m<sup>2</sup>.

## **2.5 SEISMIC LOADS**

Earthquake load shall be computed using the ground motion values given in "Seismic Zoning Maps of the earthquake affected areas" issued separately by NESPAK. The seismic zoning maps show Peak Ground Acceleration (PGA) values for 10% Probability of Exceedance in 50 years (500 years return period) and PGA values for 2% Probability of Exceedance in 50 years (2500 years return period). In accordance with the International Building Codes (IBC) guidelines, ordinary housing should be designed for PGA values of 500 years return period while all important structures should be designed for PGA values of 2500 years return period.

The PGA values shown on these maps are for firm-rock (shear wave velocity of 760 m/sec) site condition. For soil sites amplification of ground motion is introduced therefore appropriate amplification factors should be used keeping in view the geotechnical properties of the subsoil. Taking average shear wave velocity of 400m/sec of the sub-soil in the earthquake affected areas, the average value of amplification factor of 1.3 should be used.

## **2.6 THERMAL LOADS**

The temperature effect will be investigated against a maximum differential temperature of  $\pm 20$  degree centigrade for the frame structure.

## **2.7 SHRINKAGE & CREEP**

Shrinkage of reinforced concrete shall be considered as a shortening of 0.04 inch per foot (3.33 mm per meter). This can be reduced to 0.02 inch per foot (1.67 mm per meter), if effects of creep are included.

## **2.8 SNOW LOADS**

The roofs shall be designed for snow loads or live loads whichever is more severe.

Actual load due to snow will depend upon the shape of the roof and its capacity to retain the snow; and each case shall be treated on its own merits. In the absence of any specific information, the loading due to the collection of snow may be assumed to be 1.3 lbs/sq.ft per in (2.441 Pa per mm) depth of snow. The possibility of total or partial snow load should be considered, that is, one-half of the roof fully loaded with the design snow load and the other half loaded with half the design snow load. In the case of roofs with slopes greater than 50 degrees snow load may be disregarded; where, however, there are possibilities of formation

of snow pockets, these shall be taken into account, where data on ground snow load is available the specified snow load shall be determined by multiplying the ground snow load by 0.8.

Snow load in excess of 20 lb/ft<sup>2</sup> (1 KPa) may be reduced for each degree of pitch over 20 degrees by  $R_s$  as determined by the following formula:

$$\begin{aligned} R_s &= S/40 - \frac{1}{2} \\ R_s &= \text{Reduction snow load in lb/sq.ft per degree of pitch over 20 degrees.} \\ S &= \text{Total snow load in lb/sq.ft.} \end{aligned}$$

$$\begin{aligned} R_s &= S/40 - 1/40 \\ R_s &= \text{Reduction snow load in KPa per degree of pitch over 20 degrees.} \\ S &= \text{Total snow load in KPa.} \end{aligned}$$

## 2.9 LOAD COMBINATIONS

The various load cases applied to structures in combination with the required strength factors are indicated in Table -3. The load combination producing the largest resultant forces and moments shall be used in design.

## 3.0 STRUCTURAL SYSTEM

Structural elements e.g. slabs, beams, columns, walls and footings are combined in various ways to create structural systems for buildings. For the selection of a suitable framing system for a building, the determining factors are:

- Appearance, functional & aesthetic requirements.
- Limitations on the size of structural members as imposed by architectural design and practical constraints on the basis of structural considerations.
- Clear spans and height required.
- Loads, including special loads.
- Availability of materials, skilled labour and construction equipments.
- Integration of structure with respect to architectural details, mechanical equipment, occupancy requirements etc.
- Economy, not merely in structural system but also the overall economy in the finished structure.

Except for the very simple and ordinary structure, study of several alternative systems, materials and layouts shall be made, before the final scheme is set. From many alternatives, the criteria for the selection of the best structural system for a building would be its

compliance with the functional and aesthetic requirements in an efficient and technically sound manner.

#### **4.0 FLOOR CONSTRUCTION**

##### **4.1 SELECTION OF PROPER FLOOR AND ROOF SYSTEM SHALL BE BASED ON:-**

- Spans, loads, deflection limitations, etc.
- Acoustical and thermal insulating properties
- Fire resistance.
- Framing details: Attachment to supports, support of hung ceilings, ducts, light fixtures, piping, etc.
- Lateral support provided by the floor system.

