the working chamber to the bottom of the excavation. A 4-inch water pipe also passed through the caissons, and supplied water at 100 pounds pressure to six jets. One of these jets was directed at the sand around the bottom of each blow-pipe, and served to loosen it so thoroughly that the air pressure in the caisson proved sufficient to blow the sand up through the pipe and out over the edge of the caisson. When the caisson reached solid rock, the whole interior of the working chamber was filled in with tightly rammed concrete, the interior of the caissons above the roof being also filled with the same material, thus providing a solid concrete and timber mass from the rock below the bed of the river to the top of the caisson, which stands at a level of 37 feet below mean high water. Above the caissons was built a solid masonry pier whose coping is 23 feet above mean high water, the total depth from coping to the caissons being 60 feet. The construction of the foundation and piers on the Manhattan side was practically identical, the only difference in dimensions being that due to the difference in depth to rock bottom.

Upon the top of each of the masonry piers were built four massive steel footings, and upon these were erected the plate-steel legs or columns of the steel towers. Each tower consists of four apparently slender but actually exceedingly heavy and stiff columns that rise 322 feet above the water level. Each pair of columns is braced together by a truss system, which extends continuously from base to top, except where it is omitted in two panels to provide for the passage of the lines of railway track. Each pair of columns, as thus connected, is braced together by transverse trusses, one below the floor of the bridge, another at the level of the upper deck and a third at the top of the tower.

In previous suspension bridges it was customary to cradle the main cables, but in the Manhattan Bridge the cables lie in the same vertical planes as the respective legs of the towers over which they pass. In respect of its carrying capacity, the Manhattan Bridge is the largest of the four great bridges across the East River. The suspended roadways are carried on two decks. Upon the lower deck provision is made for four surface tracks, a 35-foot roadway, and two 11-foot passenger walks; while upon the upper deck there will be four elevated railway tracks. To carry so great a load, the dimensions of the cables and anchorages are necessarily very large. The anchorages measure 175 feet in width by 225 feet in length, and the cables reach the unprecedented diameter of 21¼ inches, as compared with the diameter of 18¾ inches on the Williamsburg Bridge and 15¾ inches on the Brooklyn Bridge. The necessary stiffness will be given to the suspended roadway by four heavy riveted nickel-steel trusses, lying in the planes of the four cables and suspended from them.

For the construction of the cables four temporary cables, each consisting of four 1¾-inch diameter steel ropes, were strung from anchorage to anchorage over the towers. Upon them were laid four working platforms for the accommodation of the workmen. The stringing of the wires in each cable is accomplished by means of two traveling sheaves, carried on opposite legs of an endless steel rope reaching from anchorage to anchorage. Each sheave consists of a 3-foot grooved wheel, attached to the hauling rope by brackets. The hauling rope runs on heavy rollers supported on uprights on the temporary foot-bridges. The wire is delivered to the bridge on enormous reels weighing 3 tons each, half of them being placed on each anchorage. The end of the wire from a reel at each end of the bridge is put over the hauling sheave at that end and fastened to the anchorage, and each hauling rope is driven by a 50-horse-power, 220-volt Crocker-Wheeler form W motor. The hauling machinery is then started, and, as the sheaves move across the bridge, they unwind one wire from each reel, and two wires are thus strung by each sheave every time it makes the trip across the bridge. There are 256 wires in each strand, and as the strands are completed they are lifted from the temporary saddles in which they rest and placed in the permanent saddle. Each cable contains 37 strands of 256 wires each, so that there is a total of 9,472 wires in each cable. The total length of single wire in all four cables will be 23,100 miles. The wire has a breaking strength of 215,000 pounds to the square inch. The weight of the four cables in their completed condition will be 8,600 tons. The side spans of the bridge are 725 feet and the central span is 1,470 feet in length. When the bridge is completed the total weight of steel in the structure will be 42,000 tons.

THE QUEENSBOROUGH CANTILEVER BRIDGE.

