Evolution of the Skyscraper

by John E. Drey

1951

This thesis was submitted to the Department of Architecture and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Architecture.

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B. of Arch., Univ. of Notre Dame, 1951

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Instructor in charge

May 1951
TABLE OF CONTENTS

INTRODUCTION TO THE SKYSCRAPER.................................................. 1
Definition of a skyscraper.............................................................. 2
Domination of the skyscraper over the skyline of U.S. cities and architecture............. 4
Factors leading to its development.................................................. 6

HISTORICAL DEVELOPMENT................................................................... 7
Vertical transportation........................................................................... 9
  Early passenger elevators............................................................... 10
  Hydraulic elevators.......................................................................... 12
  Electric elevators............................................................................ 13
Skeleton frame construction.............................................................. 14
  Cast iron construction.................................................................... 14
Pre-skyscrapers.................................................................................. 18
First structure to employ skeleton frame construction........................................ 21
The first skyscraper — Chicago.......................................................... 22
Appearance of the skyscraper in
  New York City.............................................................................. 26
Structural development......................................................................... 28
Foundations......................................................................................... 29

ARCHITECTURAL DESIGN OF THE SKYSCRAPER...................................... 32
Chicago school.................................................................................... 32
Classic revival...................................................................................... 36
Classicism............................................................................................. 36
Gothic design....................................................................................... 37
Modern design...................................................................................... 38

RESTRICTIONS PLACED UPON THE SKYSCRAPER.................................... 43
Arguments against the skyscraper....................................................... 44
  Traffic congestion.......................................................................... 44
  Public safety.................................................................................... 45
  Public health: light, air................................................................. 47
  Economic......................................................................................... 48
Zoning Laws......................................................................................... 49
  New York, 1916............................................................................. 49
  New zoning proposed for New York................................................ 51

FUTURE OF THE SKYSCRAPER................................................................ 52
Future of cities..................................................................................... 52
Skyscraper city of the future.............................................................. 54

BIBLIOGRAPHY...................................................................................... 55
<table>
<thead>
<tr>
<th>Illustration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>New York City by night (Plate 1)</td>
</tr>
<tr>
<td>2.</td>
<td>E. V. Haughwout Building</td>
</tr>
<tr>
<td>3.</td>
<td>Early existence of the elevator</td>
</tr>
<tr>
<td>4.</td>
<td>Vertical Hydraulic elevator</td>
</tr>
<tr>
<td>5.</td>
<td>Harper and Brother's Building</td>
</tr>
<tr>
<td>6.</td>
<td>Demolition of the Harper Building</td>
</tr>
<tr>
<td>7.</td>
<td>Monadnock Building</td>
</tr>
<tr>
<td>8.</td>
<td>New York World Building</td>
</tr>
<tr>
<td>9.</td>
<td>First design for a skyscraper</td>
</tr>
<tr>
<td>10.</td>
<td>Home Insurance Building</td>
</tr>
<tr>
<td>11.</td>
<td>Tacoma Building</td>
</tr>
<tr>
<td>12.</td>
<td>Early steel column sections</td>
</tr>
<tr>
<td>13.</td>
<td>Demolition of the Home Insurance Building</td>
</tr>
<tr>
<td>14.</td>
<td>Masonic Temple</td>
</tr>
<tr>
<td>15.</td>
<td>Empire State Building</td>
</tr>
<tr>
<td>16.</td>
<td>St. Paul Building</td>
</tr>
<tr>
<td>17.</td>
<td>Carson, Pirie, Scott Building</td>
</tr>
<tr>
<td>18.</td>
<td>Woolworth Building</td>
</tr>
<tr>
<td>19.</td>
<td>Saarinen's entry, Tribune Competition</td>
</tr>
<tr>
<td>20.</td>
<td>Chicago Tribune Building</td>
</tr>
<tr>
<td>22.</td>
<td>New York Telephone Building</td>
</tr>
<tr>
<td>23.</td>
<td>Equitable Building</td>
</tr>
<tr>
<td>24.</td>
<td>Wall Street</td>
</tr>
<tr>
<td>25.</td>
<td>Rockefeller Center</td>
</tr>
<tr>
<td>26.</td>
<td>Le Corbusier's skyscraper city</td>
</tr>
<tr>
<td>27.</td>
<td>Secretariat Building</td>
</tr>
</tbody>
</table>
INTRODUCTION TO THE SKYSCRAPER

Look out over the skyline of New York, of Chicago, of any American City. Look at this irregular, towering silhouette that man has seemingly thrown up against the sky without plan or consideration of nature, and then consider all the majestic beauty of power and mass that is to be found here. Yes, there is beauty and greatness to be found in the skyline of a large American City: no one can possibly look upon such a sight without feeling it. Even the most staunch critics of the congested vertical city, such as we are now considering, cannot deny it as being both greatly impressive and beautiful. Le Corbusier, for instance, who in his writings considers New York to be a catastrophe, lessens the sting of his words, by admitting it to be a beautiful catastrophe.

What is it then, that has given our failing cities this glamour? What aspect of these same cities has created so impressive a skyline? The answer is obvious: it is the towering mass of buildings, which themselves compose the skyline; it is the tall, multistoried building, the skyscrapers. Of this there can be no doubt, the skyscraper is the basis of the modern American metropolis. It is almost impossible to even imagine New York City, or any other large city within the United States for that matter, without these tall structures, for today our very conception of a city is based upon the grouping of these skyscrapers. And yet, only eighty years ago, within a lifetime, the only element of height in the New York skyline was that of a few church spires rising above a low, flat sea of rooftops. For at that time commercial buildings were not able to exceed five or six
stories. To this almost monotonous picture of a City the skyscraper has today added color, beauty and greatness.

But just what is a skyscraper - can it be classified as any tall structure that rises to a dominating height over the surrounding area? Are the towering cathedrals of Europe and the Eiffel Tower, along with the Empire State Building, to be considered as skyscrapers? No, they are not, for height alone is not the only requirement: to be a skyscraper a structure must fit into a far more definite category. Briefly, a skyscraper is a tall, commercial building of skeleton frame construction and serviced by elevators.

Thus it is easily seen how cathedrals and even the Eiffel Tower are completely eliminated as possible skyscrapers. But in some cases a still more precise definition is needed to designate true skyscrapers, especially when concerning the terms "tall" and "skeleton frame construction". First, that of skeleton frame construction. This denotes that the structure contains no self-supporting walls, thus reducing the exterior walls to mere protective curtains supported, as is the rest of the structure, at each floor level by a system of beams and girders, which in turn transmit their loads to continuous columns. It is interesting to note that during the early stages of development towards the skyscraper, tall masonry buildings (constructed with self-supporting, solid masonry walls) serviced with elevators obtained heights up to sixteen stories. And although these tall buildings visably challenged, and in many cases exceeded in height, the true skyscrapers of the period, they cannot, because of their construction, correctly be called skyscrapers. By some historians, these tall masonry buildings with elevators have been termed, pre-skyscrapers".
The restrictive term, "skeleton frame", itself offers room for controversy. When one considers skeleton frame construction in connection with the skyscraper, he almost always thinks in terms of structural steel construction: of "T" beams and of "H" columns. And yet there are today many tall buildings, of skyscraper proportions, that are of reinforced concrete, skeleton frame construction which also seemingly answers the definition of a skyscraper. The question is therefore raised as to whether these concrete frame buildings are to be equally upheld as true skyscrapers along with the more popular and taller, steel frame buildings? Although there may be many sides to this question, I personally do not believe that a reinforced concrete building can be classified as a true skyscraper. The term, skyscraper, itself implies great heights, and whereas the steel frame combined with the high speed elevator has made height theoretically almost unlimited, construction with the reinforced concrete frame is definitely limited as to height. I would, therefore, include, "steel skeleton frame construction", into any definition of a true skyscraper. Even so, it is still undeniable that the expression and character of a tall reinforced concrete skeleton frame building so closely resembles that of a true skyscraper, that it cannot go unnoticed and warrants special consideration. I would, therefore, consider it to be a skyscraper in a more or less limited sense, as a "limited skyscraper".

Height is also a very controversial subject in connection with the skyscraper: the question being just how "tall" must a building be, to be classified as a skyscraper. Is there a definite minimum height of a skyscraper? Providing that it meets the other requirements, can a building be classified a skyscraper if it exceeds five
or six stories, the pre-development limit of commercial buildings? If it exceeds ten stories? Twenty, or forty? Actually, however, there is no definite height. It is more or less a relative situation, completely dependent upon the buildings association with the surrounding skyline. Throw up a ten or twelve story office building in a small mid-western city: the people here would proudly look up to it, because of its domination over the other buildings in the city. It would without a doubt be a skyscraper to these people and to their city. And yet this same building would sink almost unnoticed below the skyline of New York City. The height of a skyscraper is, therefore, a relative matter, depending upon the buildings, location, and the people who view it.

The domination of the skyscraper over the skyline of the American city is today an accepted fact. Both commercialism and men themselves have found, in these uplifting towers of steel and masonry, a home well suited to the modern city. They undoubtedly are the best known and most typical structures of the Twentieth Century, and yet few building types have appeared, developed, and matured in so short a time. Fifty years covers the entire span from William LeBaron Jenney's first multi-storied metal frame structure to the Empire State Building. Perhaps this rapid development has not resulted in the ideal solution of a modern city; perhaps there has been a great lack of foresight and overall planning. Yet we are proud of our skyscrapers. We are proud of them as symbols of the success and wealth of our cities. We are proud of their majestic beauty; of their greatness in mass. But most of all, we are proud of their height. This feeling of personal pride in the skyscraper can easily be shown
by the air of distinction and individuality that is associated with a very tall building — almost any person is able to identify the tallest, or taller buildings within his respective city; whereas he most likely would be unsure as to the identity of other structures. This distinction, enjoyed by taller buildings, has at times been capitalized upon by owners who have built to exceptional heights, mainly for the publicity thereby gained. However, it was not to satisfy this mental desire for height that brought about the development of the skyscraper, for its development is bound up with the creation of a modern office building, an administrative center.

