VOLUME XII / NUMBER 1 / FIRST QUARTER 1972

MODERN STEEL CONSTRUCTION

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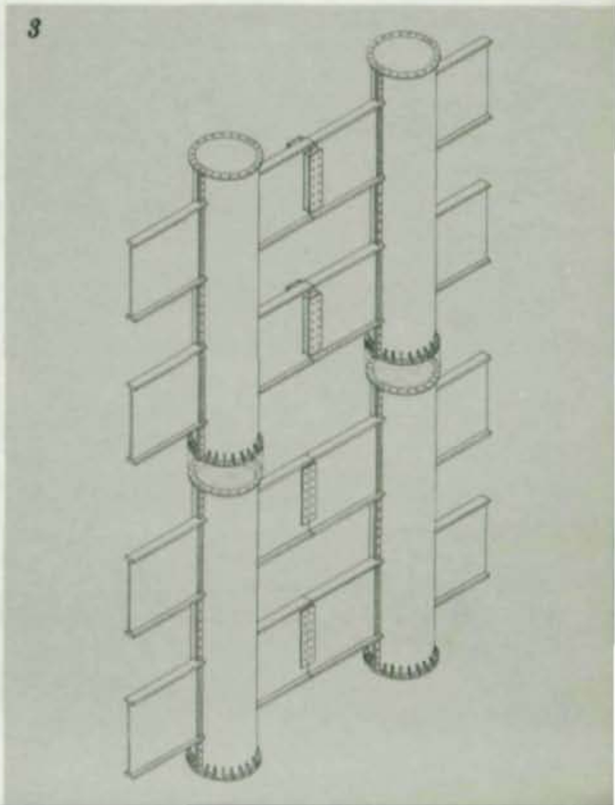

MODERN STEEL CONSTRUCTION

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1972 PRIZE BRIDGE COMPETITION

Entries are invited for the 44th Annual Prize Bridge Competition to select the most beautiful steel bridges opened to traffic during the calendar year 1971.

The members of the 1972 Prize Bridge Jury are:

Gerard F. Fox, M.ASCE *Partner, Howard, Needles, Tammen & Bergendoff, New York, N. Y.*

Robert M. Mains, F.ASCE *Professor, Civil and Environmental Engineering, Washington University, St. Louis, Missouri*

Robert B. Richards, F.ASCE *President, DeLeuw-Cather & Co., Chicago, Illinois*

John E. Rinne, F.ASCE *President-elect, American Society of Civil Engineers; Earl and Wright, San Francisco, California*

Alan M. Voorhees, M.ASCE *Former president, American Institute of Planners; Alan M. Voorhees & Associates, Inc., McLean, Virginia*

Entries must be postmarked prior to May 27, 1972 and addressed to the Awards Committee, American Institute of Steel Construction, 101 Park Avenue, New York, New York, 10017.

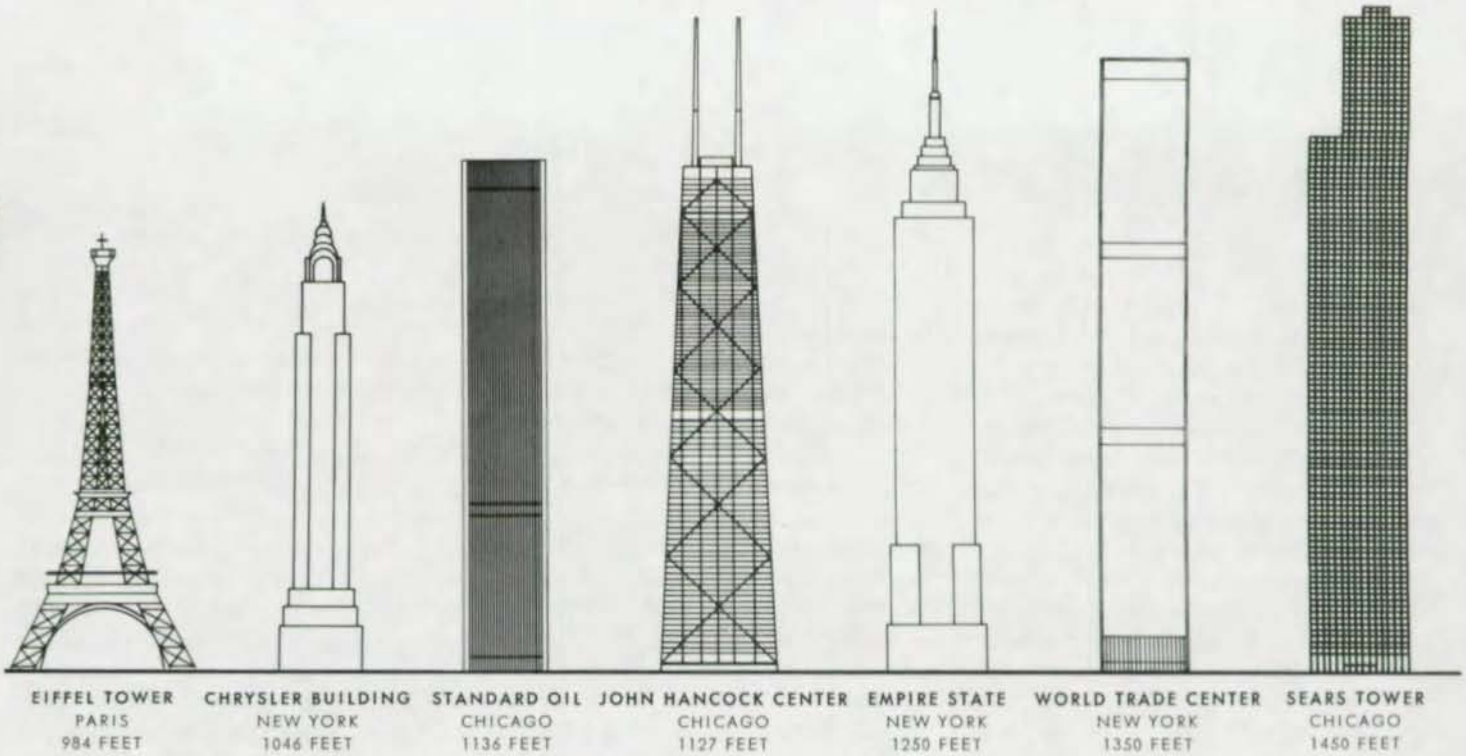
1972 FELLOWSHIP AWARDS

Four engineering students have been awarded $3,000 fellowships in the 10th Annual Fellowship Awards Program. The program is designed to encourage expertise in the creative use of fabricated structural steel.

Rich F. Davidson	*New Mexico State University*
Adam M. Glass	*University of Wisconsin-Milwaukee*
Ernst H. Petzold, III	*Washington University-St. Louis*
Stephen W. Yordy	*University of Notre Dame*

OUR APOLOGIES

On page 4 of the 4th Q., 1971 issue of MSC, the Architectural Awards of Excellence winners were announced. Inadvertently, the name of Vincent G. Kling and Partners, Phila[illegible] was omitted as one of the architects for the Richmond Coliseum, Richmond, Va.



