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A CRACKING SHELL
At the University of California

by
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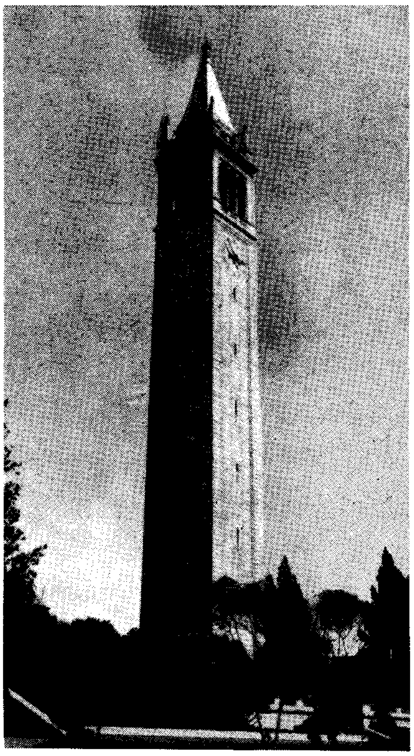
N*ESTLED* at the foot of the Berkeley Hills is the Campus of the University of California. Standing serenely in the midst of this Campus is the gray stone Sather Tower, sometimes called the Campanile. It is 234 feet high, has a fine set of chimes, and a four faced clock below the belfry. There are formal walks and grass plots in front of it, planted with rows of English elms and a granite drinking fountain. It is one of the focal joints of the school, and students gather here between classes to sit on the big uncomfortable redwood benches or lie on the grass and get burned by the warm California sunshine.


JOHN GALEN HOWARD ARCHITECT

This California sunshine is pretty "hot stuff," and it has not been too kind to the Tower. On its southeast and west sides, the granite facing has been cracking in many places for 20 years, and there are more cracks on the east and west sides where the sun is the hottest.

When this cracking was first discovered in 1940, there was great concern, as the Tower was very carefully designed and constructed in 1914. The eminent John Galen Howard of San Francisco was the architect, and his name appears in bronze letters in the brick pavement at the entrance. It was built only eight years after the great San Francisco earthquake, and for this reason the designer and builder took especial care.

Modern skyscraper construction was used for the Tower except that the structural steel does not carry the composite masonry shell at each story. However, the steel frame was painstakingly designed and erected to resist earth tremors. The whole structure rests on a foundation 18 feet below grade and consists of a grillage of steel beams encased in 8 feet of concrete. This foundation not only supports the steel frame but also carries the self-supporting masonry shell to its full 234 foot height. The masonry shell or wall is tied to the steel frame for lateral stability. Of course, in other respects it is a fake, as it has no structural value except to support itself. The wall on each side is slightly battered in its full 234 foot height and as "masonry" consists of 8″ reinforced concrete and 6″ to 8″ of stone. *The concrete was poured directly against the stone* and that was the tragic error. The stone courses are granite, 20″ high, and the blocks are from 60″ to 72″ long overlapping 6″ at alternate courses. The stones are tied together at the top of each vertical joint with a ½″ galvanized round rod bent like an inverted paper staple. These are fitted into ⅝″ holes drilled into the granite. Thus each stone course forms a rigid band completely around the Tower except where there are openings. This fact, I think, is the basis of the whole trouble.

All the stone for the Tower is Raymond Granite quarried in Northern California in the Sierra foothills. It is a light gray and not as hard as eastern granites found in Minnesota, New Hampshire, and Vermont.

For more than a decade after its completion no damage of any sort was observed on the shell of the Tower; but 13 years after its construction, a few small cracks were noticed at the Southwest, Southeast, and Northwest corners. During the next ten years the cracks continued to develop—for the most part on the sunny exposures and running from the top each block down to the vertical joints thus: From time to time small pieces of stone have fallen off, mostly on the corners, so for safety's sake, a 4 foot board fence was erected around the Tower at a distance of 10 feet from the 34 foot square base. Now the authorities are talking of filling the ten foot space around the Tower with a garden to keep people from getting hit by falling pieces of granite.

This damage to the shell of the Tower has, of course, been of great concern to the University authorities, and they have taken measures to learn the cause and take steps, if possible, to remedy the trouble. So there have been investigations and studies during the past few years carried on under the general direction of the Division of Architecture and Engineering of the University of California assisted by Mr. Walter T. Steilberg, Consulting Architect. Helping in these investigations and studies have been various architects, engineers, builders, and geologists; the United States Coast and Geodetic Survey; the National Bureau of Standards; and several quarrymen's associations. As a result of these careful investigations and studies, two progress reports have been issued. The last re-

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port concludes that it is highly unlikely that these cracks are caused by:

1. Injuries due to foundation settlement.
2. Injuries to stone surfaces due to weathering or chemical changes such as rusting of anchors, etc.
3. Injuries due to vibrations from various causes such as earthquake shocks, wind pressure, the striking of the clock bell, and ringing of the chimes.
4. Possible defects in materials and workmanship.

