A THESIS

Presented in application for the degree
of
CIVIL ENGINEER
at the
Virginia Polytechnic Institute
Blacksburg, Va.

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To-

Col. R.A.Marr, Dean of the Engineering Depart,ent; and
Professor of Civil Engineering.

HIGH BUILDINGS

Note-

I certify upon my honor that the within paper has been
prepared ahd worked out personally by me

Original Drawings will be attached
about June 10th.
Mr. Tanner is giving all spare time to
these; being occupied daily with
the work of his position.
June 5th, 1912.

6-26-'35

Approved:

Prof. in Charge and
Dean Eng. Dept.

HIGH BUILDINGS.

P. A. Tanner.

May 29, 1912.

HIGH BUILDINGS.

Some immense structures have been built ever since the days of the Pyramids. The construction of very high buildings for commercial use primarily and for architectural effect secondarily, is of modern practice. We have no records or experience by which we may determine whether these buildings are permanent or temporary as compared with world renouned buildings of other countries. Some parts of our so-called fire proof buildings are expected to deteriorate in a few years but the larger part is designed with great care and is expected to last, how long, we cannot say.

Since the invention of fire proof structures there have been various materials used for fire proofing but all have been more or less temporary. The introduction of the hollow tile in 1871 is, however, an exception and this material is considered the best fire proofing material of the present time. Iron is, and always has been, used for columns and floor beams on account of its fire proof properties as well as its superior streanght.

In the early days of the high buildings, a building of eight or ten stories was considered the practical maximum of height. The walls were designed to carry their share of the floor loads and the beams and girders rested on them. In the buildings of today, however, the skeleton structure is made to carry the walls as well as the floor loads. The walls of the modern high building carry no load whatever. This may be said to be the essential difference between the old and the modern high building, that the walls carry no load and are carried by the skeleton structure instead of carrying the floor loads, beams and girders.

The theory of the modern high building is that the steel skeleton construction shall be complete in itself, furnishing the entire strength and rigidity, all other portions of the structure, inside and out, live and dead loads, shall be carried by it. From this we can see that the walls should be no thicker at the bottom than at the top. These walls are called durtain walls as they are merely a covering on the outside and form a protection from the weather. They are, however, quite rigid as well as protect the steel structure.

In designing a modern high building the work should naturally be taken up in the following order: select first the fire proof floor arch; arrange the spacing of beams, girders, and columns, determine the wall sections and method of supporting walls; make schedule of loads on columns and foundations; design the foundations; calculate sizes of beams and girders; calculate the columns; calculate wind bracing.

In this discussion the above details will be discussed briefly with a few suggestions and concrete examples from practical works.

Before proceeding further, however, we must determine the live load for which the building is to be designed to carry. In general, good practice calls for 40 to 75 pounds per square foot on floors used for office purposes, hotels or dwellings; 100 to 120 pounds per square foot on floors for stores, ball rooms, theatres, or places of public assembly and 150 pounds per square foot and upwards for factory and warehouse floors or floors subject to shock or vibration. The New York City building law requires 70 pounds per square foot for hotels and dwellings; 100 pounds for office buildings; 120 pounds for floors of public assembly and 150 pounds and upwards for factories, warehouses, stores, etc. These loads include weights of partitions, stationary and movable furniture, and all live loads.

The choice of the fire proof arch depends somewhat upon the purpose for which the floor is to be used. In general, however, that floor system which weighs the less will be the most economical as the metal in beams and columns will be less. Each case must be studued independently, however, as the conditions vary widely. There are quite a few good floor systems in use now, some of which are the following: hollow tile system of arching, metropolitan system, Rodling system, Melan system and others. Each one of these has its individual advantages and a study of each in regard to the existing conditions for which it is to be used should be carefully made.

In designing the floor beams the use of the following formula is common.

$$R = \frac{3Wl}{2T}$$

in which

R = section modulus in inch units

W.= uniformly distributed load over whole beam.

l = span of beam in feet

T = allowed fiber stress in lbs. per sq. in.

After finding R from the above formula the proper size I beam may be found from any of the mill handbooks. The lightest beam which will fill the conditions should be selected. If no beam can be found near the above modulus then the beams may be rearranged and a new modulus computed. Care must be taken to slect a beam which will not exceed the limiting span which, in New York, is determined by the condition that the center deflection shall not exceed 1/360 of the span when beam is fully loaded.