A Comparison of the World's Tallest Structures

The Future of the Super Hi-Rise Building

These days the record for the world's tallest structure has the longevity of a weather report.

The 954-ft Eiffel Tower held its record 41 years, from 1889 until 1930 when New York's 1,252-ft high Empire State Building was constructed. Surmounted by its Zeppelin mooring mast and TV antennae, that building held its record until the day of October 19, 1970 when the first of the twin towers of the New York World Trade Center passed the 1,252-ft mark on its way to its final height of 1,350 ft.

It is estimated that the Trade Center will hold its world's record for the world's shortest time, probably three years, when Chicago's Sears Tower passes the 1,350 ft mark on its way to its own new world's record of 1,450 ft, more than a quarter of a mile high.

Although stories seem the convenient way to measure the height of a high rise building, height in feet is the accurate measurement, because a story can vary from 9 to 12 ft in height.

What has caused the sudden emphasis on ultra high buildings? Has there been a technological breakthrough that's made the superskyscraper possible? How high can a structure be built? Are ultra high buildings economical? What ultimate effect will the superskyscraper have on high rise office buildings?

Unique Design Concept

These questions were put to Dr. Fazlur R. Khan, the structural engineer, whose unique design concepts have permitted the erection of current ultra high buildings, including the upcoming Sears Tower, a 110-story steel structure which will be the world's highest.

Ultra high office buildings are a response to mounting socioeconomic pressures to produce more efficient land use and to create a more attractive centercity urban environment.

The new superskyscrapers have become possible because of the development of revolutionary new steel structural systems embodying economies in design, and in the progressive lightening of the frame and components of a high structure.

The new structural systems, in turn, have come about because of the development of newer, stronger structural steels, development of high strength bolts and welding methods, the more imaginative use of conventional lighter gage steels in floors and curtain walls, and using the computer.

Buildings as high as 150 stories may be expected in the next decade. Buildings of 100 stories will become more commonplace, but the major effect of the economies produced by the new high rise structural systems will be the lifting of the height of the average office

Empire State Building

Sears Tower

building from 30 to 50 stories, up to 40 to 70 stories. Because of the newer structural concepts, the premium for added floors will be very moderate and, therefore, will justify the added height.

So says Dr. Kahn, who is regarded as one of the country's most innovative structural engineers. He is the present leader of the rebirth of the original spirit of "Chicago School" of architecture, which "invented" the steel-framed skyscraper about 80 years ago. It has been Dr. Khan whose work produced tall structures which do "scrape" the sky. Dr. Kahn, born in Dacca, Pakistan, is a citizen of the United States, with three graduate degrees in engineering from the University of Illinois. He is the engineering partner in the Chicago office of Skidmore, Owings & Merrill.

*Runaway construction costs and in*creasing mid-city real estate values have forced buildings to grow taller. Height now serves as a function of a community's urban development. A fine example of this can be seen in Chicago's John Hancock Center. Operating round-the-clock, this 100-story structure is built on a relatively small base in an attractive plaza.

The Sears Building illustrates how simple economics combined with need for more open environment dictate the erection of superskyscrapers. The mercantile firm will concentrate its many Chicago headquarters' offices in the new building, which is to comprise 4.4-million sq ft or 108 acres of floor space. Sears will occupy half of that vast space, renting out the remaining half to tenants. The income from the rentals will provide an attractive return on the owners' investment.

Dr. Khan told how the Hancock Center became the first full scale United States effort, expressed in an ultra tall building, to make the cities more livable.

Making the Mid-City Livable

The original plan called for two structures set side by side on the same plot. One was to be a combination garage and office building, the other a taller apartment house. Bruce J. Graham, an architectural partner of Skidmore, Owings & Merrill, suggested a combination of two structures in one. Dr. Khan's unique steel structural system made it possible to do so with a saving of about $15-million in steel. The single structure consists of seven stories of garages, 29 stories of offices, 47 stories of apartments, along with a 44th floor "sky lobby," and other floors for stores, and the vast amount of mechanical equipment required, including emergency power equipment for the massive structure. It is believed that the John Hancock Center enjoys more continuous, 24-hour use than any structure on earth, and may be a practical answer to saving central cities. It approaches the Parisian concept of mid-city living.

"Paris, for example," says Dr. Khan, "*is one of the few cities in the world* with minimal mid-city slums or ghettos, yet it keeps a pleasant mid-city living environment because it has avoided building only office buildings which create downtowns. Housing is spread throughout the city, as well as in suburbs. Perhaps the concept behind the John Hancock Center may help revitalize downtowns and central cities."

So much of what has been happening is the result of a newer and closer relationship that is being established between engineers and architects. Where once an architect designed a structure and handed the drawings to an engineer saying "Here, make it stand up," today engineer and architect sit down together, exchange views, and thus pool their best ideas; even though the engineer often remains the anonymous member of a design team.

In tracing the development of his new structural systems, Dr. Khan recalled that the original 10-and 12-story "skyscraper" of 80 years ago was designed with a forest of vertical steel columns. Extending from the top of a building to its foundation, the columns were connected at 12-ft intervals with floor beams. The columns supported the weight of the structure and its contents.

This structural system dominated most high rise construction until the past decade. The tallest example is the Empire State Building. Its shortcoming has been the enormous amount of metal required for tall structures.