Twenty or thirty floors of offices in one stack, joined by rapid vertical transportation, are immeasurably more efficient than those same offices spread out in only five or six stories. Eliminate all these tall structures from our cities and you would rob them, not only of their glamorous, but of the centralization and unity for which the city stands. Thus the skyscraper is a symbol of our age — it employs into its nature the architectural form of our business minded nation. It is a commercial structure designed as a home for business.

The skyscraper also dominates the skyline of American architecture. It is our greatest contribution to the field of architectures, and it remains, even today, as the most distinctively American building type in the world. Here to there is pride in the skyscraper, in its very existence and in our ability to conceive, evolve and produce the materials and mechanisms that compose this type structure. But there is no great pride in the overall picture that is presented by our "skyscraper cities" as they stand today, crowded and congested. Here the mistakes and shortcomings are being realized, and plans and designs for the future are being formulated, in an attempt to
eliminate the reoccurrence of these defects and to help remedy those of the past.

The skyscraper was born during a period of economic expansion within the United States. During the second half of the nineteenth century our cities found themselves not only as crowded manufacturing centers, but also as the centers of large sales and distribution networks spreading across the nation. The rapid growth of these cities resulted in large concentrations of people in relatively small areas; thus creating an important social factor towards the development of the multi-storied building, "urban congestion". This congestive situation was even further exaggerated by the tendency of commercial and business offices to crowd together towards the trading center of the city; the result, of course, being that the value of land at this point was enormous. And as these land values, and likewise property taxes, rose to such heights it became necessary for owners to get an increased return from their property; this could only be done by demanding equally enormous rent for office area, or by adding to the rentable area of the property. Since it was found to be almost impossible to raise rents above a competitive point, and because there was yet a seemingly endless demand for additional office space, the land owners turned towards the possibility of increasing the rentable area of their property: taller buildings, to build vertically instead of horizontally. However, here too they were met and stopped by a limiting factor, a limit imposed by man's own reluctance to climb additional flights of stairs. Rental values for office space progressively fell off above the third floor, thus reducing the commercial value of the upper stories and confined all commercial structures to five or six stories. Yet the desire for, and the necessity of the
tall building had been firmly established: the need was now for a building type especially designed to fulfill the function of maximum office area within a minimum of land area.

In addition to this social factor, there were two structural factors which made the skyscraper possible: the development of the elevator, which made the tall building a commercial success, and the steel skeleton frame, which made the tall building of twenty or more stories structurally possible. It was through the elevator that was found the immediate answer to the demands of property owners for increased office area in the form of taller masonry buildings. And then a bit later through the development of steel frame construction that they were able to achieve the great heights that we today proudly point to as the American skyscraper.
REFERENCES:


1. New York City by night.
It has long been held as an undeniable fact, by perhaps even the majority of the people who are at all familiar with the term, "skyscraper", that the invention of the steel skeleton frame was the initial cause, if not the only cause, of the modern skyscraper. And it is easily understandable just how they have come to this conclusion. Whenever we watch the construction of a tall building, we see this frame-work of steel rise first to the sky, and we think, how this use of steel has permitted such wondrously high buildings. Even in the definition of the term, "skyscraper", the steel skeleton frame is brought to light as being the decisive factor in its determination: we are able to point out two buildings, quite similar in height and appearance, and yet because one is not of steel frame construction it cannot be classified as a true skyscraper. Thus people have come to hold a close association between the terms: "skyscraper" and "steel skeleton frame construction", and consequently are of the opinion that the development of the skyscraper dates from the introduction of the steel frame into the building.

In reality, however, it was the elevator that was the initial cause of the skyscraper, and the steel frame its consequence. As we have seen, before the development of the multi-storied building the height of all commercial buildings was limited to five or six stories. This was not because greater heights were structurally impossible, but rather because of the difficulties and loss of time involved in the climbing of more than four or five flights of stairs. At almost any point during the history of civilization man has been able to erect masonry structures to far greater heights. And even these
office buildings of five and six stories were dwarfed by non-commercial structures within the same cities: the zenith of New York City's skyline at this time was the Trinity Church steeple, which reached some 284 feet above the streets, the approximate height of a twenty-five story office building. Man had found himself restricted from the more efficient multi-storied building through his own unwillingness to climb to these heights. However, with the appearance of the elevator all floors, no matter how high, were given equal accessibility; thus permitting the development of the tall building in accordance to the demands of property owners.

Through the use of the elevator masonry, office buildings were quickly carried to ten, twelve, and even sixteen stories, but here again a limit as to height was reached. This time due to the weight and bulkiness of masonry construction itself: the higher the building, the heavier and thicker must be its lower walls. And already at ten and twelve stories these masonry walls had arrived at such enormous proportions that vast amounts of valuable ground floor area was being lost to them. It therefore became obvious, that if the structure was to keep pace with the ever improving elevator, a new and lighter type of construction must be developed. The ultimate outcome of this, of course, being the steel skeleton frame.

Had it not been for this development of vertical transportation, there would not be any skyscrapers today, nor any need for skeleton frame construction. We can, therefore, quite safely state that the actual development towards the skyscraper began with the introduction of the elevator into the commercial building, i.e., the elevator was the initial cause of the skyscraper. And as the elevator evolved, so did the skyscraper. The phases in the development of the multi-
storied structure can be traced in those taken by the elevator. Look
again at the skyline of New York or Chicago, look at the buildings
themselves in respect to their variations in height. There are those
buildings of five and six stories, the old "walkup" type, of the period
before the passenger elevator made its appearance. There are those
of twelve, fourteen, and maybe twenty stories, whose main artery is
the hydraulic elevator. And then there are the record breakers of
thirty and more stories, which were made possible by the speed of
the electric elevator.

VERTICAL TRANSPORTATION

Realizing the absolute importance of the elevator in relation to
the evolution of the skyscraper, it is only natural to devote some
space to the history of its development. A complete report of its
history is, of course, unnecessary for such would entail ones going
much farther into the past than is required for a study concerning
its application to the commercial structure for passenger service.
Ancient woodcuts and tapestries have furnished evidence of the eleva­
tors existence centuries ago, in the form of crude hand powered lifts:
which were almost without exception limited to the carrying of goods,
unless perhaps in some rare instance circumstances warranted the
hazardous lifting of a passenger. It is also believed that types of
lifting devices were used in the construction of the pyramids of
Egypt and the Indian Temples of the Americas.

The first development of any relative importance to the multi­
storied building was the invention of several freight platforms by
Henry Waterman in 1850. These early elevators are of special note,
because they were designed and constructed along the same line of a
modern elevator: a rectangular platform, mechanically hoisted by rope through a shaft cut within the build itself. Although they were dangerous to operate and completely unsafe to ride, they served the purpose of which they had been designed, that of lifting industrial freight. Also, attributed as an important incident in its history was, "a mechanism for hoisting observers to the top by steam power", of a three-hundred foot central tower; as was proposed by architect John Borgardus for the Crystal Palace Exhibition of 1853 in New York City. And although never carried into reality, Borgardus had nevertheless proposed the first passenger elevator in the world.

What is generally considered to be the first passenger type, or safe elevator was an industrial freight elevator designed and installed by Elisha Grave Otis in 1852, and equipped with an automatic device to prevent its ever falling even should the hoisting rope break. Otis then set up a small factory for the manufacture of this type elevator, and in 1853 he demonstrated his "safe" elevator at the Crystal Palace Exhibition in New York City by riding up and down on the platform himself and at times even cutting the hoisting rope.

The first actual "passenger" elevator was installed by Otis in 1857 at the M. V. Haughwout China Store, a five story building at Broadway and Boone Street, in New York City. This elevator was a steam powered, belt driven mechanism, and it marked the beginning of an era in which elevators have made possible buildings of ever increasing height: the beginning of the development towards the skyscraper.

It was not until two years later, in 1859 that a second passenger elevator was installed. This time in the new Fifth Avenue Hotel, a six story structure also located in New York City. This elevator was called a "Vertical Screw Railway" and had been invented by Otis
Tufts. The elevator car was set upon a vertical iron screw extending
the whole height of the elevator well and actually passing through
the center of the car itself. It was propelled upward by a steam
engine revolving the iron screw, moving as would a great nut traveling
along a revolving bolt. Tufts also installed a similar elevator in
the Continental Hotel in Philadelphia, but they were frequently getting
out of order and were far too slow for practical use in a building of
consequent height.

The development of the elevator continued at this slow pace,
very few even being installed, and they were not yet popularly accept-
ed as successful by the general public: break downs and accidents
were frequent and stories of these were circulated in highly exaggerat-
ed forms. Many people still preferred to walk five flights of stairs,
than what they thought would be to jeopardize their lives by riding
an elevator. However, in 1871, architect George B. Post supervised
the installation of the first passenger elevators ever to be placed
in an office building in the First Equitable Building of New York City.
This installation proved to be an immediate success, and for the first
time the elevator began to receive favorable publicity. Then in 1872
Cyrius W. Baldwin, a member of the Otis organization, invented the
vertical hydraulic elevator, a radically different type elevator, cap-
able of much higher speeds than had ever been possible with steam
power. It was this development which definitely established the
elevator in the commercial building and furnished the incentive for
the erection of higher buildings. Although comparatively slow, by
todays standards, the hydraulic elevator did permit the speed necessary
to carry the masonry structure to its limit; thereby giving rise to
the need for skeleton construction.
The vertical hydraulic elevator consisted of a cylinder and piston mounted vertically in the elevator shaft, and was arranged to raise and lower the car by means of a system of sheaves and cables geared to an mechanical ratio. A vertically geared hydraulic elevator with a rise of 240 feet and a geared ratio of 8 to 1, would only require a hydraulically operated piston of slightly more than thirty feet in length. The water pressure necessary to operate the piston was supplied by steam driven pumps and a system of tanks, which along with required piping occupied a considerable amount of space in the basement of the building serviced. A variation of this type elevator was the horizontally geared hydraulic elevator, which had the operating hydraulic cylinder and piston located horizontally in the basement.

