In this problem you will be doing some preliminary calculations needed to begin the design of a small office building. The building is roughly 60 by 80 feet in plan as shown on the attached sheet. Initially, bay spacing has been selected to be 20 feet in each direction.

A joist floor system has also been selected. In this system, a thin slab transfers load to closely spaced beams (joists) which in turn transfer load to girders and then to columns. This system is light because of the thin slab between the joints, but is relatively expensive because it requires considerable formwork (typically reusable metal forms).

In this problem,

Given: Building configuration on last page and the following discussion.

Required: Estimate the ultimate dead and live loads carried by the slab, joists, girders and columns.

**Dead Loads**

Dead loads consist of the self-weight of the reinforced concrete slab, plus any permanent loads attached to the structure. In this case, we can consider the following loads to be uniformly distributed over the entire floor area:

<table>
<thead>
<tr>
<th>Dead Load Source</th>
<th>Load [psf]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor finishes</td>
<td>5</td>
</tr>
<tr>
<td>Ceiling finishes</td>
<td>11</td>
</tr>
<tr>
<td>Fire and Sprinkler system</td>
<td>8</td>
</tr>
<tr>
<td>Heating ventilation and air conditioning equipment (HVAC)</td>
<td>6</td>
</tr>
</tbody>
</table>

In addition, partition loads need to be considered. Where partition locations are not known or may change, building codes, like the Uniform Building Code (UBC), generally require that a uniformly distributed load of 20 psf be considered. Where partitions are of a permanent nature, like the fire walls required around stair shafts or the exterior cladding on the building, specific loads determined for those particular walls should be used in the design calculations.

a. For this problem, we first need to determine the floor area tributary to each member (slab, joist, girder, and column) and compute the effect of distributed dead loads (psf) in terms of dead load per linear foot of member (plf). Since the joists are closely spaced, loading on the girder is usually considered uniformly distributed rather than as a series of concentrated loads. For the column, of course, only the total load added to the column by the floor is needed. For the slab, consider a 1 ft. wide strip of slab.

The self-weight of the structure is estimated from the volume of the concrete tributary to the element under consideration. However, at this stage of the design nothing has been designed so the member dimensions are not known. These member dimensions can be estimated by a trial and error procedure (estimate size, design the member and resize it), on the basis of experience, or from table 9.5(a) in the ACI code. This later table is used to
select member depth such that displacements need not be checked (generally a laborious process to be avoided if possible). From this table, the member depths should be about 1/18.5 times the span length, or about (240 inches/18.5 =) 13 inches. In our situation, we have selected the joists to be 12 inches deep and the girders to be 18 inches deep. Joists are typically narrow and have been selected here to be 4 inches wide. The width of a girder is usually 1/2 to 1/3 of its depth; thus, we will select a 10 inch width.

<table>
<thead>
<tr>
<th>Member</th>
<th>Simply supported</th>
<th>One end continuous</th>
<th>Both ends continuous</th>
<th>Cantilever</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid one-way slabs</td>
<td>1/20</td>
<td>1/24</td>
<td>1/28</td>
<td>1/10</td>
</tr>
<tr>
<td>Beams or ribbed one-way slabs</td>
<td>1/16</td>
<td>1/18.5</td>
<td>1/21</td>
<td>1/8</td>
</tr>
</tbody>
</table>

From ACI 318: Building code Requirements for Structural Concrete

b. For this problem, we need to compute self-weight of the concrete supported per unit length of member. (i.e., take the weight of the girder and the total of the joist loads tributary to the girder and divide their sum by the girder length).

c. To get the total ultimate dead load combine the dead loads due to self-weight with those based on uniformly distributed applied loads and multiply the sum by the appropriate ultimate load factor.

LIVE LOADS

Live loads intensity depends on the expected occupancy. The UBC stipulates minimum live loads for various occupancies in Table 23-A (see attached). For example, a office structure would be designed for 50 psf plus a single concentrated load of 2000 pounds distributed over a square space 2.5 ft on each side (that is, over an area of 6.25 ft2). This latter load accounts for possible heavy equipment (safes) and other unusual loading conditions. A separate table is used by the UBC for roof loads.

In selecting the occupancy type, it should be recognized that future modification of the structure may be limited by the category selected. For instance, it will not be possible for the owner to convert the structure at a later time to retail sales, computer applications, a library or material storage, since these all require considerably higher design live loads.

Live loads may be reduced to account for the unlikely prospect of loading a large area simultaneously with the full live load. Thus, design live loads decrease with increasing tributary area. A member must have a tributary area of at least 150 square feet to permit this reduction. Details of the procedure are found in Section 1607.5 of
the UBC (Uniform Building Code). Since slabs are generally designed as having only a foot effective width, their design live loads are generally not reduced.

From 1997 Uniform Building Code Volume 2

d. Determine the service level live load for use in the design of the slab, joist, girder and column. Again, consider the live load to be added to the column by the floor.

e. Determine the ultimate design live loads by multiplying the service load by the appropriate load factor.

**Design Moments and Shears**

At this stage design moments and shears can be determined from an analysis of the frame. Because of the difficulties in determining effective stiffnesses of cracked floor systems and the routine (repetitive) nature of such designs, the ACI code permits moments and shears to be estimated in many instances by means of simple yet conservative moment and shear coefficients (see Section 8.3.3). Alternately, standard analysis methods can be used.
Alternative Structural Systems

It is common to consider many alternative structural systems. For the joist system considered above, the spans could change. For instance, the joists could remain 20 feet long, but the girder spans could be increased to 26 ft - 8 inches. Or the joist could be made 30 ft long, thereby reducing the number of spans in the transverse direction to two. Both of these alternatives would reduce the number of columns and foundations that would have to be constructed and provide more uninterrupted floor space in the building, but would increase member sizes, design forces and costs. In general, determination of optimal spans for design requires considerable engineering effort.

Some Bay Spacing Alternatives

Similarly, there are other structural systems that can be used. For instance, a slab-beam-girder system is quite common. This situation, shown schematically below reduces formwork costs and for short spans steel costs.

Slab-Beam-Girder System

However, the depth of the slab increases for this system. For the case considered above with a 20 foot span subdivided by a central beam, a minimum slab depth of \((120\text{in.}/24 = 5\text{ inches})\) is required by ACI Table 9.5(a). This is a significant increase over the 2 inches considered above for the joist system. This increase in depth will penalize this system for longer spans (design moments increase with span length squared) and for seismic
loading (where design forces depend on the weight of the structure). Other systems, such as flat plate, two way slabs, waffle slabs and so on are also possible. Selection depends on economic considerations as well as functional requirements.