BUILDING TYPES STUDY® 492

ENGINEERING FOR ARCHITECTURE

INTRODUCTION

This is our third annual mid-August issue on Engineering for Architecture. Like the previous two, this issue explores the vast array of technical expertise available for problem-solving in the building industry. But perhaps even more dramatically than in the previous issues, the work and ideas presented on the pages that follow demonstrate the *individual* excellence and resourcefulness that engineers and architect can bring to bear on a building project. Apparent everywhere is great agility of thinking . . . .

For example: The case studies in this issue show engineers and architects taking wholly different (even revolutionary) approaches to what before might have seemed commonplace problems—as in the design for Citicorp Center (overleaf), a most uncommonplace high-rise office building. The case examples also show engineers and architects engaged in work once assumed to be the province of more specialized disciplines—such as the Roosevelt Island tramway (page 86) and the Los Angeles "pedways" (page 78). And they show deft integration of services with structure—as in the inventive ceiling system of a Montana museum (page 108) and the carefully conceived design for the Bank of Canada (page 72), which is highly rationalized in function but at the same time provides a level of style and comfort that clearly makes this "a building in the grand manner."

The case histories also show some highly unusual problems solved ingeniously *and* handsomely—such as a California firing range, a vacation house with a 300-lb snow load, a school in an "almost impossible" acoustical environment, stadium grandstands that float on films of air or water, and a "water wall" that mitigates the effect of weather.

On page 98 is a profile of the work of Gensert, Peller, Mancini that demonstrates a very thoughtful engineer's attention to the pragmatic aspects of building—beyond the structure to all of the alternative implications of mechanical system integration, construction techniques, and cost.

Elsewhere, the issue describes new technologies—new, resourceful, and rational approaches to tent-structure engineering; the economics and design integration of solar-energy systems; and the psychological, economic, and design implications of newly developed task/ambient lighting.

Finally, the issue takes a look at some of the special consultants working in the more exotic reaches of engineering thought and design ("For Every Problem There is a Problem Solver," page 92); and the ever-present need for better technical backup for architecture—discussed in the Round Table on page 116.

An issue of ideas . . . and the people who generate those ideas . . . .

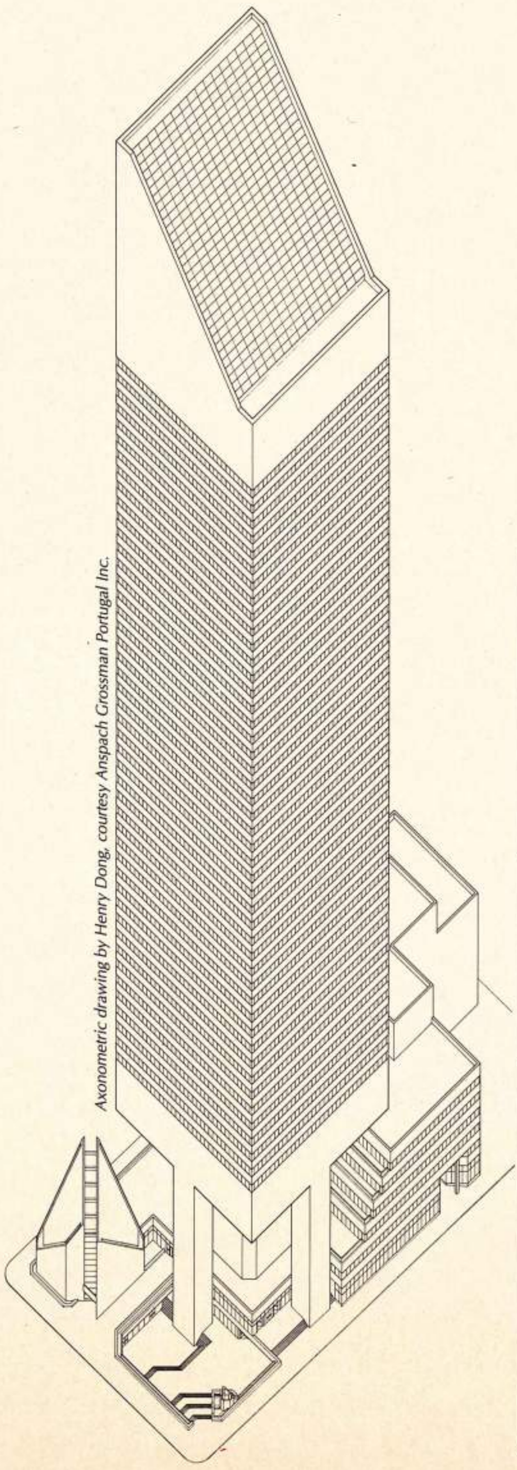
At New York's Citicorp Center, a structure of masterly invention underlies the urbane face of a skyscraper in the grand manner