Choosing the Superskyscraper

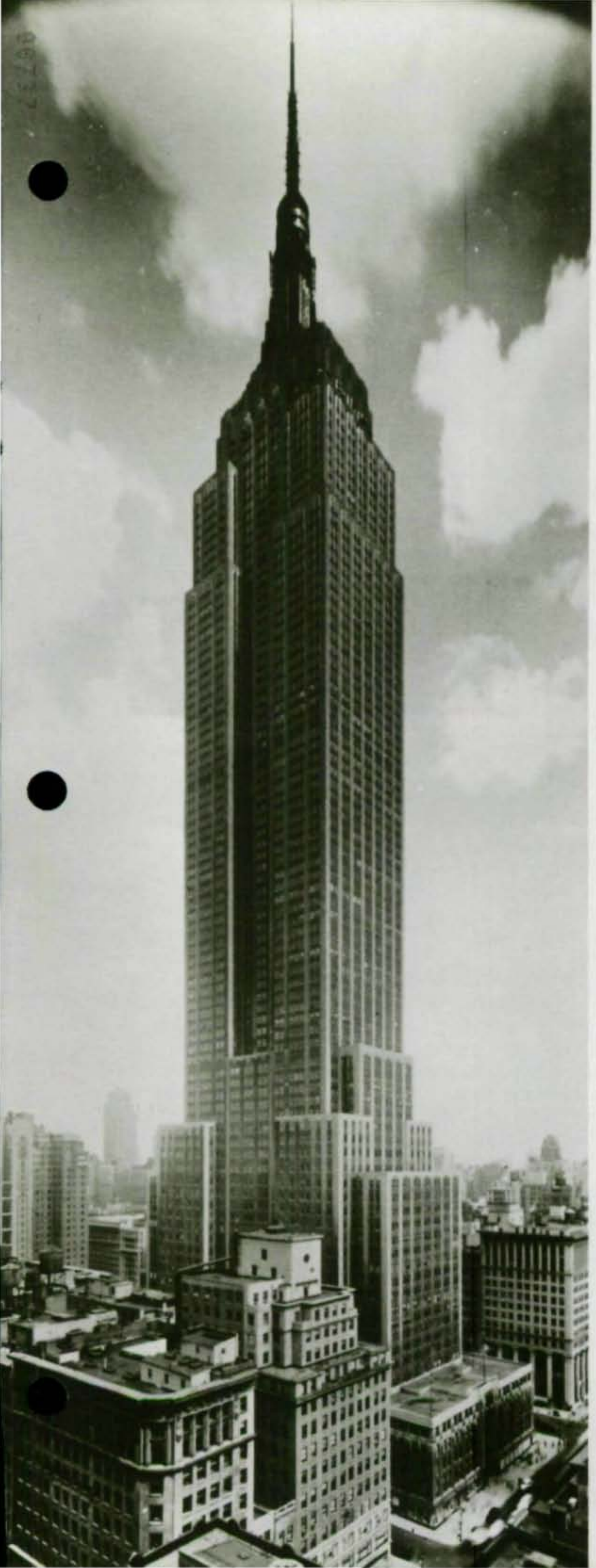
To a large extent, four major factors have been primarily responsible for the new ultra high rise office building and its reduction in weight per square foot, says Dr. Khan. The first consists of innovative structural systems. He gave two examples. One is the diagonally braced exterior wall system used in the John Hancock Center. This system requires less steel per square foot than that used in a conventional design. In the case of the Hancock Center, this meant a savings of $15-million. This design is distinguished by a series of huge vertical steel "X's" plainly visible in the exterior walls. These carry a substantial weight of the structure to the four enormous corner columns.

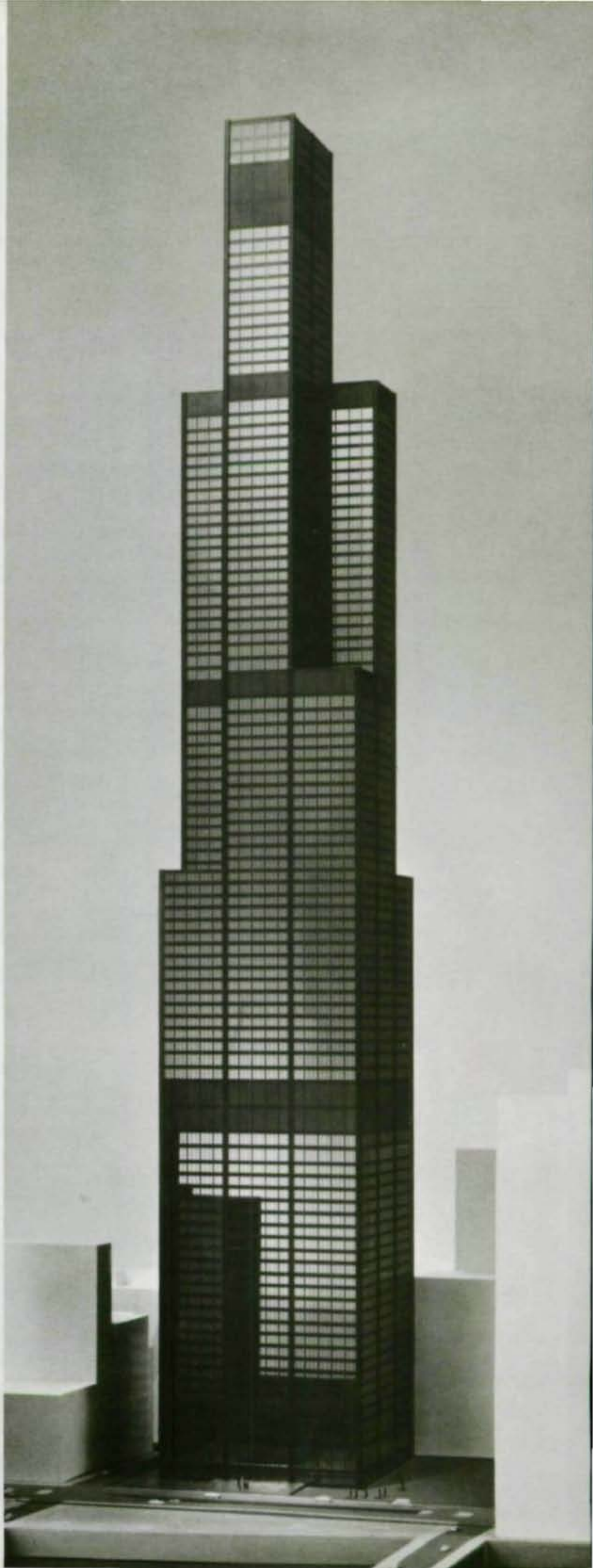
At every floor level, the exterior wall is connected to the service core in the center of the building which, with the exterior walls, supports the entire weight of the building. The core houses the elevators, stairways, and all utilities.

The sheet steel floors, formed into channels, also contribute to lightening the building's weight. Welded at each level to the exterior wall and the service core, and covered with only 1½ in. of concrete, the steel floors act compositely with the floor beams to give the structure rigidity.

Additionally, the cellular steel floors house conduits through which electrical power and communications wires feed the vast amount of office equipment. The light covering means quick and inexpensive "tappings" for new outlets. In 23 years, a Boston building has had its cellular steel floors opened for new outlets a total of 36,000 times.

Lightweight sheet steel used for the facade or as a curtain wall eliminates the need for heavy masonry walls. Thin steel insulated removable walls with painted or textured surfaces not only lighten interior walls, but also allow for quick economical remodeling.





Chrysler Building

John Hancock Center

Bundled Tube Structural System

Dr. Khan also cited the bundled tube structural system used in the Sears Tower. The building consists of nine tubes, each 75 ft square, joined three in a row, to form a "bundle." The rigidity of this "bundle" is intensified because the adjoining "tubes" share common walls. Had this structure been designed as a "conventional steel cage," it would have cost about $25-million more.

The progressive lightening of the frame of a steel-framed building represents good design, as well as economical construction. Dr. Khan illustrated the continued reduction in the weight per sq ft of tall buildings. With a gross area of 2.75 million sq ft the 1930 Empire State Building weighs 42.2 psf, in contrast with the 1968 John Hancock with 2.8 million sq ft of space which weighs 29.7 psf. The 1974 Sears Building with 4.4 million sq ft will weigh 33 psf. The 1972 World Trade Center with 9 million sq ft weighs 37 psf.