The Queensborough cantilever bridge, formerly known as the Blackwell's Island Bridge, is the latest of the four great bridges across the East River. Commencing from the Manhattan shore, the dimensions and positions of the successive spans of the bridge are as follows: First there is an anchor span 469 feet long; then a channel span 1,182 feet long, followed by what is known as the Island span crossing Blackwell's Island, which is 630 feet long. Then comes a 984-foot span over the east channel of the river, and a 459-foot anchor span extending over the Long Island shore. The total length of the bridge, including the approaches, is 8,600 feet. The maximum depth of the trusses at the towers is 185 feet, and the extreme width of the bridge is 88 feet. As originally planned, the bridge was designed to carry a maximum congested live loading of 12,600 pounds per lineal foot, on four surface trolley tracks, two elevated railway tracks, a roadway, and two footwalks. Following a change of administration and engineers, it was decided to add two additional elevated railroad tracks on the upper deck of the structure, and a heavier congested loading was adopted of 16,000 pounds to the lineal foot. When the bridge was nearing completion, the engineering world was startled by the fall of that other great cantilever structure, the Quebec Bridge; and it was natural that considerable anxiety should be aroused regarding the Queensborough Bridge, since it was not only designed on the same general principles, but was a heavier structure in itself and was to be subjected to a heavier load than the bridge that went down. Two separate investigations of the strength of the bridge were made for the Bridge Department; and in both cases it was found that not only was the bridge over weight, but that if it were loaded according to the requirements of the specifications the stresses in some of the members would exceed the specified stresses by from 25 to 47 per cent. One of the consulting engineers recommends the taking of considerable dead load from the bridge and the removal of two of the elevated railway tracks. The other report advises the removal of all elevated tracks.

The fall of the Quebec Bridge and the conditions existing in the Queensborough Bridge cannot fail to raise a doubt in the minds of engineers as to the suitability of the cantilever system to the construction of heavily-loaded bridges of over 1,000 feet in length of span; and this, in spite of the fact that troubles in both cases were due chiefly to faulty design. The Queensborough Bridge is an enormously heavy structure, the weight of the whole mass from abutment to abutment of the cantilevers being 52,000 tons. The 630-foot span across the Island alone weighs 10,400 tons, or 16½ tons to the lineal foot. The trusses are built partly of a special nickel steel and partly of the ordinary commercial structural steel, the latter being used generally for the compression members and floor system and nickel steel for the eye-bars or tension members. In the structural steel the specifications called for an elastic limit of 28,000 pounds, and an ultimate strength of 56,000 pounds. The requirement of the nickel-steel eye-bars are an elastic limit of 48,000 pounds and an ultimate strength of 85,000 pounds, from which it will be seen that the nickel-steel bars are from 40 to 50 per cent stronger than ordinary structural bars of the same weight.

The erection of the bridge was done by the overhang method. First the anchor arms on the Manhattan and Long Island shores and the span across the island were erected on steel falsework. Then the four river arms of the cantilevers were built out by overhang to a junction in midstream by means of two massive travelers each 120 feet in height. This traveler was in itself a huge and costly affair weighing 500 tons and capable of handling a load of 70 tons. It is probable that the bridge will be opened during the year 1909. In closing our article on the long-span bridges of New York, mention should be made of the fact that the plans have been drawn for a massive 1,000-foot steel arch bridge which is to carry a four-track railroad across the East River at Hell Gate, and form part of an important link connecting tracks of the New Haven Railway with those of the Pennsylvania Railway on Long Island.

In a remarkable paper read at the meeting of the American Philosophical Society in Philadelphia, Dr. Alexis Carrel of the Rockefeller Institute showed how the knee-joint of a dead man has replaced the injured joint of a living person; how the arteries of husband and wife have been successfully joined, so that the wife might endure the shock of a surgical operation; how an infant's blood has been revitalized by the blood of its parent; how a human artery and jugular vein have been interchanged and are fulfilling each the other's function; how the kidneys of one cat were substituted for the corresponding organs of another, and how a living fox terrier now frisks about upon the leg of a dead companion. "In my experiments to preserve arteries," states Dr. Carrel, "I found that desiccation would not do, but produced a state of absolute death. Then I put the arteries in refrigerators and kept them inclosed in hermetically sealed tubes, at a temperature a little above freezing. I found that an artery could be kept alive for sixty days and substituted for the artery of a living animal." Clearly, the day is not far off when the perfect organs of a man who in life had been free from disease may be kept in cold storage after his death and used to replace diseased organs in living men.