A later development of the hydraulically operated elevator in 1898 was that of the "direct plunger method"; which offered high speed and smooth operation, but were exceptionally expensive to install. They required that the cylinder be sunk into the ground, immediately below the elevator, at a distance slightly in excess of the travel of the elevator; the plunger being attached directly to the elevator car. Although mainly used for short rises, a number of them were used for passenger service in buildings of twenty or more stories, and a few in buildings thirty stories high.

The hydraulic elevator had made possible the masonry pre-skyscrapers and had caused the birth of the true skyscraper, but even it soon became a height limiting factor in the further development of the skyscraper. The reason that the hydraulic elevator was not often used in buildings of twenty or more stories was the all-important "Time factor". The hydraulic elevator was too slow; consequently the skyscraper had to wait until the speed of the elevator made height almost
The electric elevator first appeared in 1887 and in 1889, the Otis Company installed the first two successful electric powered elevators in the Demarest Building, New York City. These early elevators were operated by worm-gear ed drum machines with direct current motors, which were far from producing the smooth, high speed power that the electric elevator has today. They were slow, their speed limited by the worm-gearing, and their height of travel was also limited by the width and size of the drum on which the hoisting cables were wound. Hydraulic elevators, therefore, continued to be used for all high speed, high rise installations. However, in 1895 the multi-voltage principle of control was adapted to the electric elevator, giving it almost perfect smoothness of operation. And then in 1902 with the development of the gearless traction electric machine; a machine using no gears, the driving sheave being mounted directly on the armature shaft of the motor, which made the electric elevator capable of any rise and any desirable speed, the limitations of available methods of control the principle factor in determining a practical elevator speed. It was found that even skilled operators could not effectively control an elevator at a speed in excess of 600 feet per minute. The perfection of the electric elevator, therefore, resulted in the development of automatic controls. In 1915 the effective speed of elevators was increased through the invention of a device for automatically bringing the car platform to a stop level with the floor landing. And approximately five years later a complete system of automatic controls was developed, relieving the operator of all duties except that of pressing buttons to register the destinations of passengers. The ability of the operator no longer being a limiting
factor, permitted comfortable speeds up to 1400 feet per minute and made possible even such structure as the Empire State Building.

It is interesting to note that the first elevator system devised, which approached the needs of a modern skyscraper, was not associated with the development of the commercial building. It was designed for the Bifflie Tower in 1889. Four large, double decked elevators ran from the ground to the first platform, two more ran to the second platform, and the rest of the ascent was made in two stages by a pair of hydraulic elevators. The total height of the ascent was a thousand feet and took seven minutes to complete.

THE STEEL SKELETON FRAME

To accurately trace the development towards the steel skeleton frame it is necessary to drop back to England in the year 1780, where the cast iron column first appeared in building. But just what has the cast iron column to do with the American skyscraper and structural steel construction, one might wonder. The answer is to be found in the skyscraper itself — the first true skyscrapers, built over a hundred years after the cast iron column first came into use, depended upon these same cast iron columns for the vertical supporting members of its skeleton frame.

Cast iron columns were first used to replace wooden posts as roof supports in English cotton mills, where the great size of new machinery had demanded as few and as small obstructions possible. They were then considered as only lighter and stronger substitutes for wood, and were used in combination with stone, brick and timber construction. Later cast iron trusses began to replace the heavily timbered roof trusses of these same cotton mills, and later still the
cast iron girder and brick floor arch were introduced in mill construction. But it was the cast iron column, because of its slenderness, its fire resistant qualities, its simplicity and economy of manufacture, and its resistance to heavy loads; that gained immediate popularity with builders and architects, and assumed a major role in all types of building and in all parts of the world where it was to reign undisputed for over a hundred years. Not only did it become an integral part of construction, but it was also accepted as a decorative feature of architectural design, becoming an object of decorative embellishment.

The first use of cast iron columns and beams for the whole interior of a building was accomplished by Boulton and Watt, the inventor of the steam engine, for the construction of the cotton mill of Phillip and Lee at Salford, Manchester, in 1801. The mill, exceptionally high for this early period, was seven stories in height, and 140 feet long by 42 feet wide. Its exterior walls were self supporting and of masonry construction. The interior width was divided into three bays, fourteen feet in span, by two rows of columns at nine foot intervals; the brick arched floors being carried on "T" type cast iron beams, which spanned the fourteen foot bays and were supported upon the columns and the exterior walls. This mill, with its interior, cage type construction was the prototype for all fire resistant buildings of the nineteenth century, and it is recognized today as the first step in the development of the steel skeleton frame.

The first commercial structure, of any magnitude, built within the United States using cast iron beams and arched brick floors was the Harper and Brothers Building erected in New York City at Franklin
Square on Pearl Street in 1854. The year before the building previously occupied by the Harper and Brothers publishing firm had been destroyed by fire, in what was considered the greatest fire loss ever suffered by a firm to that date. And seeking to prevent the recurrence of such a disaster, the Harper firm erected this first, so called, fire-proof building of any importance in the Country. The five story structure was constructed with brick floors arched between iron "I" beams which were bolted to exposed and highly ornamented bowed girders. These girders consisted of an arched rib and a straight tie rod of cast iron, and were in turn supported by cast iron columns and load bearing masonry walls. The front of the building was also constructed or ornamented, hollow cast iron. And it is also important to note that the very first iron "I" beams rolled in the United States, by Peter Cooper in Trenton, New Jersey, were in the construction of the Harper Building.

Previous commercial buildings were to some extent almost all of frame construction, that is their floors, partitions, stairs and roof were no more than a mass of wooden beams, joists, planks, studs, furring, and lath, surrounded by exterior walls of solid masonry. In many instances cast iron interior columns supported and rested upon wooden beams or girders. But as these frame office buildings strove to reach the six story limit, imposed before the development of the elevator, it became evident that these tall, architecturally designed piles of kindling were highly susceptible to fire, and because of their height difficult to control. A trend therefore developed towards the use of fire-resistant materials in the construction of new buildings, one of the first being the Harper and Brothers Building.

Iron as a substitute for wood in building was long thought to be
fire-proof because of its fire-resistant qualities. And for this reason it was used not only to replace wood in the structure of a building, but was also used as a substitute for masonry in the fronts of buildings. This practice was due to the belief that iron was superior to masonry or stone work which would crack and flake when exposed to fire and thereby be ruined in appearance, even though it did not fail structurally. This belief, of course, proved to be erroneous and after a number of fires which resulted in total failure of such cast iron fronts, it became apparent that cast iron was completely unreliable at the high temperatures produced in a fire. Thus causing this type of construction to be condemned by fire departments and insurance companies, and forcing builders to return to the use of solid masonry for all exterior wall construction. But nevertheless these early substitutions of cast iron columns for solid masonry as a means of support in exterior walls represented a decisive step towards the development of the skeleton frame.

Commercial buildings with cast iron fronts had sprung up all over the United States between the years of 1855 and 1875, the so-called "cast iron age" of American architecture. Quite often these cast iron fronts were molded to resemble and counterfeit the masonry which they replaced and ornamented to conform to an accepted architectural style. James Bogardus' early example, the Harper and Brothers Building, was designed with a combination of wide expanses of glass separated by iron columns and arches in a Venetian Renaissance style. Other architects, taking their cue from this and other examples of Bogardus' work, almost completely lost the true expression of the iron column in their attempts to revive the ancient styles in cast iron. There were, however, a few which actually reveal a straight
forward concept of their function, a correlation with the interior
cast iron frame. Typical of this latter type are a number of buildings
located along the central river front of St. Louis, many of which
were erected by the foundries that produced the cast iron, and with no
architect having had a share in their design. The Gantt Building,
which is perhaps the finest example of the expression of the cast iron
front is located, within this district, at 219-221 Chestnut Street. Its
front is being removed by the National Park Service for future
museum use.

With the development of the vertical hydraulic elevator in 1872
the six story limit on commercial buildings was lifted, and within
three years pre-skyscrapers began to appear. They were tall masonry,
elevator buildings; the first structures to be designed around verti-
cal transportation. Their exterior walls were of solid masonry,
supporting not only their own enormous weight, but also a share of
the floor and the roof loads for here beams and girders were set directly
into the outer walls. Their interiors were supported on a frame of
circular cast iron columns and wrought iron beams; which were quite
often designed in a disjointed, haphazard fashion, leaving the
principle reliance for stability and strength upon the masonry con-
struction. These cast iron columns were still left exposed to view
and to possible contact with fire. Floors were constructed in the
only fire resistant methods known at this time: through the use of
either brick arches or corrugated iron, sprung from flange to flange
between "I" beams, and leveled with concrete. However, both methods
were heavy and faulty, adding considerably to the weight imposed upon
the masonry walls and also leaving the lower flanges of the supporting
"I" beams unprotected and open to attack from fire. The limitations
in buildings of this character; as to height, safety and freedom of architectural design; are here easily recognized.