#### **5.0 EXPANSION AND SEPARATION JOINTS**

Arrangements of these joints shall be made on the following principles:

- Joints shall be provided only to avoid extremely irregular plan shapes & to avoid excessively long interconnected structures. In general, maximum interconnected length shall be limited to about 150 feet (46 meter). This is acceptable only if the structure is temporarily separated at about 65 feet (20 meter) long intervals or less by "shrinkage control pour strips" which are left open for at least 30 days after placement of concrete on each side.
- Width of joint will be at least 1 inch (25 mm).
- Double columns shall be provided at isolation joints.

#### **6.0 FOUNDATIONS AND SUBSTRUCTURE**

The bearing capacity of the soils and other factors pertaining to foundation design shall be evaluated as per recommendations laid down in the soil investigation report. In case no soil investigations are carried out, an allowable bearing capacity of  $0.75 \text{ t/ft}^2$  ( $8.07 \text{ t/m}^2$ ) may be adopted for small residential units.

#### **7.0 MATERIAL PROPERTIES**

##### **7.1 REINFORCING STEEL**

**7.1.1** All reinforcing steel used shall be hot rolled deformed bars conforming to ASTM A615, having a minimum yield strength of 60000 psi ( $414 \text{ N/mm}^2$ ) or 40,000 psi ( $276 \text{ N/mm}^2$ ).

**7.1.2** Bar spacing, splices and reinforcement covers shall conform to the ACI Code.

## **7.2 Concrete**

- 7.2.1** All reinforced concrete shall have a minimum cylinder strength of 3000 psi (21 N/mm<sup>2</sup>) at 28 days.
- 7.2.2** Blinding concrete shall have a minimum cylinder strength of 1500 psi (10 N/mm<sup>2</sup>).
- 7.2.3** Adequate protection shall be given to concrete against direct exposure to earth and to possible physical damage at locations like vehicle entrances by use of bitumen coating, corner angles, bollards etc.

## **8.0 METHOD OF ANALYSIS**

The analysis shall be carried out using computer aided methods of analysis and design as listed below using well reputed compute software e.g..

- |    |           |   |  |
|----|-----------|---|--|
| a. | SAP-2000  | - | Structural Analysis Programme (Static & Dynamic Finite element Analysis of Structure). |
| b. | STAAD-Pro | - | Structural Analysis and Design Program   |

## **9.0 DEFLECTION**

The vertical deflection and lateral displacement of any structural component shall be limited by the values set forth in ACI Code.

## **10.0 DESIGN METHODS**

All reinforced concrete structures shall be designed by the Ultimate Strength Methods, as defined in ACI 318 except for all concrete liquid retaining or sanitary engineering structures which are designed and detailed based on the working stress design methods as recommended by ACI committee 350R. A minimum factor of safety against sliding or overturning of 1.5 shall be used for all structures.

## **11.0 CODES AND REFERENCES**

The design, fabrication and erection shall in general conform to the latest editions of the following codes which are to be applied with proper engineering judgment.

- Building Code of Pakistan.
- American National Standards Institute Specifications.
- ACI-318 (2002), Building Code Requirements for Reinforced Concrete.
- CP 8110, The Structural Use of Concrete.

- BS4 449, The Use of Structural Steel in Building.
- American Institute of Steel Construction (AISC), specifications for The Design, Fabrication and Erection of Structural Steel for Buildings.
- Uniform Building Code (UBC 1997)
- IBC International Building Code (2003 or 2006)

## **12.0 GUIDELINES FOR SINGLE TO TWO STOREY HOUSING UNITS**

### **12.1 MATERIALS**

#### **Masonry Units:**

- Concrete block work
- Cut-stone masonry
- Burnt clay brick

Avoid using random rubble masonry and adobe wall units unless you have specialist help

The bricks shall be of standard shape, burnt red, hand formed or machine made and shall have a minimum crushing strength of 1500 psi (10 N/mm<sup>2</sup>). The concrete block shall be solid blocks of 12" x 8" x 6" (300mm x 200mm x 150mm) made with 1:2:4 mix

#### **Mortar:**

Cement-sand mixes of 1:6 and 1:4 shall be adopted for one-brick and half-brick thick walls, respectively. The addition of small quantities of freshly hydrated lime to the mortar in a lime-cement ratio of 1/4:1 to 1/2:1 will increase its plasticity greatly without reducing its strength.

Where steel reinforcing bars are provided, the bars shall be embedded in a cement-sand mortar not leaner than 1:4, or in a cement concrete mix of 1:2:4

#### **Plaster:**

All plasters shall have a cement-sand mix not leaner than 1:6 on outside or inside faces. It shall have a minimum 28 days cube crushing strength of 450 psi (3 N/mm<sup>2</sup>). A minimum plaster thickness of 3/8" (10 mm) shall be adopted.