TALL BUILDINGS OF NEW YORK

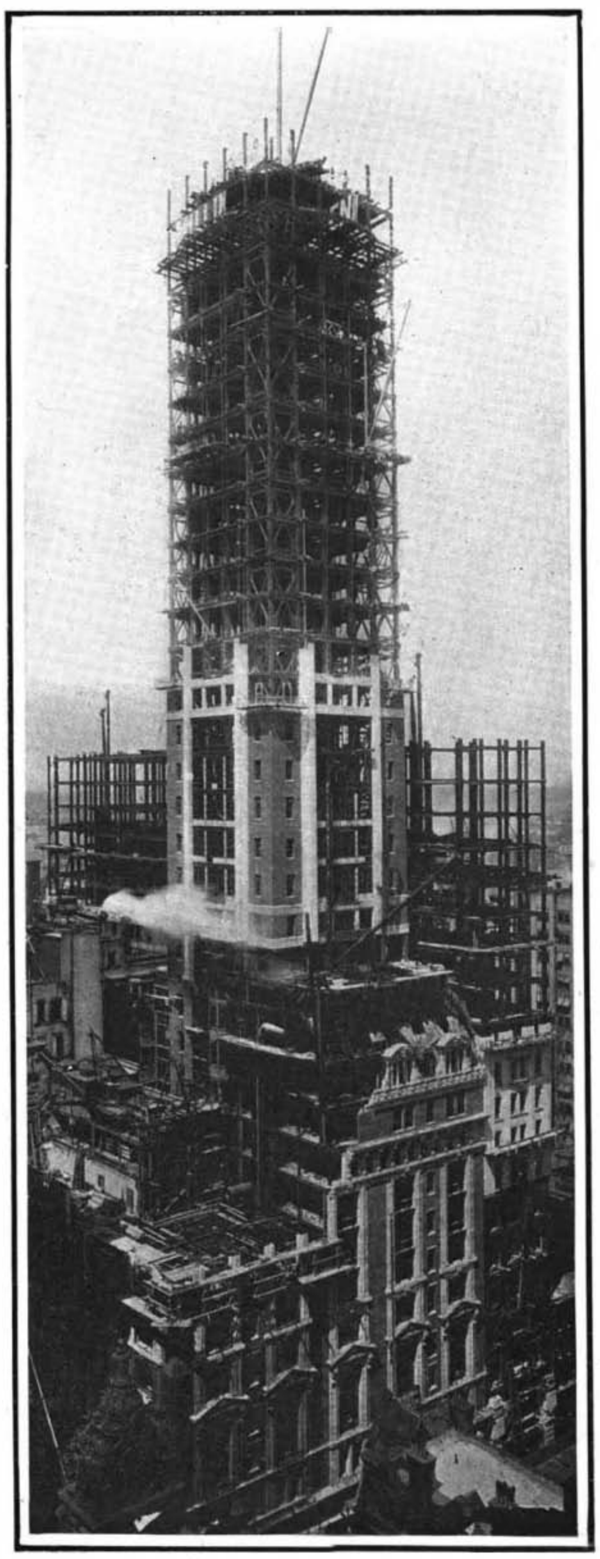
Although New York city was not the first to possess a mammoth office building of the modern "skyscraper" type, the growth of such buildings in number and size during the past few years has been so rapid as to render lower New York distinctively a city of towers. To the wonderful skyward growth of this city, several causes have contributed. Chief among these, and closely related, are the circumscribed limits of the site on which the city is built, and the high cost of the land. The high price of real estate and the restricted area of desirable sites, it is true, have served to promote the construction of lofty buildings in other cities besides New York; but nowhere have these proved such powerful and impelling motives as here. The desire on the part of large business interests to be located as closely as possible to the financial center, moreover, has helped to produce that huge pile of lofty buildings which makes lower New York, in the neighborhood of Wall Street, look from a distance as though it were a city built upon a hill. Below Chambers Street the prices of real estate will run from $30 to $40 per square foot, near the water, to $200 and $300 per square foot in the Wall Street district. The highest price ever realized was that paid for a small corner plot at the southeast corner of Wall Street and Broadway, which recently sold for $700,000 or at the rate of $600 per square foot. This is the highest price ever paid for real estate in any city of the world. It is not at all unusual for the cost of the site of a building in this city to exceed the cost of the structure itself. This was the case with the Fuller Building, popularly known as the Flatiron Building, whose triangular site cost $2,500,000. Where such vast sums are paid for the building site, it becomes necessary to add story to story until sufficient rentable floor space has been secured to guarantee a reasonable profit upon the cost both of the site and the building.