A skyscraper should be a "proud and soaring thing," Louis Sullivan said, and Citicorp Center, with its lofty bearing and smooth skin, promises to be just that. As for soaring—at 914 ft, the square tower will take seventh place among the world's tallest buildings. Architect Hugh Stubbins has, further, incorporated amenities traditional to the genre in the 1970s: landscaped plaza, shopping galleria, and a network of covered public walks.

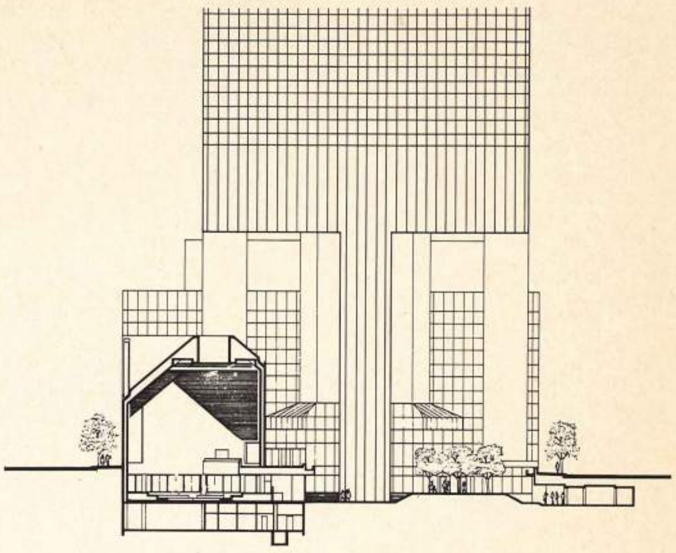
From the pedestrian's view, the most commanding aspects of the building are its overhanging corners, projecting 72 ft from the central columns, nine floors up. The unexpected location of the four supporting columns was dictated by the insistence of St. Peter's Lutheran Church, which shares the site, that its new building be freestanding. The church, widely known in New York as the "jazz church" because of the number of musicians in its congregation and because of its active cultural program, had occupied this corner of Lexington Avenue since 1905. St. Peter's agreement with the bank holding company in their joint development of the site was that it retain a distinct identity. On the Third Avenue end of the complex, the tower overhangs a low-rise building that will house offices and a three-story shopping galleria. On Lexington Avenue, a sunken plaza gives access to the subway and to the church's sanctuary (the granite-covered structure at street level is a large lantern above the sanctuary).

The 160-ft crown of the tower slopes toward the south in anticipation of collecting solar heat. A large solar-energy project, which was to have been funded by the Federal Energy Research and Development Administration, was abandoned after the building was designed when cost-savings proved less than hoped for. The crown will, however, house a tuned mass damper (TMD), a new and so-far unique device to slow the motion of the building in wind and so to reduce occupants' discomfort (see page 70).

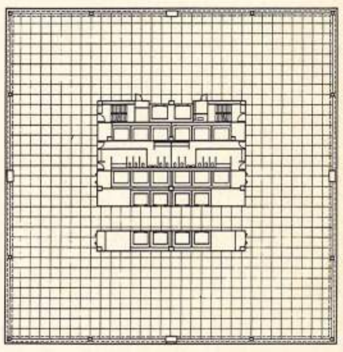
CITICORP CENTER and ST. PETER'S LUTHERAN CHURCH, New York City. Architects: *Hugh Stubbins and Associates—Hugh Stubbins (principal-in-charge), W. Easley Hamner (project architect); Emery Roth and Sons.* Engineers: *LeMessurier Associates/SCI* (structural)—*William LeMessurier (principal-in-charge), Kenneth B. Wiesner (project engineer, and tuned mass damper), Stanley H. Goldstein (partner, New York), Joel Weinstein (design engineer, Citicorp), Fraser Sinclair (design engineer, St. Peter's); The Office of James Ruderman* (structural)—*Murray Shapiro (principal-in-charge); Joseph R. Loring & Associates* (mechanical/electrical). Contractor: *HRH Construction Co.*