Says Kahn, "When optimum structural systems are used, the 'premium for height' in constructing ultra high buildings is relatively insignificant. The higher rentals which may be charged for the more desirable upper floors soon offset the moderate added construction costs, and, thereafter the upper floors become a permanent higher income producer for the owner."

How high are future office buildings likely to go?

Dr. Khan believes that within the 1980's someone may build a structure of 130 stories, although one of 150 is not beyond the limit of present technology. One-hundred story buildings will become commonplace, but the major result of the economies produced by the new structural steel design concepts will be to lift the present average height of office building of 30 to 50 stories, up to 40 to 70 stories.

Dr. Khan brushed aside, as little more than a conversational gambit, the suggestion of the late Frank Lloyd Wright for a mile high office building. Dr. Khan admits that a structure of such height might be engineered, if anyone can figure out why billions of dollars should be spent to erect a mile-high pylon of almost solid steel that would serve no economic, social, or cultural need.

Height Limitations

Dr. Khan revealed some of the behind-the-scene considerations that lead to a decision to erect a superskyscraper. First, what are the factors which limit height? Structural cost can be a major problem, but the newer structural systems can keep such costs reasonable if construction costs are within bounds.

Local zoning can limit height, as can Federal Aviation Administration regulations when high structures are likely to offer a hazard to airplanes.

Foundation conditions can be an additional problem because it is necessary for all tall buildings to be constructed on very stable soil. This is achieved by driving long piles, sinking caissons to bedrock which may be more than 100 ft below ground level, or by making very deep excavations into the ground and literally "float" the entire building. All of these special conditions can make foundation costs prohibitive.

The penalties of height must also be overcome. The new structural systems minimize the amounts of steel required. Vertical transportation can still be a significant problem for very tall structures. One innovative approach is the sky lobby located at 30- to 50-floor intervals from which passengers on the lower bank of elevators transfer to another bank ascending to higher floors.

As structures have grown taller and their populations have increased, the accompanying increased demands on power companies has led to power failures, which have become a grave concern to tenants, builders, engineers, and building officials.

As many safety conscious engineers see it, all tall buildings owe it to their tenants to be equipped with their own fall-back emergency power generating equipment. Every office building of substantial height should then be designed with such equipment. The exact height is a matter of judgment, but for the present many feel that 20 stories is a reasonable cut off point. All old high buildings should also be converted to emergency equipment. With so much of our population in the older age groups, apartment houses should have emergency power equipment for even lesser height, say over 10 stories. The tenants feel that eventually such equipment will become mandatory.

A Look To The Future

The advantages of height outweigh the disadvantages when one of the modern structural systems is used. More revenue-producing floor space can be created without adding to the structural congestion of an urban area. The top floors can be above most of the dust and noise levels of an area. Upper floors produce more revenue than lower floors, help pay the slightly higher premium cost for the higher floors, and remain as permanent premium income producers.

Where are the superskyscrapers leading us? Dr. Khan says, "To more livable cities, and a continued profitable construction industry when labor costs are kept in line."

Dr. Khan said he foresaw a great future for the 24-hour complete city building where garages, offices, stores, apartments, restaurants, and recreation are combined with open spaces of plazas and greenery on the ground level. Because these buildings must relate to the total urban scene, there is going to be more accent on overall planning of cities with mass transportation systems as a key factor in design decisions.

Many pessimists say that mid-cities are running out of land. This notion should cease with the realization that much future high rise construction will be freeing ground space, now cluttered with poorly planned buildings. Future structures, standing on sturdy steel legs, will span the air rights over railroad rights-of-way, tracks and railroad yards, and possibly even over highways near or through large communities.

On the whole, Dr. Khan feels that the future of the high rise building and the construction industry was never brighter.

LESS STEEL PER SQ. FT.

THE PROGRESSIVE REDUCTION IN THE POUNDS OF STEEL PER SQUARE FOOT IN STEEL-FRAMED HIGH RISE STRUCTURES

A significant trend to more economical use of steel in high rise construction is well under way. Its symbol and a measure of efficient design and technology has become the weight per square foot of a steel-framed structure.

The weight-per-foot figure is derived by dividing the total number of square feet of gross floor space into the total weight of the steel in the frame of the building.

Weight per sq ft has become an important kind of relative cost index because the weight of a frame is related to its cost, even though it is frequently impossible to compare either the cost or the weight of one structure with another because of many variables. Also, site conditions and other factors can sometimes make a relatively heavier *frame more desirable.*

The progressive reduction factor in the weight per sq ft is indicated in a study made by the Steel Products News Bureau which highlights the weight-reducing contributions of some of the nation's foremost engineers and architects, whose pace-setting developments have ranged from spectacular design concepts to the use of eight major factors which reduce weight. Many are less dramatic, some are innovative, others are pedestrian, but the total of which is reflected in substantial savings in steel structures ranging in height from 110 to 11 stories.

Today, a 100-story office building can be constructed with no more than 29 lbs of steel per sq ft, compared with 42.2 lbs for the Empire State Building. A 50-story building can be constructed with only 20 lbs and an 11-story structure with as few as 6.3 lbs.

The following table indicates the progress made in the reduction of weight per square foot since the 102-story Empire State Building was constructed in New York City in 1930. The tabulation can not reflect all conditions and factors which influence the reduction in weight. However, eight major factors have significantly contributed to weight reduction and have helped to make steel the most economic and competitive construction material for high rise buildings, both office and residential.

Here are the major factors identified as chiefly responsible for slimming down *the weight of a steel structural frame:*

1. Dramatic and innovative design.

2. The use of high strength low alloy steels which are up to 100 percent stronger than conventional structural steel for buildings. Quenched and tempered steels used in high strength bolts are even stronger.

3. The use of welding for fastening. Welding saves from 8 to 15 percent of the steel required in a structure that is riveted or bolted because it results in continuous construction, and it eliminates or minimizes the angles and plates which must be used when structures are fastened with rivets or bolts.

4. The increasing use of composite floor construction where steel beams act compositely with concrete slab. In some cases the steel deck acts compositely with the concrete slab.

5. The use of computers which (a) speed up and refine analysis for deflection and stress and thus result in the more accurate and economical use of steel, and (b) let engineers make alternate choices with speed and economy.

6. The "details" which consist of the arduous, painstaking steps taken by engineers in evaluating alternatives at each step of design, the total of which can produce substantial reductions in the weight of a frame.

7. The gradual increases in allowable stresses on the basis of continuing research, as indicated in the AISC 1969 Specification for the Design, Fabrication & Erection of Structural Steel for Buildings. The new AISC Specification thus more accurately predicts the strength of steel structures.