The development of the lofty office building is one of those modern engineering achievements which were rendered possible by the introduction of Bessemer steel. The limit of height for an ordinary brick or stone building of the older kind, is reached when the thickness of the lower walls becomes such as to seriously encroach on the usable floor space of the building. The tallest structures of this kind have stopped at a height of twelve to fourteen stories; this last being the height of the Singer Building, before its recent reconstruction. The walls of this structure in the lower stories are nearly three feet in thickness. With the introduction of steel columns, girders, and stringers in building construction, it became possible to transfer the loads of each story of a building directly to vertical columns, by which they were carried direct to the foundations; and the intermediate spaces between the columns required only a sufficient thickness of wall to serve the purposes of inclosure. The introduction of steel thus served the double advantage of reducing the thickness and weight of the walls and of enabling the loads to be concentrated on a specified number of vertical members, whose supporting power it was possible accurately to determine. Not only was a great reduction made in the weight, but there was a corresponding increase in the elements of safety and durability. The stresses in a tall building can be calculated with accuracy; and by introducing the proper amount of wind bracing, these structures may be made absolutely secure against being overthrown by storm, and reasonably secure against earthquake. Furthermore, the skeleton steel building is a form of construction that lends itself admirably to fireproofing; and, if the columns and beams be thoroughly protected by good terra cotta or concrete, and metal be used for the construction of doors, window sashes, frames, and, as far as possible, for the furniture, a modern office building may be rendered practically proof against fire—so far proof, indeed, that if a fire starts among the contents of an office, it will be localized for want of any combustible material upon which to seize in the building itself. The San Francisco fire proved that, where the most modern methods of fireproofing were used, a tall building could go through even such a fierce conflagration as that, and yet remain so far intact as to be capable of speedy repair. The question has often been asked, particularly since the San Francisco disaster, as to how the tall buildings in this city would be affected by earthquake shock. Judging from the results at San Francisco, they would pass through an earthquake with surprisingly little damage. This is explained by the fact that the shock is taken care of by the elastic properties of the steel frame; and where the walls and panel work have been attached to the frame by the most approved methods, the worst that can happen is a slight cracking of the masonry.

The steady increase in height of tall buildings has raised the question in the minds of many people as to how high it would be possible to go in safety. In an investigation of the problem made by Mr. O. F. Semsch, who was responsible for the design of the steel work of the Singer tower, it was found that under the restrictions of the building code as to load on foundations, it would be possible to put up a structure 2,000 feet in height on a lot 200 feet square. The building would weigh over 500,000 tons, and its weight would be so great that, in spite of the vast height, there would be a factor of safety of 8 against overturning by wind pressure, even in a stiff gale. If the tower were constructed and equipped similarly to the Singer Building, the cost would be $60,000,000. As a matter of fact, the limit upon the height of tall buildings is to be found neither in the inherent weakness of the structure, nor in the danger of upsetting in a gale of wind. The limit is determined by a clause in the Building Code of the city of New York, which says that the maximum pressure on the rock below the foundations, if caisson foundations are used, must not exceed 15 tons per square foot. As a matter of fact, the practical limitations upon height would come from the increasing thickness of the lower walls; for the Building Code states that the walls of the steel and masonry type of building must be 12 inches thick for the uppermost 75 feet of their height, and must be increased 4 inches in thickness for every 60 feet below that. Structurally considered, this provision of the Building Code is unnecessary, since the weight of the walls at each story is carried directly upon the steel framework at the base of that story; and there is, therefore, no structural necessity for making the walls at the base of a 20-story building more than 12 to 18 inches thick.