### **12.2 STRUCTURAL FORM AND BUILDING CONFIGURATION**

- Avoid creating heavy concentrated masses, particularly at roof level (eg. large water tanks).
- Make sure no heavy masses are located above stairwells etc.
- Avoid irregular floor plan shapes to avoid torsional effects in earthquakes.
- Make sure columns and walls are continuous between floors.

- Make sure buildings do not have large openings (eg. for garages or shops) as these can weaken structure and cause torsional effects.
- Make sure that building's plan shape at any floor level, including ground floor, is symmetrical.
- If shear walls are concentrated inside a building make sure it will not be subject to torsional effects or design structure, to resist this.
- If buildings must be asymmetrical, split parts of it into rectangles by creating movement gaps. Gaps to be minimum 1 inch (25 mm) floor to avoid adjacent buildings clashing during horizontal sway in an earthquake.
- Make sure structure is not long in relation to its width (W). Avoid long unsupported walls of longest length (L) does not exceed 3 W.

### 12.3 HORIZONTAL REINFORCEMENT IN WALLS

Horizontal reinforcing of walls is required in order to tie orthogonal walls together. The most important horizontal reinforcing is by means of reinforced concrete bands provided continuously through all load-bearing longitudinal and transverse walls at plinth, lintel and roof-eave levels and also at the top of gables according to the requirements stated below.

#### **Plinth Band**

This should be provided in those cases where the soil is soft or uneven in its properties. It may also serve as damp-proof course.

#### **Lintel Band**

A lintel band shall be incorporated in all openings and shall be continuous over all interior and exterior walls. The reinforcement over the openings shall be provided in addition to that of any other requirement.

#### **Roof Band**

This band shall be provided at the eave-level of trussed roofs and also below gable levels on such floors which consist of joists and covering elements so as to integrate them properly at their ends and fix them into the walls. This band is not required in case of reinforced concrete or reinforced brick masonry slabs.

#### **Gable Band**

Masonry gable ends must have the triangular portion of masonry enclosed in a band, the horizontal part of which will be continuous with the eave-level band on the adjacent longitudinal walls

The width of the RC bands (at plinth and lintel) shall be the same as the thickness of the wall. The minimum thickness of a load-bearing wall shall be 9 inches (225 mm). A cover of one inch from the face of wall shall be maintained for all steel reinforcing.

The vertical thickness of the RC bands may be kept to a minimum of 6" (150 mm) with 4 – ½" (115 mm)  $\Phi$  bars as reinforcement. For economical reasons a minimum thickness of 3" (75 mm) with 2 – ½" (65 mm)  $\Phi$  bars may be adopted.

The concrete mix is to be 1:2:4 by volume. Alternatively, it shall have a minimum compressive cylinder strength of 2500 psi (17 N/mm<sup>2</sup>) at 28 days.

The longitudinal bars shall be held in position by steel stirrups 3/8" (10mm)  $\Phi$  placed 6" (150 mm) centre to centre.

#### **12.4 VERTICAL REINFORCEMENT IN WALLS**

Steel bars shall be installed at the critical sections (i.e. the comers of walls, junctions of walls, and jambs of doors) right from the foundation concrete. They shall be covered with cement concrete in cavities made around them during the masonry construction. This concrete mix should be kept to 1:2:4 by volume, or richer.

The vertical steel at openings may be stopped by embedding it into the lintel band, but the vertical steel at the comers and junctions of walls must be taken into either the floor and roof slabs or the roof band.

#### **12.5 OPENINGS IN WALLS**

Any opening in the wall should be small in size and centrally located. The following are the guidelines for the size and position of openings.

- i) Openings are to be located away from inside comers by a clear distance equal to at least 1/4 of the height of the opening, but not less than 2 feet (0.6m).
- ii) The total length of openings in a wall is not to exceed 50 % of the length of the wall between consecutive cross-walls in single-storey construction.
- iii) The horizontal distance (pier width) between two openings is to be not less than one half of the height of the shorter opening but not less than 2 feet (0.6m).
- iv) The vertical distance from one opening to another opening directly above it shall not be less than 2 feet (0.6m), nor less than one half the width of the smaller opening.
- v) When an opening does not comply with requirements (i) to (iv), it shall be boxed in reinforced jambs through the masonry.