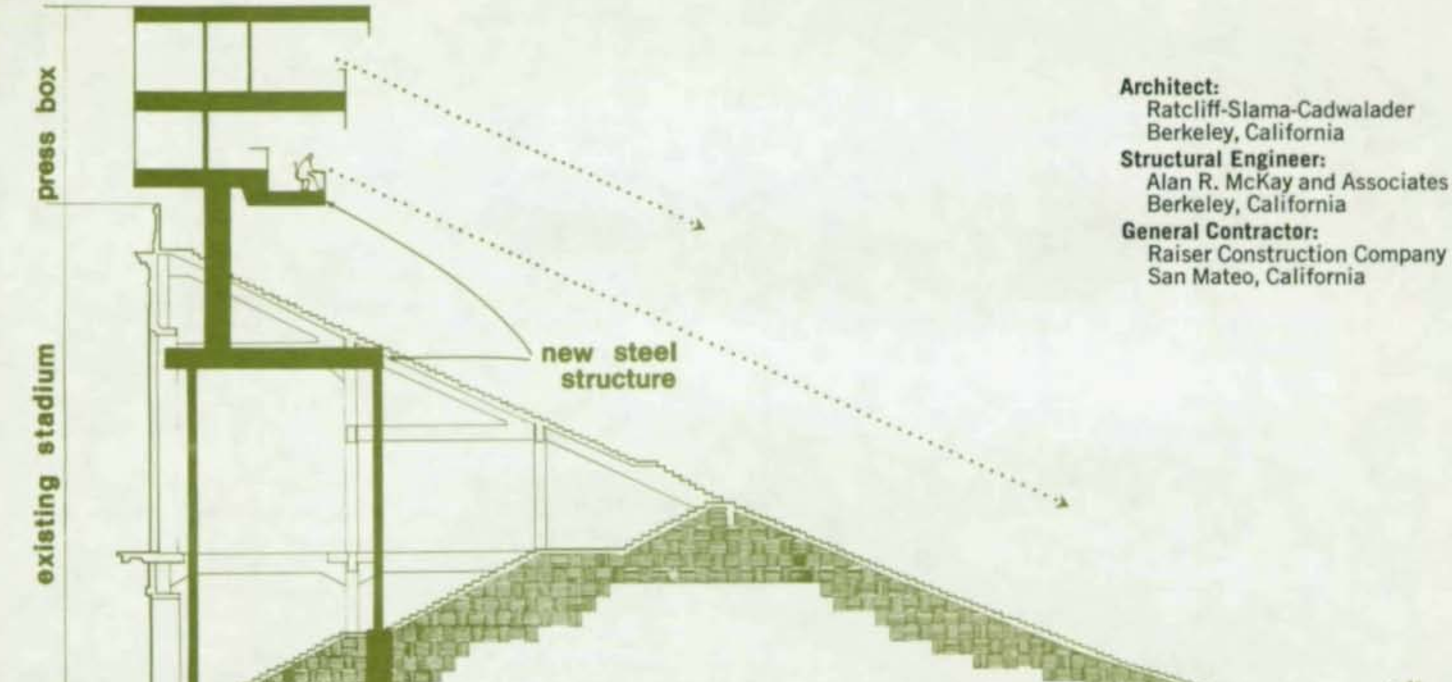
8. A reduction in the weight of other construction materials has permitted use of lighter steel frames. Lighter external and internal walls, lighter floors using cellular steel panels and lightweight aggregate, the lightening of other components and reduction of floor height all combine to reduce the deadload a frame must carry. Elimination of concrete fireproofing and the substitution of light sprayed-on material also produce a big saving.

Pounds of Steel per Square Foot	Year	Gross Area Million Square Feet	Stories	Ht-Width Ratio	Building	City
42.2	1930	2.75	102	9.3	Empire State	New York
38.	1969	2.2	60	5.7	1st Natl. Bank	Chicago
37(*)	1965	1.46	31	4.4	Civic Center	Chicago
37.	1930	1.1	77	8.5	Chrysler	New York
37.	1972	9.	110	6.9	World Trade Center	New York
33.	1974	4.4	109	6.4	Sears, Roebuck	Chicago
32.1	1961	2.8	59	6.1	Pam Am Bldg.	New York
32.	1950	.9	42	7.5	UN Secretariat	New York
30.	1971	3.1	64	6.3	U.S. Steel Corporation	Pittsburgh
29.7	1968	2.8	100	7.9	John Hancock Center	Chicago
29.5	1974	1.4	62	7.1	United California Bank	Los Angeles
29.5	1962	1.77	50	3.5	277 Park (Over RR)	New York
28.	1957	.85	42	5.1	Seagram Bldg.	New York
27.2	1945	.625	32	4.4	Esso Bldg., Radio City	New York
26.6	1950	.39	27	5.5	Sinclair Oil	New York
26.5	1971	2.	54	5.1	One Liberty Plaza	New York
26.5	1971	1.84	54	5.75	IBM Bldg.	Chicago
26.	1969	.4	26	4.	Alcoa Bldg.	San Francisco
26.	1971	2.4	51	6.5	McGraw-Hill	New York
25.7	1951	.51	30	4.1	Alcoa Bldg.	Pittsburgh
25.6	1960	.258	20	4.1	United Engineering Center	New York
25.	1972	.6	40	4.1	1st Natl. Bank, Oregon	Portland
24.5	1969	.875	50	4.9	Seattle—1st Natl. Bank	Seattle
23.	1963	1.3	46	6.1	J. C. Penney Building	New York
22.5	1967	.31	25	3.5	Connecticut Mutual	Chicago
22.	1968	.37	30	5.1	Owens-Corning Fiberglas	Toledo
22.	1957	.46	26	3.1	Corning Glass	New York
22.	1972	1.2	40	4.1	One Beacon Street	Boston
22.	1956	1.7	42	5.5	Socony Mobil	New York
21.6	1963	.231	13	1.67	IBM Bldg.	Pittsburgh
21.3	1970	.206	30	4.1	Two First Natl. Plaza	Chicago
21.	1970	.88	42	4.1	Boston Co. Building	Boston
20.3	1950	.64	25	4.2	Mutual Life Insurance Bldg.	New York
20.	1960	1.92	43	3.1	1290 6th	New York
20.	1968	1.8	50	4.1	Burlington House	New York
19.1	1955	.44	33	4.1	641 Lex. Ave.	New York
18.9	1967	.84	41	3.4	437 Madison	New York
18.7	1958	1.10	38	2.3	80 Pine Street	New York
17.9	1959	.69	22	4.5	Gateway Center Bldg. #4	Pittsburgh
17.9	1971	1.5	54	6.1	IDS Center	Minneapolis
16.8	1957	1.50	30	1.7	2 Broadway	New York
16.7	1958	.15	8	1.2	Deering-Millikin	New York
16.	1969	.5	29	3.1	77 Water Street	New York
8.78	1970	.15	10	6.1	200 No. Glebe Road	Arlington, Va.
6.5	1969	.148	17	3.1	Housing Project	St. Paul
6.3	1966	.168	11	6.1	Stevenson Apts.	Bladensburg, Md.
6.3	1971	.13	10	5.1	Low income Housing (HUD)	Brockton, Mass.

NOTE—Gross area includes all framed area in building above and below grade. Number of stories are above grade.