There is a movement among our architects to limit the height of buildings in such a way as to permit the erection of tall buildings only under restrictions which will insure that they do not unduly exclude the light from the streets or from one another. This desirable object is to be secured by a law making it necessary, after a building has been run up so many stories on the building line, to step back a specified distance before erecting the next series of stories, the offsetting being repeated as often as is necessary to admit the desired amount of light to the adjoining street. The center of the building plot is to be reserved for the main, tower-like, portion of the building, which may be carried up as high as the owner may wish. The question of the architectural treatment of tall buildings is one of the most difficult problems that has ever presented itself to the profession. In the earlier structures the architects made the mistake of trying to mitigate the appearance of height by introducing heavy horizontal elements in the way of cornices and offsets; but the results were not pleasing architecturally. The modern office building is first and last a tower, and as a tower it should be treated. Those architects who have recognized this fact, and have emphasized the vertical as against the horizontal lines, have produced the most successful buildings. Our illustrations include two buildings, the Singer and the Metropolitan Life, whose capacity has recently been enlarged by the erection of additions, in the form of towers of unprecedented proportions.

Although the Singer tower measures only 65 feet on each side, the top of the dome stands 612 feet above the sidewalk. It is erected upon thirty-four caissons sunk to bedrock, which, in some cases, lay 90 feet below the street level. From an engineering point of view, the most interesting feature is the method of framing the steel skeleton to enable it to resist the heavy wind pressure, when the thunder squalls of summer and the heavy gales of winter sweep over Manhattan. It was impossible to run continuous diagonal truss members across the building from wall to wall, because such an arrangement would have encroached upon the window space. Therefore it was decided to consider the structure as being built up of four square corner towers, and a central tower forming the elevator well, with wind bracing running continuously through each wall of each tower from top to bottom, the five towers being tied together in lateral planes at the various floors. The corner towers are 12 feet square from center to center of columns. This arrangement provides an open space 36 feet in width, free from diagonal bracing, extending down the center of each face of the building, and these faces are occupied by large bays filled in with glass, as shown in the accompanying illustration. This method of bracing involved high stresses in the chords of the trusses which, in this case, are the vertical columns of the tower, and the latter are of unusually heavy construction. The wind pressure at 30 pounds per square foot exercises a total overturning moment on the whole tower of 128,000 foot tons. Although the total weight of the tower is 23,000 tons, the wind pressure would have a tendency to lift the windward side of the building, the total uplift on a single column amounting, for maximum wind pressure, to 470 tons. To provide against this the columns are anchored to the caissons, and the margin of safety against lifting is in no case less than 50 tons to the column. The effect of the wind pressure on the leeward side of the building also affords some interesting figures. Thus, the total dead load at the foot of one of the leeward columns is 289.2 tons, which represents the weight of the steel work and masonry. The live load, which includes furniture, fittings, and the maximum crowd of occupants, totals, at the foot of this column, 131.6 tons. The downward pressure on the leeward side of the building due to wind pressure is 758.8 tons, and this, added to the dead and live loads, brings the total load on these columns up to 1,179.6 tons. The architectural treatment of the building is decidedly pleasing, and Mr. Ernest Flagg, the architect, is to be congratulated in having done so well in a field for which there was no precedent.



Showing the diagonal wind bracing at each corner. The tower is 612 feet high; its total weight is 23,000 tons.

CONSTRUCTION OF THE SINGER TOWER.

Rises 363 feet above a triangular base. There are 23 stories in the tower. Total floor space, 117,000 square feet. Copyrighted 1905 by Irving Underhill.

THE TIMES BUILDING

Popularly known as the "Flatiron." This building, 310 feet high, stands on a triangular base measuring 215 feet on Broadway, 198 feet on Fifth Avenue, and 86 feet on 22d Street. The site cost $2,500,000. Copyrighted 1903 by Irving Underhill.