#### **12.6 VERTICAL JOINTS BETWEEN ORTHOGONAL WALLS**

For convenience of construction, builders prefer to make a toothed joint which is later often left hollow and weak. To obtain full bond, it is necessary to make a sloped or stepped joint. It should be constructed so as to obtain full bond by making the corners first to a height of 24 inches (600 mm), and then building the wall in between them. Alternatively, the toothed joint shall be made in both the walls in lifts of about 18 inches (450 mm).

#### **12.7 DOWELS AT CORNERS AND JUNCTIONS**

Steel dowel bars shall be provided at corners and T-junctions to integrate box action of the walls. Dowels are to be taken into the wall to sufficient length so as to provide their full bond strength.

## **12.8 GENERAL RECOMMENDATIONS**

- Make sure all external and internal walls are continuous, and interlocked with toothed details at L and T corners of all wall connections.
- Make sure all walls are continuous from foundations to roof level.
- Make sure masonry buildings do not exceed 2-storey height. Also, ensure floor heights do not exceed 10 ft (3 meter) at any storey.
- 1st and 2<sup>nd</sup> Floor slabs should continue past face of walls
- Avoid using gable walls to roofs. If unavoidable use RC gable bands as above.
- Use pitched or flat roofs.
- Pitched roofs need to be adequately braced to walls and roof bands. They also need require adequate bracing.
- Avoid having
  - Long cantilever balconies;
  - unreinforced parapets at roof level
  - architectural decorative motifs above 1.5 m
  - free standing walls which fall over under lateral loading
- Do not place services through corners of buildings inside masonry units as these can weaken corners. Equally do not put rain water pipes into corner walls
- Make sure drainage services are not cast inside walls at plinth level.
- Avoid having canopy structures with slender columns as they are weak in resisting shear, and soft storey type collapse can occur.

## **13.0 GUIDELINES FOR MULTI-STOREY FRAME STRUCTURES**

The reinforced concrete frame structures shall be designed to fullfill strength and serviceability requirements of ACI 318, UBC ((97) or IBC (2003) keeping in view following guidelines. Special Care shall be exercised in the detailing of reinforcement joints and other critical areas.

### **13.1 BUILDING LOCATION**

- Check location of building
- If area to be build upto in fill are\*a, near toe of hillside, on sloping ground, or on loose sand close to water gain specialist Geotechnical advice as the area may be unstable or ground may liquefy, Specialised ground treatment works and/or foundation types may required.

### **13.2 MATERIAL TYPES FOR WALLS**

- Concrete block work units
- Cut-stone masonry units
- Reinforced Concrete walls (expensive alternative)
- Factory manufactured brick units
- Avoid using random rubble masonry

### 13.3 STRUCTURAL FORM AND BUILDING CONFIGURATION

- Avoid creating heavy concentrated masses, particularly at roof level (eg. large water tanks).
- Make sure no heavy masses are located above stairwells or lift shafts etc.
- Avoid irregular floor plan shapes to avoid torsional effects in earthquakes.
- Make sure columns and walls are continuous between floors.
- Make sure buildings do not have large openings (eg. for garages or shops) as these can weaken structure and cause torsional effects.
- Make sure that building's plan shape at any floor level, including ground floor, is symmetrical.
- If shear walls are concentrated inside a building make sure it will not be subject to torsional effects or design structure, to resist this.
- If buildings must be asymmetrical, split parts of it into rectangles by creating movement gaps. Gaps to be minimum 1 inch (25 mm) per floor to avoid adjacent buildings clashing during horizontal sway in an earthquake.
- Make sure structure is not long in relation to its width (W). Avoid long unsupported walls of longest length (L) exceeding 3 W.

### 13.4 FOUNDATIONS

- Check soil type and water level.
- Use reinforced concrete strip footings under main load bearing walls and columns.
- Soft clays and loose-medium dense sand, which is waterlogged, may liquefy during an earthquakes. Seek specialist advice on piled foundations and structural design.

### 13.5 MASONRY SHEAR WALLS

Masonry walls acting as non-structural "shear" walls to resist lateral shaking:

- Make sure walls are made with good strength
- Make sure wall are build first and use shutters for columns to give strong bonding between masonry wall a d column.
- All masonry units to be bonded with mortar, of 1 part cement to 3 parts sand.
- Make sure all walls are continuous from foundations to roof level.
- Make sure masonry buildings is tied to floors and columns at suitable intervals

#### Reinforced Concrete Walls

- These can be combined with columns to provide additional shear resistance against earthquakes.