The wall sections should now be determined and the question at what floors to carry the walls settled. In New York the law requires all 12" walls to be carried at each floor and permits a 16" wall to run two floors unsupported. This same law says that the walls of the four top floors shall be 12 inches wide and that for each four stories or fifty feet downward 4" shall be added to the width of walls of section just above.

This is said to be a a far too rigid requirement and the Board of Examiners makes many concessions in regard to it. However, 12" walls are not allowed throughout the entire structure.

The next work to be taken up is to calculate all the column loads down through the building. If the building is to rest on yielding soil, the live and dead loads should be kept separate. Most authorities agree that the floor beams should be calculated to sustain all the assumed live loads in addition to the actual dead load. The Chicago building law requires that the girders shall be calculated to carry eight tenths of the assumed live load in addition to the dead load and that columns be calculated to carry six tenths of the assumed live load in addition to the dead load. In New York all of the girders and columns are calculated to sustain the total assumed live load for each floor in addition to the actual dead load and that this total load be assumed to rest on the foundations. This, however, is said to be in excess of the practice of the engineers. This, however, is left to the discretion of the engineer except when laws compel him to do otherwise. Each column is usually numbered on the plan; the different stories of the building are denoted by the letters of the alphabet, A being the first story. The loads are generally divided into three parts; floor loads, wall loads, and special loads. The floor loads are understood to include an allowance for fireproof partitions, the beams, the girders, the weight of interior columns and fireproofing them, and for plumbing and heating fixtures, etc., all of which items should be calculated and reduced to a uniform amount per sq. ft. of the floor area and added to the dead load of the floor itself. The wall loads include, besides the weight of walls, the wall columns, the windows and everything in walls themselves. In New York one half weight which would fill the window is deducted from weight of walls. Under special loads, allowance for wind, weights of tanks, vaults, safes, elevators, and all permanent machinery are included. The column loads are placed in a table. For each column is given its dead and live loads and its total load. From this table the total load on the foundations is obtained.

The foundations of a modern high building are probably the most important part. Should the foundation be too weak to carry the load of the structure, the building is likely to collapse at any time. The material upon which the building is built is important in determining the nature and class of foundation. The high buildings of today are constructed with such small bases that it is difficult to get the required bearing area for the various classes of soil. Whenever possible the foundations are acrried to solid rock. When the solid rock is near enough to the surface to be reached by piles, these are driven, in the area of the base until solid rock is reached. Then up on the top of these piles and the soil, which are level, grillage made.

Grillage consists of concrete in which are palced I beams running in both directions. Grillage is used by many engineers for the foundations of these buildings and in nearly all cases where solid rock is not reached. The thickness of the grillage, the size and length of the I beams, etc., depend on the load and the manner in which this load is transmitted to the foundation; whether by one single column or a number of columns, etc. The general classes of foundations from which the builder has to select are the following:

First. Simply building the foundation walls or pillars on the natural bed, spreading the bases with projecting courses of masonry.

Second. Obtaining the necessary spread with a timber platform or grillage.

Third. Driving piles, either to some hard or firm material or to rock.

These two methods may, however, cause settlement by rotting of the timber.

Fourth. Building the walls on beds of concrete of sufficient area, either alone or strengthened by iron or timber beams built in the concrete.

Fifth. Sinking cylinders of iron or caissons of timber or iron of such dimensions as to support either a single column or a series of columns or walls, these caissons being sunk either to rock or to such a depth and material as will preclude the possibility of failure occurring from any of the above mentioned causes.

Generally all buildings which have a height over 1 1/2 times their least horizontal dimension must be provided against wind pressure which in generally taken as 30 pounds per square foot of exposed surface. Factors of resistance to wind pressure are; dead weight of structure, especially in its lower parts; diagonal braces; rigidity of construction between vertical and horizontal members; and construction of iron and steel columns in such manner as to pass through two stories with joists breaking in alternate stories.

In the erection of a high building much depends upon the accurate alignment of the base plates or shoes for the basement columns; they should be set exactly both for line and for level, and securely bolted in their places on the foundation. Built steel columns are usually erected in two story lengths, sometimes in three story lengths, a practice which results in much saving of time and expense.

The beams and girders are first bolted temporarily in their places, about one third of the bolt holes being filled; if any of the connections are to be riveted, a riveting gang follows closely behind the erectors.

Columns should be jointed just above a tier of beams so that the beams frame near the top of the column. The rapidity of erection is not determined so much by the cubic contents of the building as by its linear height, the rate of putting the work together being about two tiers of beams per week without regard to the size of the building.