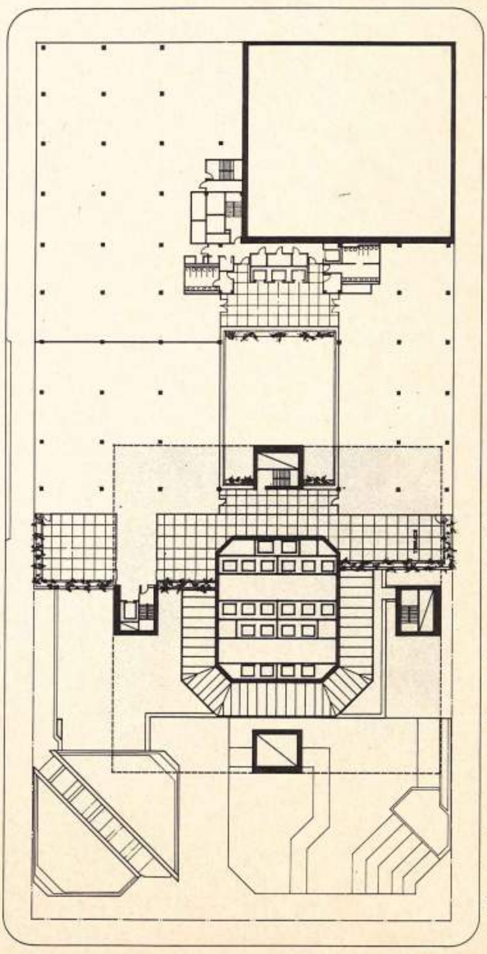


Axonometric drawing by Henry Dong, courtesy Anspach Grossman Portugal Inc.



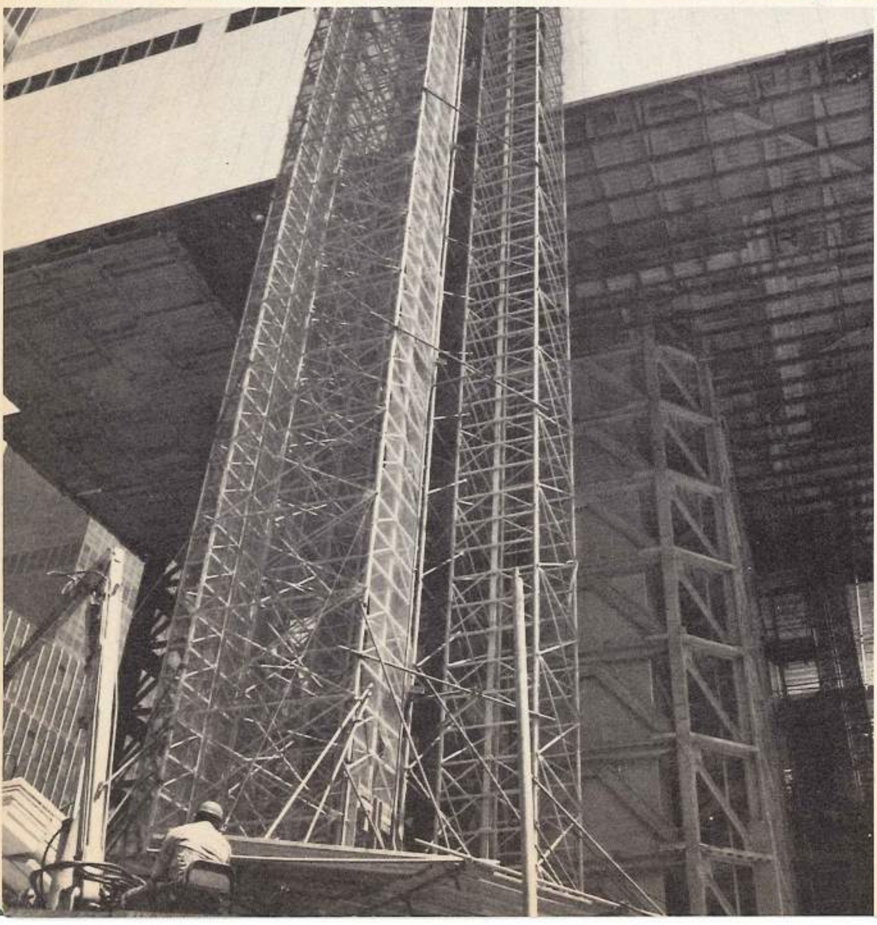
The open space beneath the office tower is conceived as a midtown mini-center of culture and commerce. The church's facilities will include a chapel designed by Louise Nevelson, a theater and a room for jazz performances. Developers envision a complex of international food boutiques.