*The 37-psf weight of the Chicago Civic Center illustrates the need to consider a number of variables in comparing structures on the basis of their different per-foot-weights. The Civic Center rises to a height of 640 ft yet is only 30 stories high and has 87-ft spans due to architectural requirements and variations in the size and location of the many court rooms in the structure.

ADDITION for the PRESS



Architect:
Ratcliff-Slama-Cadwalader
Berkeley, California

Structural Engineer:
Alan R. McKay and Associates
Berkeley, California

General Contractor:
Raiser Construction Company
San Mateo, California

The new Press Box for Memorial Stadium, at the University of California, Berkeley, replaces a smaller wood frame structure, built in 1923, which was supported on the reinforced concrete structure of the stadium. Since the stadium is built over a major earthquake fault, it was felt that a new and larger structure would have to be structurally independent. In addition, the University preferred a scheme that would only eliminate a minimum number of spectator seats.

The solution to the problem was, therefore, a steel and plexiglas sheathed steel frame structure, cantilevered on huge wide-flange steel columns, which are embedded in a new concrete footing system. This new structure, 24 ft wide x 180 ft long, hovers above the west rim of the stadium, using a minimum of the existing seat space, and avoiding any visual blind spots.

The planning of the Press Box is based on obtaining clear visual sight lines. The metal-framed plexiglas window panels are constructed in such a manner as to swing up and out, thus eliminating posts and mullions from view. The transparency of the front face is further expressed by the use of bronze-tinted plexiglas spandrels, revealing both the floor line and structure.

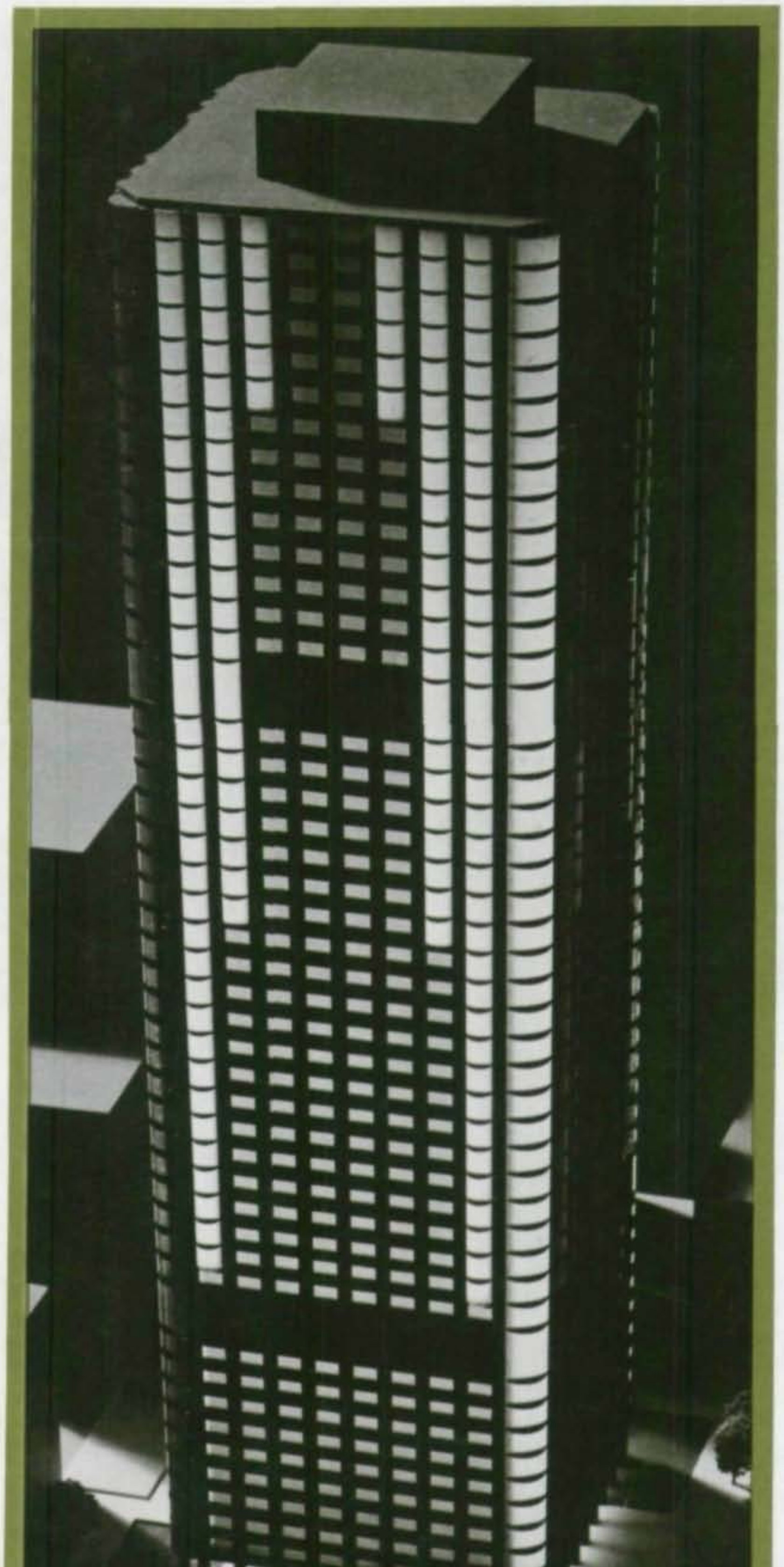
The siding material is made of factory-finished corrugated steel, which spans from floor to floor. Its "skinlike" character is visually expressed by revealing thin edges, wrapping around the back corners and ending with sharp edges at the front corners.

Two tiers accommodate the working press, radio and television coverage, coaching staffs, statisticians, and VIP's. Along the back of both tiers are the supporting functions: snack bar, toilets, storage, film changing room, and the like. An elevator connects with the ground level entry, 90 ft below.