The first of these elevator buildings, or pre-skyscrapers, was the ten story New York Tribune Building, erected by Morris Hunt in 1874. And the last and tallest of them being the Monadnock Building in Chicago, designed by Burnham and Root in 1893, which managed to reach sixteen stories but required masonry walls nearly fifteen feet thick at the basement level. Two other important buildings of this period were: the New York World Building, designed by George B. Post in 1890, which was thirteen stories high not including a seven story dome rising out of its roof; and the Chicago Auditorium Building, by Adler and Sullivan in 1890, which although only ten stories to its main roof, was dominated by a seventeen story masonry tower. Adler and Sullivan later maintained their architectural office on the top floor of this tower.

As these pre-skyscrapers developed, their limitations became more noticeable. The higher they went, the heavier and thicker became their lower walls to counter-act the crushing weights imposed upon them. At twelve and fourteen stories, the lower walls had assumed such ponderous proportions, that not only did they occupy great amounts of valuable first floor area, but window openings were necessarily reduced in size and were so deep that natural light was all but excluded. Also, the weight of these heavy walls was so great that the load per square foot on the floating type foundations then used was too much for the soil, causing considerable soil compression or settling. Further increases in loads per square foot of foundation area were virtually impossible.

When considering the thinly covered skyscrapers of today, it is
difficult to imagine buildings with outer walls of five or more feet in thickness — it does not seem possible that business offices could be located behind such a barrier. Realizing the serious limitations imposed upon the tall buildings by the bulkiness of these load bearing walls, architects and builders attempted to devise new and lighter means of construction. Their first efforts, of course, being directed towards the possibilities of lightening and scaling down the proportions of these masonry walls.

An early attempt to lighten these load bearing walls without weakening them, was that of building cast iron members into the walls to assist the brick and masonry in withstanding the crushing weight applied to it. The cast iron most usually being placed between window openings, where narrow piers were especially desirable. This practice, however, proved unsuccessful in most cases; because the cast iron and masonry were here being used as one mass to resist the compressive forces acting on the wall, and whereas the brick and masonry joints would themselves compress or settle the cast iron would not. Thus causing undesirable strains and surface cracks in the masonry finish of a wall. A partial answer was, however, found in the reduction of the dead loads carried by these walls. The heavy, brick arched floors accounted for most of this dead weight, and with the invention of the hollow tile flat arch, by Balthaser Kreischer, the total weight of floor construction could be greatly reduced. Hollow tile floors weighed only one-fourth as much as did those of brick. This new type floor construction also offered the advantage of superior fire protection; the tile could be formed so that it would recess around the previously unprotected lower flange of supporting "I" beams. Even further reductions in the weight and size of masonry construction
were made possible by the use of cast iron columns, set independent of the walls, to carry all the roof and floor loads that before had been transmitted into the walls. For the first time masonry walls could be constructed where were only "self-supporting", that is they were free of the interior structure, supporting nothing but their own weight. An example of this type of construction is found in the New York World Building. Here, the load relieving columns are recessed into the thicker walls at the lower stories, but emerge and are some distance clear of the walls at the top. Even so, while only self-supporting, the exterior masonry walls of the World Building required a nine foot thick base to reach its height of thirteen stories — the answer to lighter construction was not to be found within the limits of masonry construction. The next step, although bold, was logical: if masonry was so heavy that it could not even successfully support itself, then why not also support it upon a cast iron frame as had been done with all other loads? From these early attempts to lighten and fireproof construction: the using of cast iron fronts, the embedding of cast iron compression members into masonry, and the relieving of the masonry wall from its load bearing duties; the skeleton frame evolved in answer to the demands of the tall, commercial building.

The first building employing a true skeleton frame in its construction was, however, not built in the United States. Nor was it in any way connected with the development of the American skyscraper. It was the chocolate works, erected in 1872 by Jules Saulnier at Noisiel-sur-Marne, near Paris, France. The factory is constructed upon four large iron girders which rest upon stone piers set into the Marne River. The skeleton frame, which could be seen on the surfaces
of the walls, was of cast iron and carried the whole weight of the building. The exterior walls were of hollow brick and merely served as filler between the cast iron members. Although widely published in French reviews, this building remained unknown in the United States and, therefore, in no way influenced the development of the skeleton frame within the United States. The chocolate works, itself, was only a four story building without any vertical transportation, and cannot be classified as a skyscraper.

Generally recognized today as being the first true skyscraper actually built, was the ten story Home Insurance Building in Chicago, Erected by William Le Baron Jenney in 1884, it represents the first application of the skeleton frame to an elevator serviced commercial building. Jenney had done, what had never before been attempted, he carried the entire building: roof, floors and exterior walls upon a frame work of cast iron columns and wrought iron and steel "I" beams, with the exception of the two interior party walls which were yet of load bearing masonry construction. When construction had reached the sixth floor, the Carnegie-Fhipps Steel Company asked Jenney's permission to substitute newly rolled Bessemer steel beams for wrought iron beams on the remaining floors. Jenney consented, and the Home Insurance Building also became the first commercial building to employ structural steel in its construction.

The reasons for Jenney's departure from accepted methods of construction, and the system he devised are best explained by Jenney himself, as given in a statement read before the American Institute of Architects in 1891:

"The condition of a very compressible soil carrying only a light weight per square foot necessitated a different method of construction from those in general use. The
piers must be narrow in order that proper space might be left for windows, the wall must not be as heavy as in the old construction, or there would not be sufficient space on the ground for the foundation. A column in each pier was the natural solution of the problem. Lintels between columns, forming heads of windows, carried the street walls story by story, the brick work reduced to the thickness necessary to hold window frames or to fireproof the metal columns and lintels. 3

In 1931, during the demolition of the Home Insurance Building, tests were conducted to determine the exact nature and extent of the skeleton construction employed, to verify the building’s position in the development of the skyscraper. Typical piers between window openings were stripped of all masonry, leaving only the exposed cast iron column, to determine whether or not the exterior masonry walls were completely supported by these enclosed columns. In each case, the masonry above remained undisturbed with no cracking or other apparent masonry failures. At the conclusion of these tests, the committee in charge made no hesitation in coming out with the statement that the Home Insurance Building was the first tall building to utilize the principle of skeleton construction in its design, and because of this priority and its immediate success was the principle influence in the establishment of skeleton construction. In the opinion of the committee, there can be no doubt that it was the first, true skyscraper ever built.

Although Jenney’s Home Insurance Building is recognized as the first skyscraper actually erected, there is still controversy as to who was the actual inventor of the skyscraper. That is, who first conceived the idea of supporting the multi-storied building upon a skeleton frame. Besides the claim which Jenney naturally has to this honor, the claims of Leroy S. Buffington, a Minneapolis architect,
have been advanced more often than any others. And in one or two
cases he attempted to establish a legal claim to skeleton construc-
tion. Buffington claimed to have invented the skyscraper in 1880,
receiving his inspiration from the published lectures of a French
architect, Viollet-le-Duc; in which Viollet-le-Duc remarked that,"a practical architect might not unnaturally conceive the idea of
erecting a vast edifice whose frame should be entirely of iron,...
preserving (that frame) by means of a casing of stone." Realiz-
ing the possibilities of a skeleton frame covered with masonry,
Buffington made designs and sketches for several such multi-storied
buildings of twenty, thirty and fifty stories in height. He called
them "cloud-scrapers", and even went so far as to make calculations
of column sizes for different heights. However, it was not until
1888, four years after the Home Insurance Building had been construct-
ed, that he published his designs and applied for a patent upon the
structural system he had devised. This, along with the fact that
the system he advocated, concerning solid laminated steel columns,
was highly extravagant and impractical, weakened the effectiveness
of his claim that he was the inventor of the skyscraper.

Another possible claim to the invention of the skeleton frame
was that raised by George B. Post's Produce Exchange Building in New
York City. Completed in 1884, simultaneous with the Home Insurance
Building, the principle of skeleton construction was partly used in
its design. Post, had supported four heavy fireproof stories of its
interior court upon iron girders and columns, and only the New York
building code had prevented him from using this same form of con-
struction for the exterior walls of the building. Although the Produce
Exchange Building competes with the Home Insurance Building for the
honor of being the first to use skeleton frame construction in a modern sense, it was not designed in the spirit of the skyscraper and has no claim as such. Its skeleton frame had not been planned to obtain height, but only as a convenient method of supporting the heavy court walls, and its low height does not in any way express the character of a skyscraper.

Also in 1884, architect Fredric Brumann published a pamphlet in which he gave a complete outline concerning the design, construction, and advantages of skeleton framed, multi-storied buildings. Whereas Jenney and Post had only partly employed skeleton frame construction in their designs, Brumann had published the first vision of a complete skyscraper.

Considering the validity of these various claims, it seems only fair that the credit for the invention of the skyscraper be divided among these men; each receiving just recognition for his part in its development: Jenney and Post, for having devised and executed the first skeleton frame; Buffington, for having created the first design for a skyscraper; Baumann, for the first complete vision of a modern skyscraper; and again, Jenney, for having actually constructed the first skyscraper.

It was not until three years after the completion of the Home Insurance Building, 1887, that a second skyscraper, the fourteen story Tacoma Building, was erected. Also built in Chicago, it was designed by the architectural firm of Holabird and Roche. Its exterior walls were supported upon an iron frame of improved design, and for the first time, the walls were started at points midway between the ground and roof. The party walls, as in the Home Insurance Building, were of solid masonry construction. By the use of skeleton frame construct-
ion, the Tacoma Building gained rental area equivalent to that of an additional story.

In 1889, the skeleton frame evolved into fundamentally the same structural system that is used for multi-story buildings today. In that year, Burnham and Root designed and constructed the Rand McNally Building, which employed the first skeleton frame made up completely of rolled structural steel beams and columns riveted together. And also in 1889, Jenney erected his second Leiter Building, the first skyscraper of pure skeleton frame construction. That is, the first without any load-bearing or self-supporting walls. Its method of construction, at last perfected, the skyscraper began to reach for new heights. In 1890 Jenney designed the Manhattan Building, and then in 1891 Burnham and Root erected the Masonic Temple, twenty-one stories high, and the tallest building in the world at that time. It was also the first skeleton framed structure to exceed the heights previously attained by masonry buildings.