### **13.6 MINIMUM BEAM, COLUMN AND SLAB SIZES**

#### FOR GUIDANCE ONLY

- Studies from this earthquake have shown that floor slabs and beams for domestic properties of following sizes have worked.
  - 10 ft (3 m) span concrete floor slabs, minimum depth 150 mm
  - 15 ft (4.5 m) span beams, minimum 18 inch x 12 inch (450mm x 300mm)
  - Concrete columns – average 12 inch x 12 inch (300mm x 300mm)
  
- Make sure that all main reinforcing bars in concrete are high yield deformed bars, not plain bars. Links could be either. Make sure that all links have ends tucked back into the column.

### **13.7 GENERAL RECOMMENDATIONS**

- Avoid having
  - Large water tanks on roof
  - Long cantilever balconies;
  - unreinforced parapets at roof level
  - architectural decorative motifs above 1.5 m
  - free standing walls which fall over under lateral loading
  - roof tiles not fixed to battens
  
- Do not place services through corners of buildings inside masonry units as these can weaken corners. Equally do not put rain water pipes into corner walls
- Make sure drainage services are not cast inside walls at plinth level.
- Avoid having canopy structures with slender columns as they are weak in resisting shear, and soft storey type collapse can occur.

## TABLE- 1

### DEAD LOADS

1. Roof Finishes including insulation and water proofing treatment	55 psf. (2.75 KPa)
2. Floor Finishes:	
i) Terrazzo/ Marble/ Local granite flooring	30 psf. (1.5 KPa)
ii) Ceramic/ Glazed/ Vinyl tiles flooring	30 psf. (1.5 KPa)
iii) Plain cement concrete flooring	20 psf. (1 KPa)
3. Ceiling Finishes:	
i) Plaster	5 psf. (0.25 KPa)
ii) False Ceiling including supporting structure	3 psf. (0.15 KPa)
4. Piping, Ducts, Cables:	10 psf. (0.5 KPa)
5. Masonry Walls	as per actual location and actual weight
6. Light Partitions for Office areas	25 psf. (1.25 KPa)
7. Wall Finishes:	
i) Plaster	5 psf. (0.25 KPa)
ii) Cladding with marble, granite etc.	15 psf. (0.75 KPa)
8. Fixed Service Equipments Mechanical/Electrical equipments for example elevators, pumps, fan coil units compressors etc.	As per actual loads according to manufacturer's information.
9. Facades including glazing tiles etc.	As per actual weight

**TABLE - 2**  
**LIVE LOADS**

1. Monument Deck Levels	125 psf. (6.25 KPa)
2. Libraries	
i) Reading	60 psf. (3 KPa)
ii) Book storage area	150 psf. (7.5 KPa)
3. Mosques, Stairs	100 psf. (5 KPa)
4. Museum	80 psf. (4 KPa)
5. Offices	
i) Filling and storage space	100 psf. (5 KPa)
ii) Office for general use	50 psf. (2.5 KPa)
iii) Office with computing data processing and similar equipments.	75 psf. (3.75 KPa)
6. i) Corridors first floor	100 psf. (5 KPa)
ii) Corridors above first floor	80 psf. (4 KPa)
7. Roof	
i) Accessible	40 psf. (2 KPa)
ii) Inaccessible	20 psf. (1 KPa)

### TABLE -3

#### LOAD COMBINATIONS

Concrete Structures  
(Ref. ACI 318\* and ANSI A58.1\*\*)

1.	U	=	1.4 (D + F)
2.	U	=	1.2 (D + F + T) + 1.6 (L + H) + 0.5 (Lr or R)
3.	U	=	1.2 D + 1.6 (Lr or R) + (1.0L or 0.8W)
4.	U	=	1.2 D + 1.6W + 1.0L
5.	U	=	1.2 D + 1.6W + 1.0L + 0.5 (Lr or R))
6.	U	=	1.2 D + 1.0E + 1.0L
7.	U	=	0.9 D + 1.6W + 1.6H
8.	U	=	0.9 D + 1.0E + 1.6H

Load combinations for sanitary engineering structures shall be in accordance with recommendations of UBC 97 and ACI 350.

Load combinations for lateral earth pressures shall be in accordance with ACI.

#### Notations:

D	=	Dead Load
L	=	Live Load
W	=	Wind Load
T	=	Thermal Load
Lr	=	Roof live load
EQ	=	Earthquake Load
R	=	Rain load
F	=	Fluid Pressure
H	=	Earth Pressure
U	=	Required ultimate strength for concrete structures to resist design loads or their related internal moments and forces as defined in ACI 318.