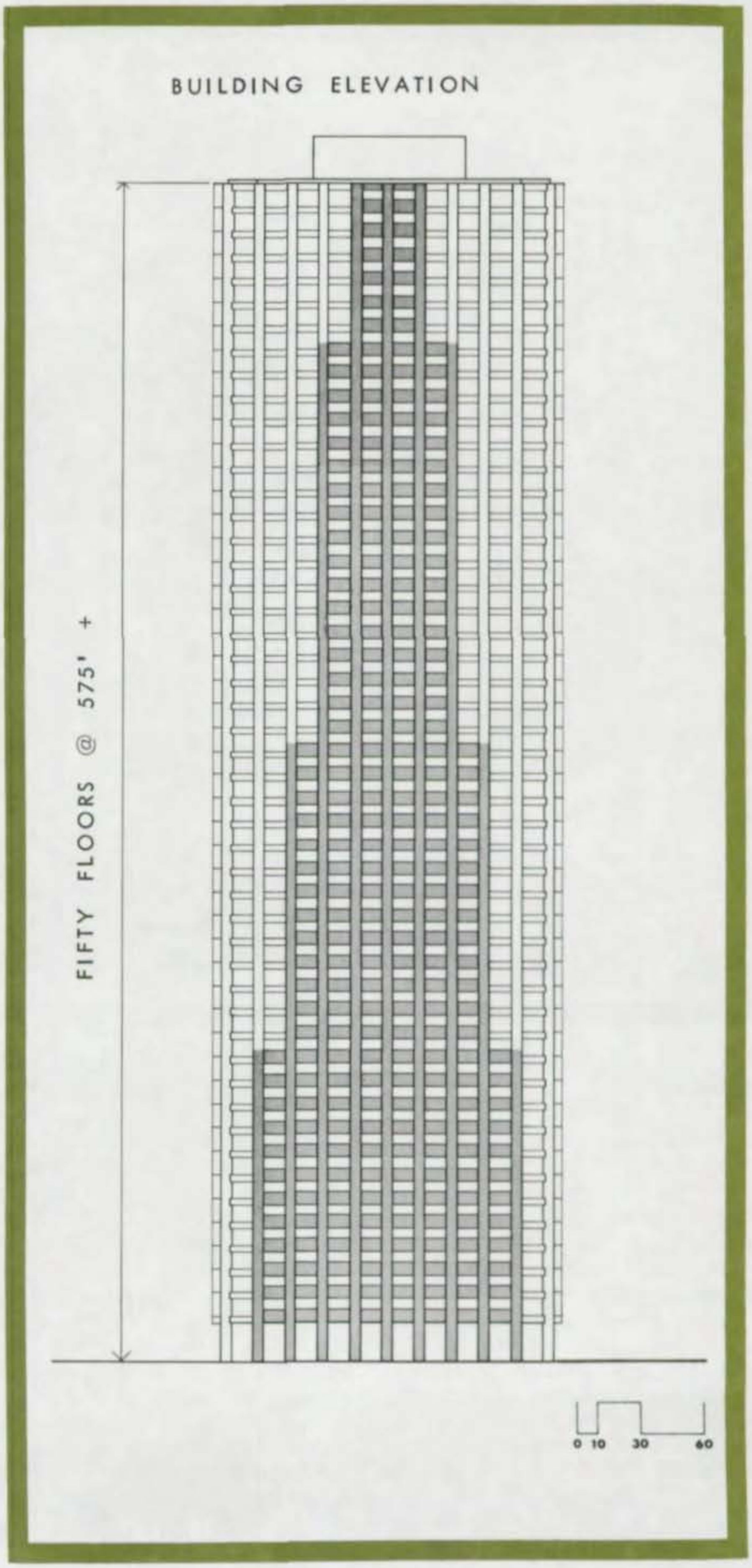
The use of steel is based on several factors. Of primary importance is the structure of the Press Box itself. Installation, accessibility, the need for long spans, and the necessity of a relatively lightweight material were prime considerations in choosing steel as the building material.

Aesthetically speaking, the character of steel and glass were employed to contrast with the existing stadium in both form and texture.

Concrete-Filled Steel Columns for Multistory Construction



by Alexander G. Tarics



The columns inside of the shaded area participate in lateral load resistance. These are interconnected with 6 ft deep girders. The lateral load resisting frame closely approximates the shape of a cantilever of equal stress.

The columns outside of the shaded area carry vertical load only, and are interconnected with shallow girders under the floor slab. Here the floors cantilever outside the line of columns, adding 80,000 sq ft of usable area to the building.

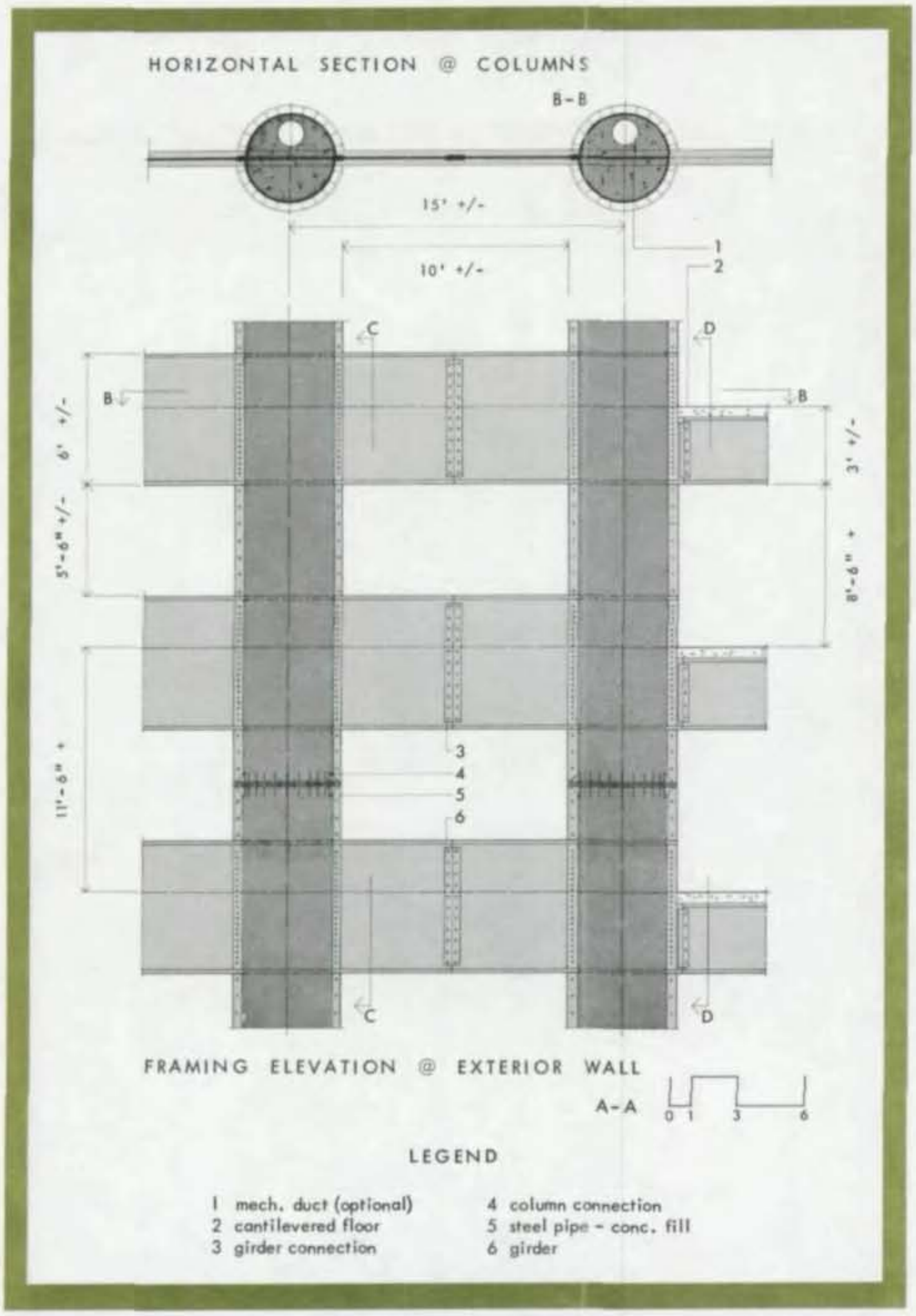
In conventional construction the high tensile strength of structural steel and the high compressive strength of concrete are successfully combined into a single structural unit in composite construction.

