Design of Portal Frames

Introduction:
It is defined as the frame with fixed joint at the junction of beam and columns. They are used as viaducts. We can use these frames in stiffening large span bridge girder and also in the construction of industrial buildings. There are following types of portal frames.

Portal frames may be single bay or double bay. Now days, there are commonly single storey frames are used. But in many industries, two storey frames are also desirable. In many cases sloping roofs are provided with the portal frames. There are various types of frames. But mainly, there are three types of portal frames.

Types of frame structures

Frames structures can be differentiated into:

1. Rigid frame structure

Which are further subdivided into:

- Pin ended
- Fixed ended

2. Braced frame structure

Which is further subdivided into:

- Gabled frames
- Portal frames

Rigid Structural Frame

The word rigid means ability to resist the deformation. Rigid frame structures can be defined as the structures in which beams & columns are made monolithically and act collectively to resist the moments which are generating due to applied load.
Rigid frame structures provide more stability. This type of frame structures resists the shear, moment and torsion more effectively than any other type of frame structures. That's why this frame system is used in world's most astonishing building Burj Al-Arab.

Braced Structural Frames

In this frame system, bracing are usually provided between beams and columns to increase their resistance against the lateral forces and side ways forces due to applied load. Bracing is usually done by placing the diagonal members between the beams and columns.

This frame system provides more efficient resistance against the earthquake and wind forces. This frame system is more effective than rigid frame system

Pin Ended Rigid Structural Frames

A pinned ended rigid frame system usually has pins as their support conditions. This frame system is considered to be non rigid if its support conditions are removed.
Fix Ended Rigid Frame Structure:

In this type of rigid frame systems end conditions are usually fixed.

Gabled Structural Frame:

Gabled frame structures usually have the peak at their top. These frames systems are in use where there are possibilities of heavy rain and snow.

Portal Structural Frame
Portal structural frames usually look like a door. This frame system is very much in use for construction of industrial and commercial buildings.

**Load path in Frame Structure:**

It is a path through which the load of a frame structure is transmitted to the foundations. In frame structures, usually the load path is:

- **Fixed portal frame:**
  
  In the fixed portal frame, all joints are fixed. Fixed portal frames are used in small structures where moment transferred to beams and then to foundations. These types of frames are simply constructed at any place.

- **Two pin portal frame:**
  
  This type of frame are used at base joints. They are used to eliminate tendency of base rotating. Two pin portal frames are greater in strength than the fixed portal frames. The joints are strong as compare to Fixed portal frames.

- **Three pin portal frames:**
  
  In this type of frame, all the connections are fixed. The joints are provided at the base and some time at the center. Three pin portal frames are used to reduce bending moment in the spanning members. It is also used to increase the deflections.
Advantages

There are following advantages of portal frames.

- Portal frames are easy to construct than walls or any other structures. It require less time to construct the portal frames.
- They are economic in nature. The cost of maintenance is low.
- They provide good floor to ceiling heights.
- Portal frames saves time and money.
- Portal frames are easily available at all the places.
- It is easy to carry the Portal frame's equipment's from one place to another place. The material is easy to carry from one place to another place.
- Portal frame structures provide good ventilation and lighting.

Disadvantages

Following are some limitations of the portal frames.

- It is not easy to build the portal frame anywhere. They can be constructed only hill, valley, and sloppy areas.
- Sometime, they also depends on the type of structure. Building shape should be square, rectangular only. Roof pitch should be shallow, steep, mono-pitch.
• We cannot construct any structure above the portal frames. It is very difficult to construct a structure above the portal frame, due to its sloppy head.

• Only skilled workers are required to construct the portal frames.

• The strength of portal frame structure is less than RCC structure. It is very difficult to compare it with the reinforcement structure.

• More accuracy required to build these types of structures. The portal frames are placed at regular intervals.

A portal frame consists of vertical member called **Columns** and top member which may be horizontal, curved or pitched. The vertical and top members built monolithically are considered as rigidly connected. They are used in the construction of large sheds, bridges and viaducts.

The base of portal frame may be hinged or fixed. The portal frames are spaced at suitable distance and it supports the slab above the top members. Various forms of RCC portal frames used in practice is shown in Fig.6.1

![Portal Frame Types](image)

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Fig. 6.1

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The portal frames have high stability against lateral forces such as wind and earthquake and the moments in the top beam are also reduced. But at the same time, large moments are induced in the columns which become more costly. A portal frame is a statically indeterminate structure.

In the case of buildings, the portal frames are generally spaced at intervals of 3 to 4m with a reinforced concrete slab cast monolithically between the frames. Frames used for warehouse sheds and workshop structures are provided with sloping of purlins and asbestos sheet roofing between the portal frames. The base of the columns of the portal frames are either fixed or hinged. Generally the columns having raft or piles are considered as fixed for analysis purpose.

Analysis of frames can be done by any standard methods like i) Slope deflection method, ii) Moment distribution method, iii) Strain energy method, iv) Kani’s method. Columns are designed for axial force and bending moment, whereas beam is...
designed for bending moment and shear force. These forces are obtained from the analysis carried out on the frame. Limit state method of design is used for design of members. Tables given in SP16 may be used for design.

### 3.2 Procedure for Analysis and design of Portal frames:

#### Step1: Design of slabs

Slabs are supported on beams and are designed as continuous. Generally these slabs are designed as one way slabs. Maximum bending moments and shear forces are computed using the coefficients given in tables 12 and 13 respectively of IS456-2000. For the assumed depth the required steel is computed from table 1 to 4 or 5 to 44 of SP16. Area of distribution steel are computed based on the minimum steel requirement ie., 0.12% of gross area.

#### Step2: Preliminary design of beams and columns

Depth of the beam is generally decided on the basis of span to depth ratio. For lightly loaded beams it is taken as 20 and 12 to 15 for heavily loaded beams. The width of the beam depends on the architectural requirements. Generally the width of the beam kept equal to the width of the wall or column. The size of the column is decided based on axial load calculated as reaction of beam or by experience.

#### Step3: Analysis

The forces on beams and at joints if any are first calculated and then forces in columns and beams are calculated using any standard methods of analysis like slope deflection method, moment distribution method etc., or tables given in SP43 can also be used for finding the shear force and bending moment.

#### Step4: Design of beams

Using the end moments and superposing simple support bending moment diagram, the design moments at mid span and at ends are computed. The mid span section of intermediate frame is designed as T-beam using the tables 57 to 59 of SP16. The sections at ends of the beam are designed as rectangular beams. For the depth of the beam used at mid span, the steel required is computed from finding steel percentage using the tables 1 to 4 of SP16. These sections are also designed for shear using tables 61 to 63 of SP16. The beam is checked for deflection using span to effective depth ratio.

#### Step5: Design of Columns

The columns are designed for uniaxial moment using the charts 24 to 85 of SP 16. The tie reinforcement of the column is designed on the basis of recommendations given in clause 26.5.3.2 of IS456-2000.

#### Step6: Design of footings

The footings are designed for flexure, single shear and punching shear. The reinforcement is generally provided on the basis of flexural requirement. If the base of the columns is analysed as hinged base, then the hinge is also designed considering the triaxial stresses.