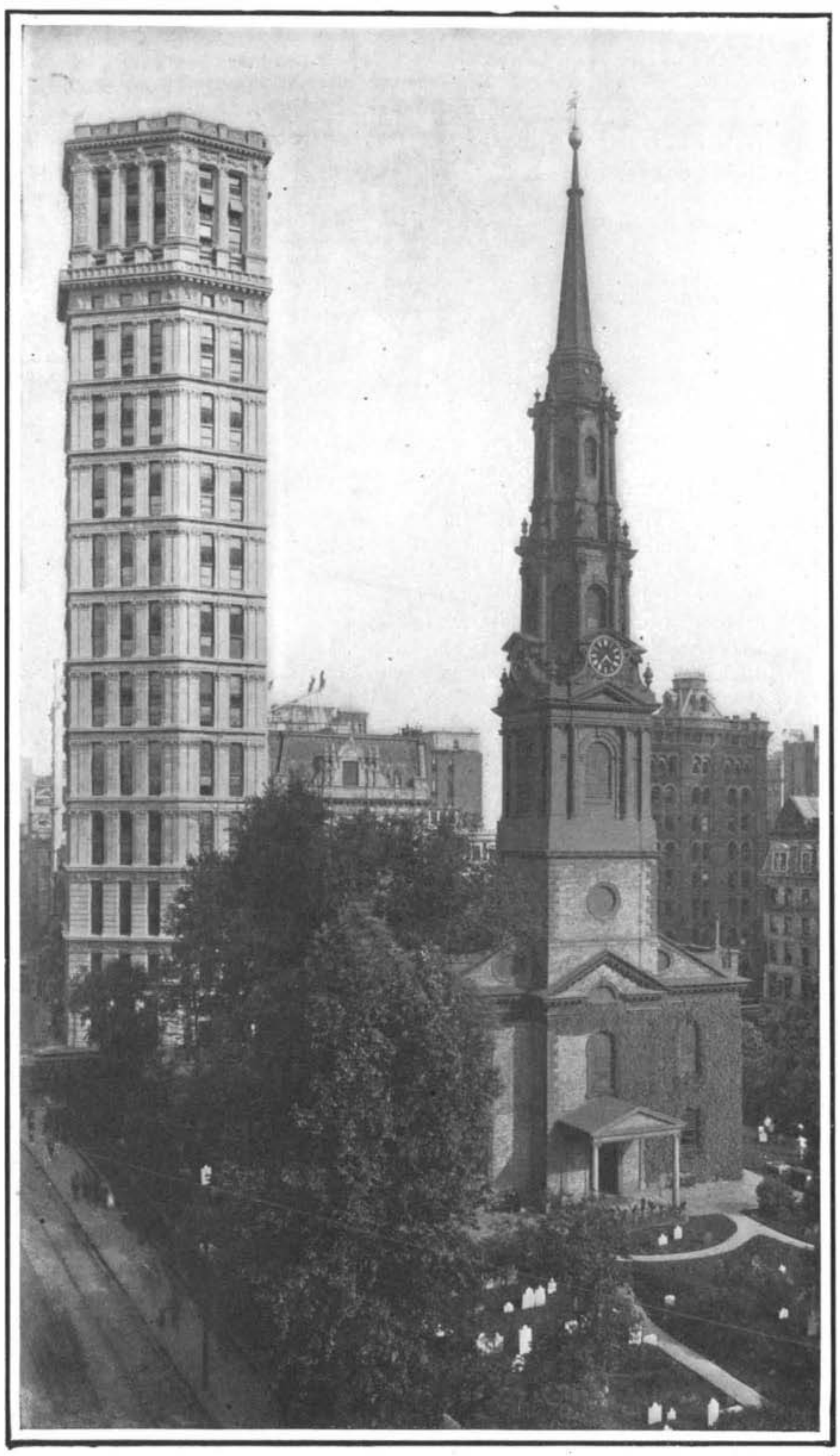
THE FULLER BUILDING.

Tower measures 75 feet by 85 feet, extends 700 feet above sidewalk, contains 50 stories, includes 8,100 tons of steel in its framework, and weighs 38,022 tons. In the building and tower combined there are over 25 acres of floor space.

THE METROPOLITAN LIFE TOWER, 700 FEET IN HEIGHT; THE LOFTIEST BUILDING IN THE WORLD.

The City Investing Building, 485 feet high, contains 31 rentable stories. It covers a lot 194 feet by 308 feet and its total floor area is 670,000 feet.

THE CITY INVESTING BUILDING AND THE SINGER TOWER.



One of the first steel-and-masonry buildings; erected 1897. Height, 317 feet. Washington was a frequent worshiper in the old church.

ST. PAUL BUILDING AND THE OLD ST. PAUL'S CHURCH.

The combination of red brick and buff stone with the bronze and copper finish of the windows and dome is decidedly pleasing, and the disposition of the windows throughout the vast reach of forty-two stories proves that it is possible to get away from that pepper-box appearance which is one of the unsightly features of the façade of the average tall building.