It should be noted that all the skyscrapers so far mentioned were built in Chicago. This is because the skyscraper was originated, established, and developed within that Midwestern City, and did not even appear in New York City until 1889. In fact, at this early date, skeleton construction was often referred to as "Chicago construction". The reason that this early development took place in Chicago was because the City was yet comparatively young and had been undergoing almost complete rebuilding, following the fire of 1871. Whereas in New York, building was now carried out in a more conservative manner, and was subject to a rigid building code, which prescribed minimum exterior wall thicknesses for different building heights and prevented experimentation with thinner walls. Therefore, skeleton construction
was permitted only after it had been proven elsewhere. The first skyscraper in New York City, the Tower Building, came about when architect Bradford L. Gilbert was commissioned to erect a tall building upon a narrow twenty foot lot. Realizing that the thick walls of masonry construction would render the lower floors useless, Gilbert planned to use thin-walled Chicago construction (skeleton frame construction). And even though this type of construction had been proven successful in Chicago, he yet had great difficulty in obtaining authorization to utilize it in New York. In 1899 the Society of Architectural Iron Manufactures of New York, placed a tablet in the lobby of the Tower Building declaring it to be the first known example of skeleton construction. Although erroneous and despite the indignation of Chicago architects, the tablet remained in place until the building was demolished in 1914.

It was not until 1892 that New York City revised its building codes to permit skeleton frame construction. This obstacle removed, skeleton frame construction invaded New York, and shortly New York City began to surpass Chicago, taking over the leadership in the erection of skyscrapers. Early in 1899, George B. Post erected the St. Paul Building, twenty-five stories in height, succeeding Chicago's famous Masonic Temple as the world's tallest building. And later the same year, the Park Row Building gained this distinction by towering some thirty stories above the streets of New York City. A book, written by Joseph Freitag, at this time concerning architectural engineering in respect to the tall building, spoke of the Park Row Building as:

"... the highest office building ever erected, and it is very doubtful whether it will be found either desirable or profitable to erect other buildings as high as this one."
But New York did build higher: the Singer, Metropolitan, Woolworth, and Chrysler buildings each successively enjoying, for a brief period, the distinction of being the tallest building in the world. Then in 1931, just as the era of the super-skyscraper was brought to a close by the depression following the First World War, the Empire State Building was completed. One hundred and two stories, 1248 feet high, it was designed by the firm of Shreve, Lamb and Harmon, and remains today the world's highest building.

Structurally the skyscraper has not undergone any drastic change. The first pure, steel skeleton frame as used in the Lelter Building, 1889, was fundamentally the same and practically as efficient as any now in use. The only recent development of any importance, being that of arch welding as a method of joining the structural steel members. Welded steel does offer a more efficient and rigid frame than is obtained through riveted joints.

Cast iron columns had to some extent continued to be used in skeleton frame construction as late as 1904, and were employed in buildings up to seventeen and eighteen stories in height: the Manhattan Life Insurance Building and the Ansonia Hotel, respectively. Although more economical, cast iron suffered in comparison with the newer steel sections being introduced. Its principle disadvantage was that beams or girders had to be bolted to it and, therefore, did not lend itself to as rigid a frame as was possible with riveted steel members. Bolts never completely filled their holes; whereas hot rivets forced into their holes almost became an integral of the beams and columns. In one case a building at 14 Maiden Lane in New York City was blown eleven inches out of plumb through the inability of bolted iron construction to resist wind pressure. The final
disappearance of the cast iron column followed the collapse of a thirteen story building in 1904, during its erection. Although its cast iron columns were probably not the cause of the failure, the association alone was enough to prevent their future use in any large structures.

Early steel columns were built up of lighter, rolled steel sections such as channels, plates, angles, Z-bars, I-beams, and even special circular sections; and were designed by the architect for a particular job. Many of these sections were patented and manufactured by only one mill. It was not until later that the standardized, wide flange H-column was developed and came into general use.

Reinforced concrete skeleton frame construction, has to some extent been able to compete with steel in the erection of multi-storied structures; although it is generally restricted to structures of twenty or less stories. Here, however, it does offer several attractive advantages: it affords a more economical construction, carries its own fireproofing, requires less skilled labor to erect, and offers a homogeneous design in beams, columns, floors and even exterior. But because of its limited nature, as to height, one does not usually consider reinforced concrete in connection with the skyscraper, and the definition of a true skyscraper excludes this possibility.

FOUNDATIONS

The development of both the elevator and steel skeleton frame was spectacular and aroused great interest in the public; with each step taken, new buildings and new heights were attained. There was, however, another development taking place at this same time which was not nearly so spectacular and for the most part progressed unnoticed, but yet was of the utmost importance to the future of the tall building.
This development took place underground, and concerned the foundations upon which all structures must rest. At the time the skyscraper began its evolution the science of foundations had not advanced past the stage set by engineers during the Renaissance. All walls and columns were carried on continuous, spread footings which rested or floated upon the surface of the earth; their size, or spread, depending upon the bearing pressure of the particular soil. All buildings settled to some extent as the soil compressed under the weight of these footings. And as the tall building began to make its appearance and the weights imposed upon such footings became much heavier, the problem of settling became quite serious. This was especially true in Chicago, because the City is built on a bed of muck along the shore of Lake Michigan. Here it was not uncommon for large structures to settle a foot or more; and it became necessary for architects to allow for this, slanting the sidewalks upward to the building in hope that when the building did settle the sidewalks would sink with it to their true plane. The extent of this settling, unfortunately, could only be guessed. Portions of the Auditorium Building settled as much as eighteen inches, and the five million dollar Federal Building, completed in 1880, settled so badly that within eighteen years it was condemned and demolished. Quite often these buildings did not settle evenly, particularly if a part of the soil built upon had previously been compressed by an earlier structure. This, of course, resulted in buildings which were considerably out of plumb. Chicago’s famous, twenty-one story Masonic Temple settled five or six inches more in the rear than it did along the street.

The first improvement over these old continuous type footings, was the use of an independent foundation for each column. This practice
permitted a more accurate figuring of column loads and this a more uniform settling; it was first for the Montauk Building by Burnham and Root in 1881. The stepped, masonry pyramids necessary for these independent spread footings, so filled the basement of the Montauk Building that the boilers had to be located at grade in the air court. Another improvement was, therefore, the substitution of steel-grillage footings for those of stepped masonry. Requiring an excavation of as little as three feet, these crossed-steel footings permitted the utilization of basement area.

Pile foundations, also an ancient form of footing, were not used to any great extent in Chicago. It was almost impossible and costly to reach hard-pan or bed rock with piles, and consequently those which were used settled almost as badly as did spread footings. However, in New York City, where bed rock was fairly close to the surface and the soil condition too variable for heavily loaded spread footings, piles were found to be a satisfactory support for early skyscrapers.

The real answer to the problem was, of course, to actually carry the footings or solid piers, upon which a building could rest, to bed rock. This was made possible through the development of the various types of caissons: open, hydraulic, and pneumatic. Although slightly different in operation, their principle is the same, that of sinking a steel drum through the soil, sand and muck to bed rock, sometimes seventy-five to a hundred feet below grade. The caisson sinks as fast as men excavate the earth from within it, leaving a sort of open shaft above, as it sinks to bed rock. When bed rock is reached the caisson and shaft are packed with concrete, leaving a solid pier from bed rock to the desired height at which the building will rest.
REFERENCES:


2. E. V. Haughwout Building, employed the first passenger elevator.

3. Early Existence of the elevator.

4. Vertical Hydraulic elevator.
5. Harper and Brother's Building.

7. Monadnock Building, pre-skyscraper.

9. First design for a skyscraper, Buffington.
10. Home Insurance Building, the first true skyscraper.
Plate 7.

11. Tacoma Building, the second skyscraper.
12. Early steel column sections.

Larimer column, 1 row of rivets.
Plate and angles, 2 rows.
Z-bar column, without covers, 2 rows.
4-section Phoenix column, 4 rows.
Channel column, with plates or lattice, 4 rows.
Gray column, 4 rows.
Z-bar column, with single covers, 6 rows.
Channels, web-plate, and angles, 6 rows.
Box column of plates and angles, 8 rows.
Latticed angles, 8 rows.
8-section Phoenix column, 8 rows.
Z-bar column with double covers, 10 rows.

14. Masonic Temple, the world's tallest building at the time of its erection.
15. Empire State Building.

ARCHITECTURAL DESIGN OF THE SKYSCRAPER

Since the development of the skyscraper, most architects have been able to master its technical and structural problems, but few have been able to clothe its steel frame in a logical, straightforward manner. Perhaps they had been too long occupied with solid masonry construction to at once realize the possibilities, and the necessity, of a new and lighter expression. To them, the skeleton frame was only a convenient means of stretching masonry walls to new heights. They designed and expressed the skyscraper just as they had done with masonry construction: many a daring structural feat was lost without a trace beneath a blanket of seemingly solid masonry. The architectural styles of the ancients: Romanesque, Classic, and Gothic were used successively to cover and hide the skeleton frame, and it was to be thirty-five years before the supporting frame was to free itself from these masonry envelopes and dictate the form and expression of the modern skyscraper.