In another kind of combination of steel and concrete, the high compressive strength of the two materials is efficiently utilized when large diameter structural steel pipes are filled with concrete to form a column. Such columns of several feet in diameter are extremely efficient, not only to carry gravity loads, but also to resist lateral wind and earthquake forces in high rise construction due to their greatly increased stiffness gained by the use of the more efficient pipe section and by the addition of concrete inside of the pipe.

These concrete-filled columns can significantly contribute to the solution of several major problems associated with high rise construction: the control of sidesway, the elimination and simplification of highly stressed connections, provisions for fireproofing, and provisions for damping in earthquake areas.

Depending on the floor load, the clear span of the floor beams, and on the magnitude of the lateral load for which the building is designed, the steel required for the framing of a typical 50-story building is in the range of 24 to 28 psf of the tower floor area.

Dr. Tarics of Reid & Tarics Associates, San Francisco, Calif., is principal in charge of design.



Sidesway

In the design of steel framed high rise buildings, the control of sidesway under lateral wind and earthquake forces represents a major problem. With conventional structural systems it is customary to use more steel than required for strength alone to keep the sidesway below acceptable levels.

There are several commercially available steels which have significantly higher yield point than the commonly used A36 steel. The modulus of elasticity, however, does not increase with the higher yield point; it remains the same for all steels. Consequently, when these steels are used in a high rise structure, the higher working stresses under lateral loads are accompanied with high strains and with increased sidesway. This does not exclude, but puts a limit to, the broad utilization of high strength steels in multistory construction.

The stiffness of the proposed concrete-filled tubular columns is so many times more than the stiffness of the equivalent weight wide flange columns, that less steel and higher strength steel can be used in the buildings without excessive sidesway. The saving in steel alone offsets the extra cost of concrete.

Connections

The conventional high rise steel structure is composed of an assembly of columns and girders. Where columns and girders meet, stresses are the highest, yet this is the point where the girders are spliced for the necessary continuity. The cost of the preparation of the connections in the shop and the cost of the field work associated with it are significant components of the total cost of the structural steel. A typical 50-story building may have thousands of such connections.

The use of large tubular concrete-filled columns simplifies the construction, because it permits columns and girders to go through at their point of intersection without interruption. The concrete in the pipe columns prevents the buckling of the web of the girder from the usual high shear stresses inside of the connection. The girders "pierce" the columns and only the web of the girder is connected to flanges of the steel columns in the most simple manner. Girders are spliced where stresses are lowest, specifically, in between columns. The number of highly stressed connections under lateral load can be also reduced to almost half by excluding certain columns from the lateral load resisting frame.

Fireproofing

The fire resistance of building elements is determined through standard fire test procedures adopted by appropriate agencies. It is expected that during fire tests these columns would exhibit good fire resisting qualities—similar to partially water-filled columns – because of large amounts of water of crystallization in the mass of concrete inside the steel pipe. Until such tests are performed on these proposed columns, they can be fireproofed as conventional steel columns.

The round shape and uniform diameter make it practical to consider the use of simple prefabricated fireproofing. Those columns which do not participate in lateral load resistance and consequently have simple connection details can also have shop applied fireproofing.

Damping

Investigations of the effect of actual earthquakes on high rise structures indicate that stiff masonry elements, acting in unison with steel frames, crack and yield after their elastic deformation reaches its limit and help to dissipate the destructive kinetic energy in the building. The concrete in this case will reach the limit of its elastic deformation, when stresses in the steel pipe are still very low, beyond that it will crack, yield, and help to dampen the lateral movements of the building, without losing its ability to carry design loads, being in an ideal state of confinement inside the steel pipe.

Substantial Savings Seen

Experience has taught us that progress in construction technology is gradual; ideas emerge along lines already started. In that sense the idea of using concrete-filled large tubular steel columns in high-rise construction to control sidesway is analogous to the concept of "composite design" for horizontal beams which carry gravity loads.

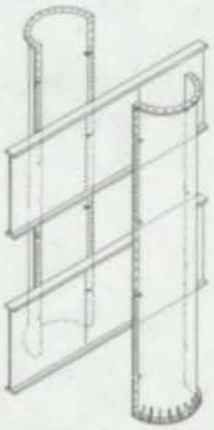
A new idea in construction has immediate value only if it produces buildings which can be built at less expense than buildings designed with already existing ideas. The concept presented here yields substantial savings through accumulation of the following:

- Minimum steel quantity per sq ft of building area
- Reduction of the number and simplification of highly stressed connections and field connections
- Reduced fireproofing requirements

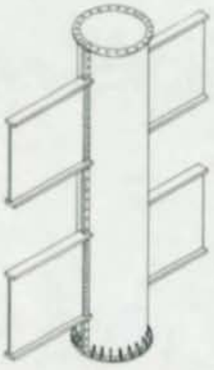
Concrete-filled steel pipe columns mean better buildings as they reduce sidesway and contribute to essential damping in seismic areas.

This novel structural concept, developed by Reid and Tarics Associates, has been presented as it applies to a 50-story office building. The concept is also suitable to the framing of any multi-story building: hospital, apartment house, research building and the like.

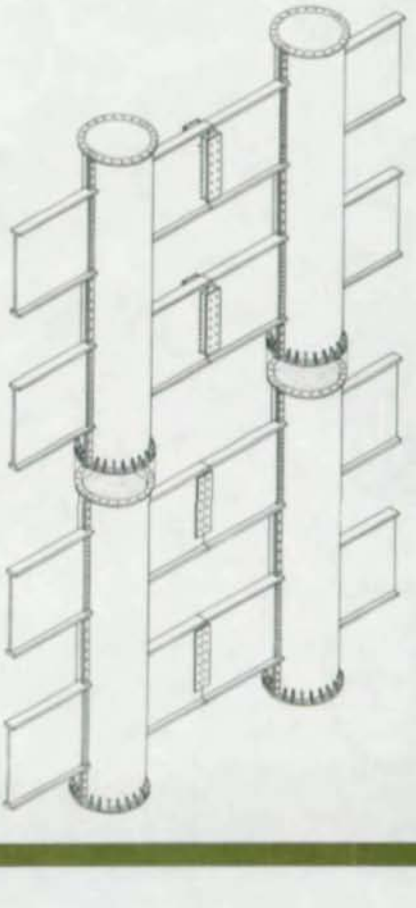
ERECTION OF STRUCTURAL STEEL



Column sections are fabricated in halves, with flanges for assembly at the site.



Columns and girders are assembled on ground with flanges of half column sections bolted to each other and to webs of girders.



Columns which are already in place are filled with concrete. Next, column-girder assembly is put into place. Field connections completed.

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