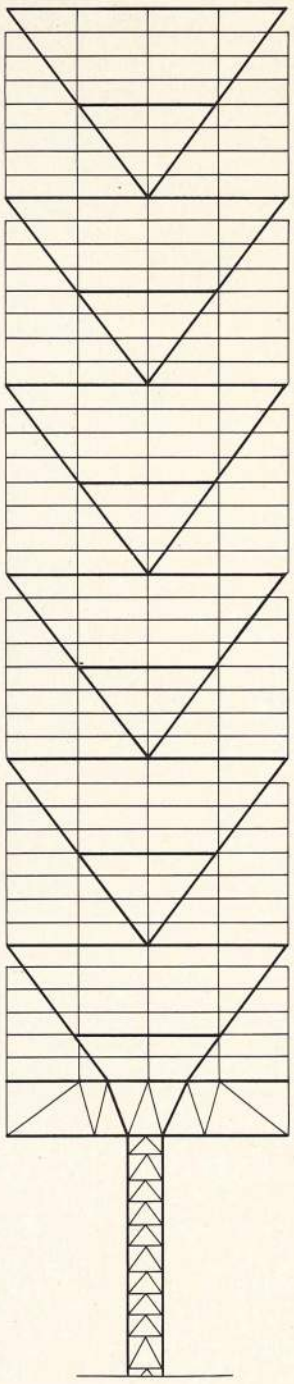


Paul Kopelow photo, courtesy Anspach Grossman Portugal Inc.

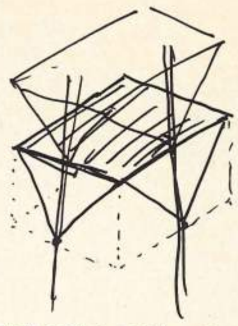

CENTRAL
ENGLISH
FRENCH



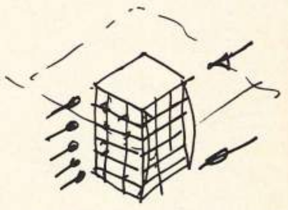
Robert E. Fischer photos



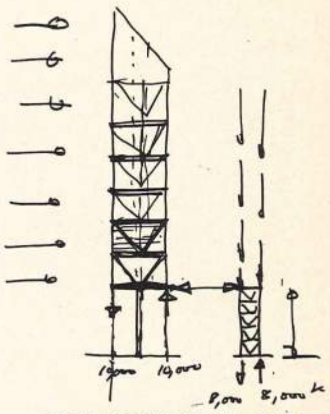
Upon reaching the bottom of the tower, the mast bifurcates at the "keystone" below top chord of the truss and transfers gravity load to the two outside columns of the legs. The 26¾-ft-deep truss, in addition to supporting the slabs for load transfer, played a major role in the construction process by providing a "getting started" platform: because the truss was constructed much as a cantilever bridge is, erection required no shoring. Below the truss, the core absorbs all horizontal shear load with four exterior bents and two interior bents (see framing plans, opposite).



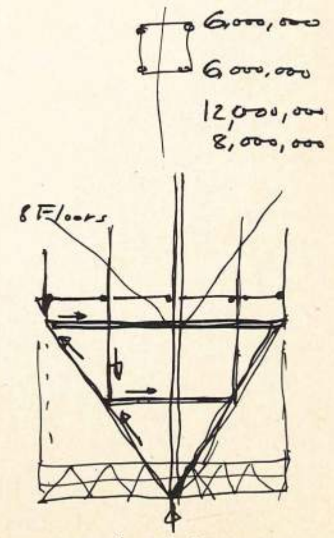
EACH EIGHT-STORY TIER IS STRUCTURALLY INDEPENDENT...