THE CHICAGO SCHOOL

Considering this long period during which the skeleton frame was denied expression, it seems almost contradictory to note that a number of the best solutions to this problem, the expression of the skyscraper, are among the earliest. However, in Chicago immediately following the development of the skeleton frame, Sullivan, Jenney, Burnham and Root, and Holabird and Roche designed a group of skyscrapers which have proven to be among the most honest, straightforward expressions of the skeleton frame. They had let the steel frames, of these early structures, be the determining factor in their designs; reducing the
masonry portion of the exterior walls to be a simple sheath protecting the frame, and leaving wide expanses of window area between the piers, which were termed, "Chicago windows". Jenney's second Leiter Building, the first complete skyscraper, tended toward a purity of architectural expression which was a fitting match to its purity of structure. And in his design for the Fair Building he made the lower two stories almost all of glass, a sharp transition from the heavy masonry bases which architecture had grown accustomed to. The Marquette Building, by Holabird and Roche, with its narrow, well proportioned piers and spandrels, and wide expanses of Chicago windows, was the typical office building of the Chicago School of design. And, of course, Burnham's Reliance Building, which was a tower of glass and white tile, completely devoid of bulky masonry. These are among the best examples of the Chicago School, that group of architects who had first spanned the schism between design and skeleton frame construction. These are the skyscrapers, that because of their honest expression of the steel frame, were termed Chicago packing cases and cheap engineering solutions by Beaux-Arts instructed architects from the Eastern states, who stood by waiting for their opportunity to turn the skeleton frame into a dress-horse for the styles and decorations of ancient civilizations.

But it was mainly Louis Sullivan who led the Chicago School, and was the greatest in his understanding and mastery of the expression of the skyscraper. In fact, the entire development of the modern movement, which was to come some thirty-five years later, may be found in his work. It was Sullivan who, in his Wainright Building, first gave the skyscraper its heaven leaping vertical; he then designed several buildings in which he emphasized the horizontal. It was he who first anticipated the set-back style of modern skyscraper, and
proposed its use in his designs for a Fraternity Temple. And then in his Carson, Pirie, Scott Building, he produced his greatest design and gave to us a beautiful example of the true expression of the steel skeleton frame. Guided by his outline of a clear and honest philosophy towards the steel framed, multi-story building; rather than by custom and tradition; Sullivan was a prophet modernism. And had he been recognized and followed, the skyscraper would not have been submitted to thirty-five years of "exterior decoration".

As far as Sullivan was concerned, masonry construction for the tall building was a thing of the past, and was to be forgotten, so that the mind of the architect might be free to solve the obviously new and different problems involved in skeleton frame construction. He believed that the function of the frame should not be suppressed by the design or style of its cover, and also that the nature of the skyscraper, height and uniformity of plan, should enter into its expression. With these principles in mind, Sullivan designed his first skyscraper, the Wainwright Building in St. Louis. Here was no attempt to imitate solid masonry construction, the windows dominate over the obviously thin protective cover of brick and terra cotta. The office floors are all identical in exterior expression, because they are alike in plan and function, and are bound together by the continuous treatment given the vertical piers. The Wainwright Building represents the first successful architectural solution to the skyscraper and it is capable of comparison with modern examples.

Sullivan repeated this vertical emphasis on the Schiller Building, 1892, in Chicago, and the Guaranty Building, 1894, in Buffalo. But in 1893 he had designed the Meyer Building in Chicago, and had here deliberately placed the emphasis upon the horizontal spandrels between
the window tiers. Actually, however, the skeleton frame is a neutral or static network, completely impartial to direction; floor loads are horizontally transmitted to vertical columns. Sullivan had merely picked out and emphasized one of these two directions. And it was in his realization of this fact, that the nature of the skeleton frame is neither vertical nor horizontal, but a series of static cages, that inspired him to his greatest design. In 1899 he erected the Carson, Pirie, Scott Building, then the Schlesinger and Mayer Building, in which the skeleton is expressed in its purest form, resulting in an exterior grid pattern. Both the piers and spandrels are of a minimum size, completely reducing the facade to its function, of admitting light. Although neither the vertical nor the horizontal members of the steel frame have been emphasized, because of its elongated Chicago windows and use of narrow bands of ornament to border the spandrels, the building had a definite horizontal organization. Considered the best skyscraper of the Chicago School of design, the Carson, Pirie, Scott Building remains today as one of the most direct and honest expressions of the steel skeleton frame.

The Chicago School was cut short by the Classic Revival, its examples and influences unnoticed and disregarded in the years to follow. And yet we are able to find designs of a more recent nature, which so closely resemble these early works that they seem to be later developments of the same idea. In 1922, Walter Gropius entered a design in the Chicago Tribune Competition, which was quite similar in expression to Sullivan's Carson, Pirie, Scott Building. It was based upon the same grid-like exterior pattern of the skeleton frame, and even employed the elongated Chicago type window. It, too, was regarded as unstylish and received little consideration in the Competition.
Many of our clean-cut, modern skyscrapers are also very reminiscent of the spirit of the Chicago School. The new Equitable Savings and Loan Building in Portland, designed by Pietro Belluschi, as an example, is seemingly a modern reincarnation of the Carson, Pirie, Scott Building. Although of reinforced concrete construction, here is such a pure and honest expression of the true, static natures of the skeleton frame that it deserves special notice in any case. The narrow piers and spandrels have been covered with an aluminum sheathing, which coupled with the wide expanses of glass gives the building an extremely light character: here is truly a glass and metal tower.

CLASSIC REVIVAL

In 1893 the World's Columbian Exposition, with its false, classical architecture exploded in the midst of the Chicago School, leaving its influences demolished and forgotten. The Exposition was to be held in Chicago, with architects from the East to assist in the design of the buildings. Daniel Burnham, a recognized leader in the Chicago School and chairman elect of the Exposition's architectural board, had, through a feeling of "cultural" inferiority to Eastern architects, permitted this Eastern delegation to gain control of the architectural board. The Eastern architects were strong in their insistence for the Classic style. The West was weak — only Sullivan fought against them. The Roman Classic style was officially adopted for the Exposition. "Culture" was brought to the West: the Chicago School choked off, and Sullivan defeated.

New York City had never even accepted Richardson's Romanesque style, her tall buildings all bore the stamp of the Classics: typical of the New York multi-story building at the time of the Chicago School.
Is George Post's World Building. And now triumphant, the Chicago School defeated, the Classic Revival spread. The United States was flooded with skyscrapers ridiculously decorated with colonnades and other Classical debris meticulously copied from the ancients. The temples of Rome and Greece were made to tower above the streets of our cities; their outer shells a disguise, the true function and structure of the building hidden within. At times even the structure was corrupted so that the exterior might appear stylistically correct. But for all their good taste and stylistic correctness, they were architecturally weak. There was no unity in them; the Classic style did not freely lend itself to great heights, and consequently one temple surmounted another until the desired height was finally reached.

In an effort to obtain an architectural unity for the tall buildings, the Classicists formulated the assumption that the facade of a skyscraper should be proportionated according to the laws of the Classic column, with a base, a shaft, and a capital. The base was usually composed of the lower two or three stories, and was designated by heavy masonry or wide columns pretending to support the above portion of the building. Above the base was the unornamented shaft, of office tiers, which was generally the best part of the design, although every effort was made to have it simulate solid masonry. The shaft was then terminated by either a colonnaded temple, or by a heavy, projecting cornice corresponding to the capital. The result of this type of design was a weighted structure that would have fitted perfectly to solid masonry construction, but completely lacked the clean, light expression that is the inherent quality of the steel skeleton frame.

One might wonder why architects had even attempted to unify the Classical style to the skyscraper. The two seem so unrelated; the
heavy, low stone temples as compared to the light, soaring characteristics of the steel framed skyscraper. Driven by this sense of conflict, architects turned towards the Gothic style. Here they found an expressive analogy between the tall building and the towering Gothic cathedrals of Europe. The inherent vertical emphasis of the Gothic style offered a welcome solution to the problem of architectural unity in the skyscraper. The Woolworth Building, designed by Cass Gilbert in 1913, is our best example of the Gothic style as applied to the skyscraper, and through it, the entire period may be summed up. The fenestration of its facade is almost true to its skeleton frame, except for the addition of false intermediate piers and excessive ornamentation. The facade does not pretend to be a solid self-supporting mass, but frankly admits that it is only a light protective curtain—thin bands of vertical, Gothic tracery replacing the heavy masonry piers of the Classic style.

This Gothic style had given the skyscraper unity and form; it had admitted the existence of the skeleton frame, but had hidden it beneath detailed Gothic ornament. It was the only decorative style that could logically be applied to the tall building, but yet, at its best it was not a solution for the skyscraper. These decorative styles were devised by past civilizations to express a certain form of construction. The skeleton frame is a new form of construction and should be expressed as such.

MODERNISM

The modern movement has attacked this problem of the creation of an original style, or styles, suited to the nature of the skyscraper's construction. It has stripped the skyscraper of all surface decoration,
permitting its expression to be determined by its skeleton frame. We call these clean, simplified skyscrapers "modern", but actually what are they except an answer to the structural honesty that Sullivan had advocated years before?

The transition from the corrupt Classic skyscraper to the modern conception took place over a rather long period of time, and was more the result of outside influences than a realization or understanding of the problem by American architects. The Woolworth Building, in all its Gothic glory, was itself unknowingly a part of this transition: here, the masonry look had been given up, admitting that the exterior wall was nothing but a light curtain supported upon a steel frame. The zoning laws installed by New York City in 1916, regulating buildings to prescribed set-backs at certain heights, were also influential to the transition. These required set-backs forced architects to give consideration to the form of their buildings. And gradually they came to rely more upon form, than upon surface decoration, to give expression to the skyscraper. The most dramatic and decisive event of the transitional period was, however, the Chicago Tribune Competition. Held in 1922, it attracted entries from all parts of the world for the design of a tower office building. The first prize went to Raymond M. Hood and John Novells for an attractive, Gothic styles design. But it was the design entered by Eiel Saarinen, awarded second place in the competition, that was hailed by critics and architects alike. Here was a refreshing design, with a clean, honest vertical expression, completely devoid of distracting stylistic decorations. Here was everything that had been desired in the Gothic style: unity, lightness; even more perfectly expressed. It was logical, powerful, and most important it was original, untainted with history.
And in this design those architects who had been tending away from surface decoration in favor of form found an escape from the ties of stylized architecture.