Unquestionably the most striking of the lofty buildings of New York city is the stupendous steel-and-marble campanile which is being erected at the northwest corner of the Metropolitan Life Insurance Company Building, between Fourth and Madison Avenues and Twenty-third and Twenty-fourth Streets. The present building, which is ten stories in height, has a frontage of 200 feet by 425 feet. The tower has a base measurement of 75 feet by 85 feet, and extends a clear 700 feet above the sidewalk. The whole building is treated in the pure early Italian Renaissance style, which has been used also in the tower; and both tower and building are finished in Tuckahoe marble.

It takes but a glance at our illustration of this stupendous marble shaft to feel assured that when it is completed, it will be an object of decided architectural grandeur and beauty. Its height is so great that fully one-half of its bulk will rise absolutely clear of the cornice lines of New York city's 20-story buildings. The highest point of the tower will overtop the highest point of the Montclair Hills in New Jersey by about 30 feet; and when the shadows of evening are falling upon the street below, the summit of the tower will be crimsoned with the rays of the sun that has already set behind the Orange Mountains. The most lofty rentable offices will be those of the forty-first story, whose floor will be 526 feet above the sidewalk. The windows of these offices will be at the same elevation as the lookout windows at the top of the Washington Monument. The table of dimensions and weights as obtained from the architects, Messrs. M. Lebrun & Sons, runs into large figures. In the tower there will be fifty stories, and in the tower and the main building combined there will be a total floor space of 25 acres. The steel framework of the tower alone weighs about 8,100 tons, and the weight of the steel work, masonry, etc., combined is 38,022 tons. When the building is occupied, the estimated live load will be 5,591 tons, bringing up the total weight of the whole building to 43,613 tons.

We have seen that in the Singer tower the wind stresses are resisted by means of continuous trusses extending throughout the whole height of the building. In the Metropolitan tower the frame is stiffened against distortion by means of heavy knee braces at the intersection of the vertical columns and the horizontal floor beams. The stresses due to wind pressure reach a very high figure, and call for a large increase in the sections of the columns, etc., to provide for them. In the principal columns on the leeward side of the tower, the load due to dead and live loads combined is 7,500,000 pounds; and the load due to wind pressure is 2,900,000 pounds, which brings the total load up to 10,400,000 pounds. Similarly, the corresponding columns on the windward side are relieved of pressure, the maximum load being reduced from 7,500,000 pounds to 4,600,000. This shows that even under the heaviest storms that may blow against it, there will at no time be any tendency on the part of the building to turn over on its foundations.

Limitations of space prevent our pursuing this subject any further than to give some particulars of a few of the most recent and notable buildings. The Metropolitan Building just described is the largest single office building in the world, containing, as we have seen, over 25 acres of floor space. The next to that is the City Investing Building, with thirty-three stories and a total height of 485 feet. The total floor space is 670,000 square feet, and it can accommodate 6,000 people. The Terminal Building is in two sections, on of which has 26,000 square feet of available area on each floor, and the other 18,000 square feet. This huge building is erected upon a coffer dam of concrete, whose 8-foot-thick walls extend down 75 feet to bedrock. The basement is occupied by the terminal station of the Hudson Companies' tunnels. The two buildings together form the largest combined office building in the world. Probably the most expensively finished office buildings in the city are the combined Trinity Building and United States Realty Building, whose total floor space is over 550,000 square feet. The land for these buildings cost $6,500,000, and the buildings themselves cost $10,000,000. The main roof is 300 feet above the street, and the tower 360 feet. There are twenty-two floors, with five in the tower, and 5,000 people can be accommodated in the two buildings. For the particulars of other notable buildings, reference may be made to the descriptive matter given beneath the cuts on pages 401-3.

In closing this chapter, emphasis must be laid upon the fact that, had it not been for the development of that distinctively American device, the high-speed elevator, the present skyward growth of our modern cities could never have taken place. In one single building, the City Investing Building, there is a row of no less than twenty-one elevators for passenger service alone. The speed of travel has risen to 400 feet a minute for the local and 700 feet a minute for the express elevators.

The necessity of increasing the number of docks continues to be felt at Hamburg no less than at other ports abroad, in spite of the already extensive accommodation for shipping existing there. Since the last considerable extension took place, viz., in 1897-8—though two new docks have been opened since then—the aggregate tonnage of sea-going vessels visiting this port has increased from about 7,500,000 to 12,040,000 register tons in 1907. In consequence of this remarkable development, and although two new docks were opened in 1903, the want of sufficient room for quay berths has been acutely felt.