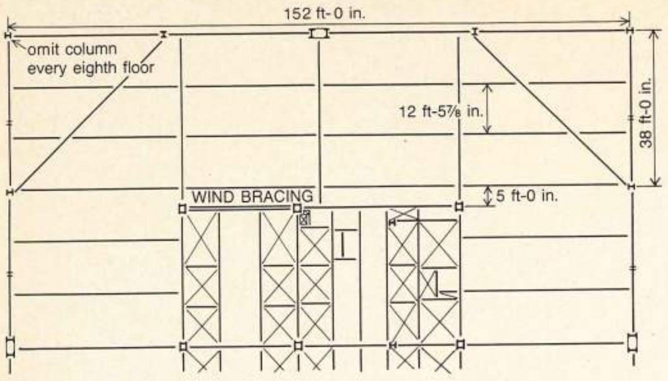
...WIND IS TAKEN BY THE CORE FOR EIGHT FLOORS, THEN TRANSFERRED TO THE TRUSSED FRAME...



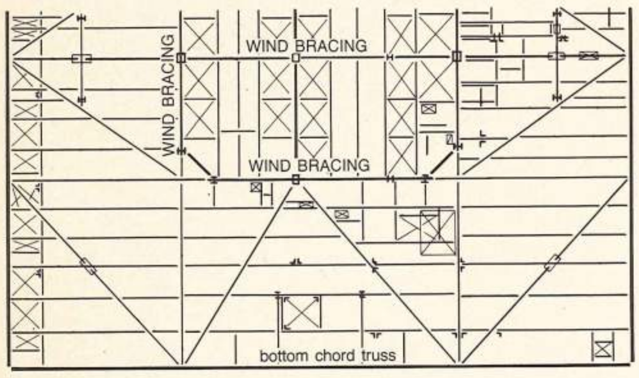
...WHICH TRANSMITS ALL WIND LOAD TO BASE OF TOWER, WHERE SHEAR IS TRANSFERRED TO THE CORE.



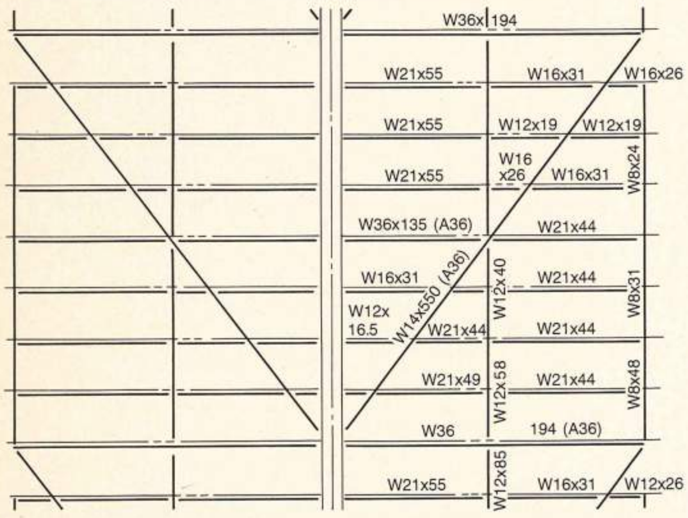
GRAVITY LOAD WORKS ITS WAY DOWN THE MAST COLUMNS.