Raymond Hood, who had won the Competition with a Gothic Tower, even realized the greatness of Saarinen's design and within a year he had erected the American Radiator Building, in to which he introduced much of the same simplified vertical expression. The Shelton Hotel and others were quick to follow, and then in 1926 the erection of the vertically sleek New York Telephone Building proclaimed the establishment of modern design in the skyscraper.

Hood carried this simplified vertical emphasis of the modern skyscraper to its extreme limit in his New York Daily News Building. The spandrels have been set deep between smooth, continuous piers and are even further subdued by the use of color: white vertical piers against dark spandrels, almost completely eliminating the horizontal from the expression of the building. This was modern design, clean simplified lines sweeping skyward. But it was far from being an honest expression of the steel skeleton frame. The skeleton frame is a static, neutral unit and such a gross over-emphasis of only one element in its function was but a corruption of its true nature and expression. Simplification from ornament and style is, alone, not the whole answer; Sullivan had shown the way in his Carson, Pirie, Scott Building.

Hood realized that he had carried the vertical emphasis past its limit, into an architectural dead end, for in his next design for a skyscraper, the McGraw-Hill Building, he turned towards a more horizontal expression. Although again missing the whole function of the steel frame, he had nevertheless made a step forward, by breaking the vertical.
Following the example set by the McGraw-Hill Building the emphasis was swung to the horizontal for skyscraper design. Architects soon began to employ cantilevered construction because of its honest horizontal expression. But this system of framing was not justified by any actual need. The real answer to the problem lay in the acceptance of the fact that the true expression of the steel frame is both horizontal and vertical. Howe and Leesage readily proved this fact in their design for the Philadelphia Savings Fund Society Building. Here both horizontal and vertical are combined to produce one of our most beautiful skyscrapers. The Equitable Savings and Loan in Portland, and the Lakeshore Apartments in Chicago, both recent developments, are excellent in their expression of the skeleton frame. The skeleton frame has at last been rediscovered.

Another recent innovation in modern skyscraper expression has been demonstrated by the Secretariat Building of the United Nations Headquarters in New York City. This thirty-nine story building is a perfect rectangular slab, its two broad facades completely of glass and thin aluminum separators. Here the exterior wall has been reduced to a thin curtain of glass, hanging as an independent unit in front of the supporting steel frame. Is this expression to be hailed as a solution to the problem of the skyscraper? Perhaps, it is light, simple and certainly quite frank in its dependence upon a skeleton frame for support; and by being a free-hanging curtain it is an escape from the problem of expressing the skeleton frame. Yet, by the very fact that the skeleton frame is hidden behind this highly reflective surface of glass seemingly leaves the problem unsolved. Are we; as the early architects who, because they were unable to create an expression suitable to the skeleton frame, hid it behind heavy masonry?
being forced, because of a lack of creative ability, to hide the skeleton frame behind a screen of glass?

It is difficult to criticize the modern movement, as a period it is not yet complete. Mistakes have been made and can be pointed out, but as a whole, by the simplification of the design and elimination of historical detail, this period is a great improvement over its predecessor. And perhaps by some of our efforts a step has been taken into the future.
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Plate 11.

17. Carson, Pirie, Scott Building.
Plate 12.

18. Woolworth Building.
19. Saarinen's entry in the Chicago Tribune Competition.

20. Chicago Tribune Building, by Hood.

Amid the congestion which grips our cities today, the skyscraper stands as both a symbol of future relief and as the monster which has forced upon us this condition. Controversy rages as to its future, and even at the present time new zoning laws and restrictions are being proposed for its control. This, however, is by no means a new situation to the skyscraper, for its entire development has taken place under bitter controversy and opposition. It was because of building restrictions that the skyscraper was not permitted to first develop in New York City. And those which first appeared in Chicago were, even then, subject to attack. These early attacks against the skyscraper were chiefly directed at the unsightly character of these tall structures which supposedly were disfiguring the streets and skylines of our cities, and also against the possibility of their collapsing into a crowded street. Such disasters were predicted for years by men of actual technical knowledge, who feared internal changes would weaken the steel members of the supporting frame.

Surprisingly, much of this early opposition against the erection of skyscrapers came from architects as well as other sources. Even George B. Post; who had done so much to pave the way for the invention of the skyscraper, by installing the first successful elevators and by being one of the first to devise and employ skeleton construction; was himself a prominent leader of this opposition. Claiming that the grouping of such tall buildings would destroy the beauty of our cities; in 1894 he presided over the Architectural League of New York City, which advocated legislation against the skyscraper. Failing in its attempt to outlaw the tall building, the League was
dissolved, and architect Post, apparently somewhat related in his feelings towards the skyscraper erected the St. Paul Building in 1899, twenty-five stories high, and at that time the tallest building in the world.

As the skyscraper developed, unrestricted, this controversy continued; the arguments for restrictions and controls becoming more plausible and obvious with each advancement in height and bulk. One has but to view this outgrowth of unrestricted skyscrapers, such as is found in lower Manhattan, to realize that some form of controls were unavoidable. In 1916, New York City passed the first comprehensive zoning laws, placing certain restrictions upon multi-story structures. Other cities were soon to follow with similar legislation. However, in most cases these restrictions have proven inadequate and have only added new fuel to the old debate over the skyscraper.

ARGUMENTS AGAINST THE SKYSCRAPER

Although there are a few arguments used against the skyscraper which are to a certain extent justified in their claims, the majority of them are equally unjustified and without basis. Considering first, one of these arguments or charges against the skyscraper that has been proven to be without basis: that charge that contends the skyscraper is the cause of, or at least is the major contributor to the traffic congestion which is choking our cities. Traffic congestion is probably the most serious problem facing our cities today and one which must be solved if the city is to survive as a business center, but to place the blame for this upon the skyscraper is fundamentally incorrect. True, the tall building has resulted in large concentrations of people in relatively small areas, but it is not the concen-
tration of people which causes congestion, rather it is their continuous movement from one place to another. The tall building offers an effective unit in which business may be quickly transacted without necessitating the use of streets and sidewalks. Whereas if these tall structures were spread out into many more but smaller buildings of six or even ten stories, the use of streets any other means of horizontal communication would be greatly increased. Height facilitates internal exchange, reducing travel, and therefore congestion.

As further proof, it may be pointed out that certain large cities which have no skyscrapers have traffic congestion problems exceeding those of skyscraper cities. London, for instance, which limits building heights to approximately one-hundred feet, has a congestive situation that exceeds even that of New York City. It is also noted that within New York City, itself, the most congested areas are not those surrounded by skyscrapers, but those which are surrounded by relatively low structures. The skyscraper is not a major cause of traffic congestion, in fact, it actually tends to relieve congestion. It has given to our streets a third dimension, taking choking horizontal traffic off the streets and converting it into vertical traffic within one building. The skyscraper is, in reality, a vertical street.

Another so-called argument against the skyscraper, which is mostly without foundation, is that concerning the dangers to public safety involved in a tall building; usually contending that danger arising from fire, earthquake and tornado increases with the height of the building. And although the excellent record of the skyscraper has all but silenced this particular argument, it is still used to some extent, especially following the occurrence of a serious fire or
other disaster.

Originally this public safety argument began with the fears of early critics that one of these steel frame structures might collapse. This fear has, of course, completely given way to those of fire and natural catastrophe and even these are slowly dying out. There is very little basis for fear of either strong wind or earth shock in connection with a modern steel frame building. The American Society of Civil Engineers, having studied both possibilities, came to the conclusion that no wind is likely to subsist at a velocity great enough to damage a steel frame building designed according to present standards, and also that there is sufficient evidence to warrant that such a structure would be able to withstand the stresses resulting from shock of intensity equal to any recorded earthquake in the State of California. As a matter of record, no steel frame building has ever collapsed during an earthquake. The fear of being trapped by fire in an upper floor of a tall building, is likewise an exaggerated argument against the skyscraper. Even though all skyscrapers are of fire-proof construction, it is true that a serious fire is yet possible because of highly combustible interior trim and equipment. This, however, is no more true of a skyscraper than it is of any type building, and is a condition that may be regulated and prevented by the use of fire resistant materials for the interior furnishing of the building. In fact, because of their great and size, skyscrapers are usually required to be better equipped for fire protection than are lower buildings. And isolated fire-tower stairs provide a means of exit free from smoke and fire. Actually the record of the skyscraper against fire is surprisingly good, with very few instances of fires resulting in appreciable losses. A most recent serious fire occurring
within a skyscraper, and certainly one of the worst on record, which has produced a series of charges against the tall building, is that of the LaSalle Hotel fire in Chicago. Here the fire fed upon combustible furnishings in the lower floors of the Hotel, the structure of the building remaining undamaged and even preventing the flames from spreading to the upper floors. "Very few deaths were actually caused by burns, most of them due to inhalation of smoke and hot gases distributed throughout the building by open stairways and pierced elevator shafts. Had it not been for these unprotected stairways and elevator shafts, it is most likely that the entire fire could have been confined to the main floor." This is, of course, now being required in all modern building. It is obvious that much can be done to improve the fire resistant abilities of our skyscrapers, but should also be noted that height does not contribute to the danger.