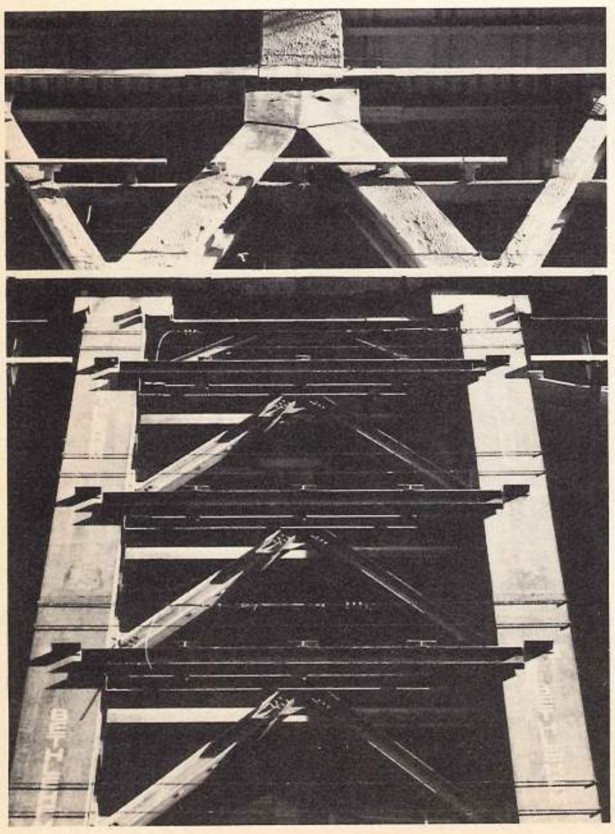
HALF-PLAN TYPICAL FLOOR

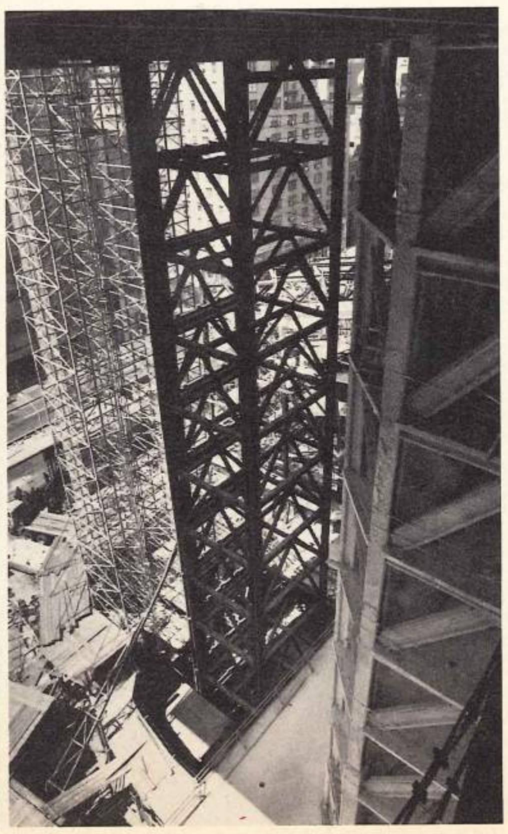


HALF-PLAN, FLOOR 9



EXTERIOR TRUSS FRAMING





Structural behavior: Even an untutored sidewalk superintendent examining Citicorp Center's unsheathed steel frame perceives that this is something new and different, something exceptional in the way of skyscraper structure. To the structural engineers, the structure represents a clean design "so simple it can be analyzed by hand," and the frame, however curious its initial appearance, does possess a straightforward and efficient elegance.

In early designs for the building, four corner columns supported the tower. This solution would inevitably have made a more or less integrated whole of church and bank and was thus unacceptable to the church (whose design contract is separate from the bank's). In a daring move, Stubbins and LeMessurier brought the columns to the center of the building face, clearing a space under the tower corner for the church.

More daringly still, most of the building's load—half the gravity and all the wind load—is brought down the trussed frame on the outside of the tower. (The remaining gravity load is carried by the core.)

On first sight, the most conspicuous members are the massive central "mast columns" and the spreading diagonals—and, on second glance, the unexpectedly slender corner columns. Only the 60-in.-wide mast column transports load down the full height of the tower. All other members of the exterior frame work only over the eight-story tier defined by the steel chevrons that feed load into the mast column.

Because the mast column accepts overturning forces, it was essential to put as much mass as possible, as quickly as possible, into this column to overcome tension. Floor load, therefore, is channeled into the intermediary columns at each level by diagonal corner beams (see framing plan), and thence to the mast column at every fourth floor. (It is the diagonal floor beams that allow the corner columns to be so slim, since they must support only a small area of the floor slab. As an almost nonchalant tour de force, the corner columns are, moreover, omitted entirely at every eighth floor, where the load is taken directly by the main structure.)

The mast column does not accept shear forces, which snake down the frame via the diagonals and ties. Within each structurally independent eight-floor tier, shear forces are absorbed by the core—a relatively inefficient necessity, although the loads are inconsequential over the short distance. At every eighth floor, these forces are gathered—"like a mother hen and her chickens," in LeMessurier's description—and taken to the exterior. At the bottom of the tower, all horizontal shear load is transferred to the core, while the "legs" carry gravity and overturning forces to the ground.

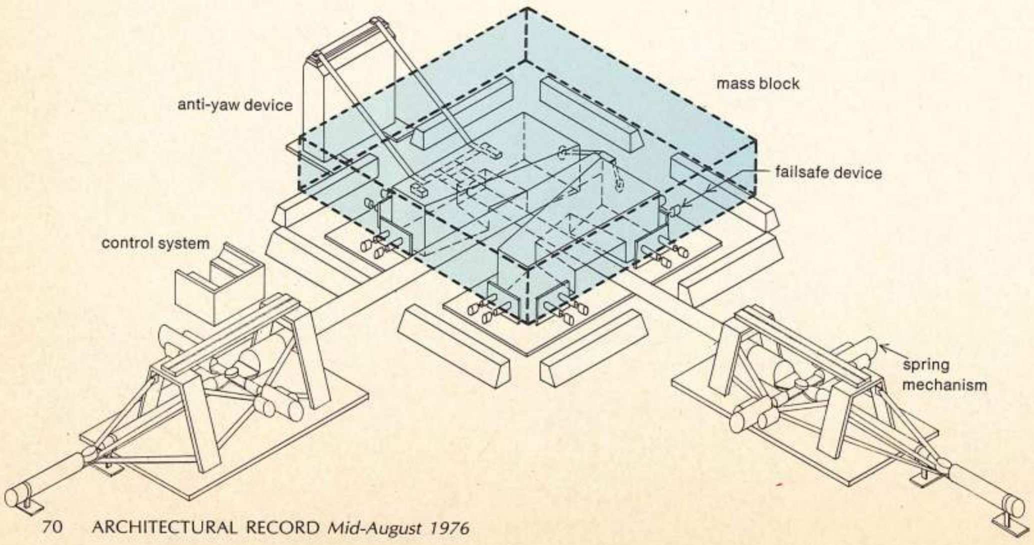
The legs comprise four columns, of which the outer two are considerably heavier than those nearest the core. According to the engineers, the legs, which measure about 17½ ft across, might have been as small as 5 ft across. They were enlarged, however, both for esthetic reasons and to house stairs, mechanical ducts and, on one side, an elevator that serves church offices and recreational spaces.

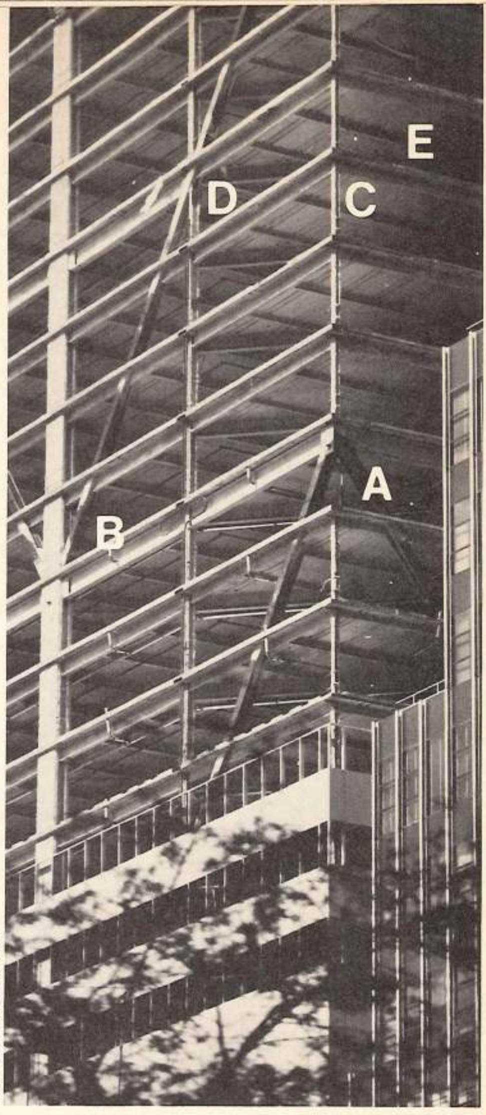
Wind damping: To slow building movement in the wind and to prevent tenant discomfort occasioned by the acceleration of the tower's sway, Citicorp will be equipped with a tuned mass damper (TMD). The device, the first of its kind in a tall building, operates somewhat as a hydraulic door closer, though it does not damp building motion simply by passive reaction but rather by countervailing movement of its own—what the engineers describe as "the application of a controlled force to a moving mass." The principle of the device is to place a large mass at the top of the building, to leave the mass "free" to remain still as the building moves, to transmit this tendency to remain stationary to the building through connections to the structure, and, further, to tune the machinery so that the period of the mass's movement equals the period of the building's movement.