In contrast to the previously mentioned arguments against the skyscraper, the charge that the tall building deprives city streets of light and air is to a certain extent justified in its claims. One has but to view the dark narrow canyon, which is Wall Street, New York City, to realize the seriousness of this charge. Unrestricted, the tall building had closed in upon the streets and upon themselves, shutting out light and air. In 1916, it was this situation that forced New York City to pass certain restrictions upon the skyscraper, requiring set-backs from the property line at specified heights, in order to open up and lighten these streets. This action has resulted in considerable improvement, but is not the whole answer. The base of the building is yet permitted to cover the entire site, crowding the streets and neighboring buildings until the set-backs come into effect at a considerable height. The problem is, therefore, not so
much one of height, as it is of concentration and bulk. Rockefeller Center has shown that with proper planning the tall building can provide more light and air than is possible to obtain with lower but congested buildings. This argument is still very much in use against the skyscraper, and should have its effect upon the legislation of new zoning laws and the future of the skyscraper.

That charge which claims that the tall building is an economic failure, is undoubtedly the most plausible argument that can today be raised against the skyscraper. Although the general claim that all high buildings are unprofitable is greatly exaggerated; there is a definite economic limit to the height of any building, depending upon the size of its lot and the land values involved, and to build beyond this limit would prove to be unprofitable. As the building rises, more elevators are required to service it properly and at a determinable point too much valuable space, in proportion to the rentable area, is lost to these elevators. Other factors, including construction costs, of course, enter into its determination. This economic limit, however, may not be reached until at forty stories, sixty stories, or even greater heights; and up to this limit the taller the structure, the more profitable it would prove to be.

Consider the fallacy of erecting only a six, or even a ten story hotel or office building upon a valuable site within New York City. In such a case a much higher building would certainly prove to have a far greater percentage of return upon the original investment. It also does not seem possible that American business interests could have made so many bad investments, as to erect skyscrapers without hope of a substantial return.
ZONING LAWS

The New York City Building Zone Resolution, adopted on July 25, 1916, represents the first comprehensive set of regulations placed upon the skyscraper. Other cities had, prior to this, established absolute height restrictions, as is the custom of European cities; but New York City was the first to attempt to control and regulate the tall building without actually imposing a limit upon height. Since 1904, Boston had restricted heights to 125 feet for buildings fronting on wide streets and 80 feet for those on narrower streets. Washington, D. C. prescribed allowable heights not surpassing the widths of bordering streets increased by twenty feet, and in no case exceeding 130 feet. And Los Angeles limited buildings to thirteen stories, none to exceed 150 feet. Shortly after Boston had passed its height restricting ordinance, the Westminster Hotel challenged the City's right to limit the height of buildings by exceeding the imposed 125 foot limit. The City sued and won their case against the Hotel, and ordered the top floor removed from the Hotel building. In 1928, Boston revoked this absolute restriction on building heights in favor of a new zoning plan, similar to that originated by New York City.

Following its introduction into New York City, the skyscraper had developed and progressed unrestricted. It had been built along the same pattern as had been the older masonry structures, covering the entire site and raising its exterior walls unbroken from sidewalk to roof, only higher, much higher. Streets were reduced to mere slits, cut between the towering, perpendicular walls of these skyscrapers, and were darkened further by cornices projecting eight to fourteen feet, from some of these cliff like structures, cut over the streets themselves. But not only were the streets shut off from light and air, these early skyscrapers had also succeeded in closing in upon
one another. Struggling for survival, they were forced to purchase or rent air rights over surrounding low buildings to protect what light and air they had. "Congestion has reached such proportions that the right to light and air is legally sold as a commodity."\(^8\)

In 1913 a Heights of Buildings Committee was authorized to conduct an investigation on existing conditions in New York City and to prepare a means of regulating height, size, and arrangement of future buildings. But it was not until 1916; following the erection of the new Equitable Building which rose perpendicular to the sidewalks for forty-two stories, its roof almost equal in area to its base; that the New York City Building Zone Resolution was actually drawn up and passed. Although setting a definite limit upon just how high a building could rise at its property line, this resolution also states provisions for additional height through the use of set-backs and permitted a tower, not covering more than twenty-five percent of the lot, of unlimited height. The height to which a building could rise at its property line was determined by the width of the street abutting it, and by the height district in which the building was to be constructed. In the Wall Street district a multiple of two and one-half times the street width was permitted; above this, the building must set-back one foot for every five feet of additional height.\(^9\)

The set-back resolution was immediately hailed as a great advancement in zoning; not only was it accepted as the ideal solution to the problem of controlling the tall building, but also as a stimulus for a new form and aesthetic beauty for the skyscraper. Other cities were quick to adopt similar measures, and architects even quicker to apply this set-backed, pyramidal silhouette to new buildings, whether required by law or not. In reality, however, its result was but a
distortion of both the form and the function of the skyscraper. The rigid set-back pattern had placed an invisible envelope around the skyscraper, through which it could not pass; it must diminish in form and function as it rises, but yet its base is permitted to cover the entire lot crowding out light and air with its massive bulk. These New York resolutions have proven unsatisfactory because they have been based upon the assumption that each structure is an individual problem and, therefore, should be individually controlled. This is incorrect, the skyscraper cannot be planned as an isolated object within its own boundaries, it must be planned in relation to the buildings and area that surround it. The skyscraper must be free to retain its most functional form at any height, under proper surrounding conditions; not cramped and restrained into a dimensioned envelope.

In an effort to remove this envelope and set the skyscraper free, but yet retain control over it; New York City is studying a new zoning plan. This proposed ordinance would do away with all enforced height restrictions and set-back clauses, controlling the skyscraper with three elastic limitations: Floor Area Ratio, fixing the total bulk for buildings in varying districts and permitting height ratios in relation to allowable bulk and portion of lot covered; Angle of Light Obstruction, giving architects freedom by fixing only an average angle of light that can be blocked off by the building; and Area for Light Access, requiring windows to have a certain arc of unobstructed view in relation to surrounding structures.
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Plate 15.

23. Equitable Building.

24. Wall Street, New York City.
The skyscraper is the outgrowth of concentration. It affords the most successful means of achieving the unified centralization upon which the city is based. Its future is thusly dependent upon the continued need for centralization, for cities.

There are those who believe that concentration is undesirable, that it is no longer necessary for the conduct of business, or for convenient living. They believe that new methods of transportation and communication have rendered the centralized city obsolete. They advocate decentralization, escape from concentration into open spaces, linear cities and small independent garden cities. Frank Lloyd Wright who has anticipated the cities disappearance in his conception of a country-side Utopia a termed, Broadacres, in which he calls for a minimum of one acre of land for each family.\(^1\) It is obvious that if these theories are realized, the skyscraper is doomed, its function no longer necessary.

This report, however, is not to debate the future of the city, but to concern itself with that of the skyscraper. And consequently shall assume a continued need for cities.

It is nevertheless noticed that both those who believe the city will presently disappear, and those who uphold that business centralization in cities will always be desirable, agree on one point — that the cramped, congested city as we know it today, cannot continue. If the city is to survive, it must be a city of concentration without congestion. And such is only possible through the use of properly spaced tall buildings, concentration in height and not in bulk. It has been this lack of proper area planning that has caused the congestion
of streets and buildings, which is today choking the efficiency of the city. The tall building, and likewise the city, cannot exist in this cramped, forced, and unhealthy atmosphere. They must be situated within a sufficient area to permit a free and easy circulation of air, light and traffic, and must be planned with consideration for their mutual relationship, not as individual structures upon small individual lots. "Their concentration in height is justified only if counter-balanced by a liberation of the surrounding land."

Sullivan had realized this, and had written in his *Autobiography of an Idea*, "The tall steel frame structure may have its aspects of beneficence; but so long as men may say, 'I shall do as I please with my own', it presents opposite aspects of social menace and danger.... the tall office building looses its validity when the surroundings are uncongenial to its nature; and when such buildings are crowded together upon narrow streets and lanes they become mutually destructive".2

It had been partly, although inadequately, realized by the early city planners who prepared the 1916 Zoning Resolutions for New York City. They had attempted to space the tall building, but the open spaces, or set-backs, they specified were too far above the streets; and they had lacked the courage to break away from the aspect of the individuality of each building. And it was finally realized and expressed by Rockefeller Center; here is proof, that given proper planning the tall building will provide more light, air, and open space than any other building type, and will relieve, rather than increase, congestion. But Rockefeller Center is yet trapped within the tight pattern of traffic congestion that creeps through New York City. The United Nation's Secretariat Building exemplifies a still further stride toward the maturity of the skyscraper: here the tall building has
been lifted from the tight traffic pattern and placed in a clear area, taking advantage of easy automobile circulation and parking. This is the true function of the skyscraper, rising unrestricted to any height, and open, open for orientation, sunshine, breezes, and communication. This is planned centralization.

Le Corbusier had perhaps offered to us a vision of the future skyscraper city. He contends that the American skyscraper is too small and too closely cramped by present street patterns; that they should be much larger and placed within huge blocks of open area. He points out, that the average building height in New York City is but four and one-half stories, and that with an average of only sixteen stories, almost three-fourths of the land could be regained for open space. But Le Corbusier has gone further in his dreams, he proposes sixty story buildings, occupying only five percent of the land, spaced by wide elevated parkways, free from cross traffic, and even permitting speeds up to ninety miles an hour through the city. Le Corbusier has retained the concentration of people, but has eliminated congestion.

An impracticable dream? Perhaps, but a beautiful solution. And a dream that is even now being realized: Pittsburgh has started construction on a group of nine office buildings, widely spaced within a twenty-three acre park. Twenty and twenty-four story towers, they are to be situated in open areas, minimum spacing between them is ninety feet, separated by wide boulevards; freely accessible to light, air. Here is truly a step towards the future.
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Plate 16.

25. Rockefeller Center.
26. Le Corbusier's skyscraper city.

27. Secretariat Building, United Nations.
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