The machinery for the TMD was developed by MTS Systems Corp., which manufactures machinery for earthquake simulation and for shock-testing army tanks. The TMD comprises 1) the mass—a 400-ton concrete inertia block mounted on oil bearings (a film of oil on a steel plate); 2) pneumatic springs, in which pistons act against compressed nitrogen; and 3) the control actuator (dashpot), in which energy is absorbed by oil. Because the building's natural period of movement cannot be determined with precision before completion of the tower, and because conditions may change over the life of the building or with different winds, both spring and damper can be fine tuned. The spring is tuned by bleeding or adding nitrogen; this process will be undertaken initially to bring the TMD into proper working order, and thereafter only occasionally. The dashpot, on the other hand, will be tuned continuously when the TMD is in operation. The TMD starts up in response to a signal that the building is moving. Oil is pumped to 12 oil bearings which lift the mass block and at the same time provide a low-friction surface.

Failsafe measures include a system of curbs and snubbers which ensure that movement remains within design limits: if the snubber is engaged, the controls shut off pressure for the bearings, and the mass comes to rest.

Analysis and wind tunnel testing of the TMD indicate a 38 per cent reduction of acceleration for the tower. The engineers figure that adding mass to the structure to achieve the same effect would have cost about $5 million, against the TMD's $1 million.



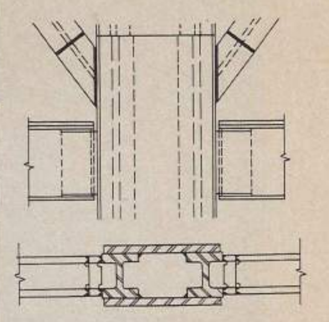


Robert E. Fischer photos

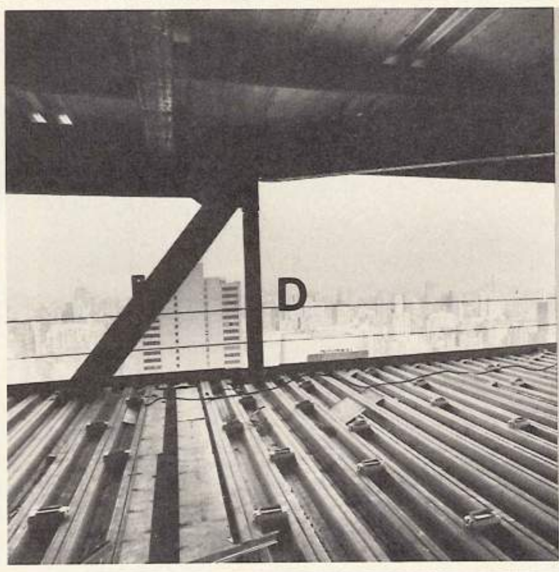
Structural details: From Citicorp's interior, views will differ according to which floor of the eight-story tier the viewer occupies. On the top floor, corner columns (A) are eliminated where diagonals meet, while columns on remaining seven floors are unusually slender (C). On the first level, diagonals join the mast column at the center of the building face (B). The central mast is built up of rolled sections and plates (details upper right); since the depth of the web in mast column components and in diagonal members is the same regardless of the thickness of the component sections, "knuckles" match dimensions of diagonals for welding. At the fourth level, the intermediary column intersects the diagonal (D). Like the topmost corner column, the intermediary column could in theory have been eliminated at this point, but it was in fact required to resist buckling of the diagonal. This column is not, however, designed for dead load, which at this level is taken by the midpoint tie. Connection between column and tie could not therefore be bolted (detail far right) until the tier was completed and diagonal loads would not feed into the column. After connection is bolted, column D carries only live (people) load. A panoramic view of the fourth level (E) emphasizes the expanse of the column-free office floors: 46 ft from core to exterior, roughly 36-38 ft between exterior columns. The building's curtain wall, now being installed, will be a smooth skin of pale, natural-colored aluminum banded by reflective glass. The simple shape and cool texture of the tower will provide a counterpoint to the complex polyhedron, that constitutes the lantern above the church.

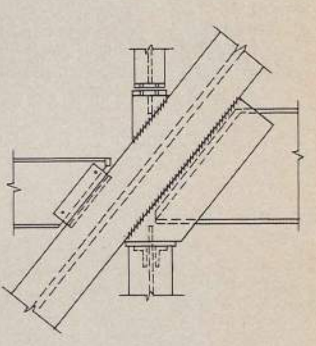

A


B




C


D




E