But the report also states that as yet, no conclusions can be reached and further investigations will be necessary.

In my opinion, it is apparent and very probable that, for the most part this cracking is due indirectly to the heat of the sun for the following reasons:

1. Most of the cracks are on the south and west sides of the Tower where the sun is hottest. 2. Day in and day out for eight months and more of each year these walls take a terrific beating from the hot rays of the California sun. This heat is carried through the six inches of granite to the concrete and steel, and the concrete and steel expand. 3. As the granite courses which ring the Tower are tightly locked together by steel and there is no give, the stone cracks at the holes drilled in the granite. This is very evident from the location and appearance of these cracks.

Granite becomes harder and more brittle with age and exposure to the air. This loss of elasticity would explain the lag in time in the appearance of cracking and the rapid acceleration in recent years.

Relatively little information is available on the properties of Raymond Granite other than its compressive strength, and it has therefore been necessary to make some special tests to get the needed information. To date, the results of these tests have not been encouraging as an explanation of the time factor in the cracking. It now seems more probable that very fine cracks developed soon after the Tower was completed but that they were not observed until much later. Even today it is necessary to employ binoculars to get a fair idea of the amount and distribution of the cracks.

HISTORICAL

The Sather Tower is of about the same proportions and about 3/5 the size of the Washington Monument, but its construction is entirely different. The Washington Monument being an all-masonry edifice with thick granite walls faced with marble for the first 150 feet of its height and all-marble for the upper 400 feet.

Other towers such as the modern skyscrapers are usually of less slender proportions. Their construction is unlike the Sather Tower in that the masonry exterior walls are supported at each floor level while the exterior concrete and granite walls of the Sather Tower are supported on the foundation. Going back to the Washington Monument; there has been much cracking of the marble facing which is applied to the granite backing, and almost none in the all-marble part of the walls above.

Masonry towers built at the close of the last century before the introduction of steel framing and reinforced concrete, were provided with a measure of flexibility in their jointing; the stones were laid in lime mortar which became hard near the surface, but which at a short distance back of the surface, remained much softer than the stone, so that cracks usually followed the joints and rarely went through the stones. Such cracks could be easily repaired. While the introduction of Portland Cement mortar produced stronger and more watertight walls, the loss of flexibility produced cracks in the present day masonry. This is true of the Sather Tower. It is also true that some of the joints have opened and admitted water which is evidenced by the dark gray streaks which show on the South and West sides. It is noticeable, too, that the Raymond Granite has a high quality of absorption and that the stone remains wet for several days after a rain.

In my opinion, it would have been much better if the 8″ concrete shell of the Tower had been poured entirely separate from the granite facing and not against the stone. Galvanized iron ties for the stone veneer could have been placed in the concrete. Then the 6″ granite veneer could have been built with a 1″ air space between the concrete and the stone. The granite should have been well tied to the concrete wall at the horizontal joints. This is like our old-fashioned brick veneer walls and provides more flexibility with no danger of cracks due to the expansion of the steel frame and the concrete.

CONCLUSION

It must be remembered that all towers are challenges to the destructive forces of nature. Perhaps the Egyptians had a smart idea in building the pyramids. These structures in the form of hills and mountains have come down through the ages and will endure even when the H-Bomb, or something else, destroys civilization. In these days when men are trying to destroy the earth by one means or another, the preservation of a fine work of architecture may seem a trivial undertaking; but there is a possibility that in seeking to preserve something of the past, one may learn to do something better in the future.

Jacob Stone, A.I.A.

Note: The details respecting the present conditions of the tower, as reported in the above article have been taken from the Second Progress Report (October, 1949) of the Investigation which is being carried on under the general direction of the Division of Architecture and Engineering of the University of California with Mr. Walter T. Steilberg, Consulting Architect in charge. I am therefore much indebted to Mr. Steilberg for the use of this report. J.S.

FOOTNOTE

By Our Technological Editor JOHN JAGER, A. I. A.

IT WOULD APPEAR to this writer, from all the evidence on hand, that the cause and cure of this problem rests on acknowledgment of the disparate *expansion and contraction* as between the *granite facing* and its *concrete backing*. It appears that this is not due, principally, to the paradoxical behavior of fluctuating *temperature* differences in the summer-hot and winter-cold granite, but to the fact that *concrete* being highly hygroscopic expands and contracts on the basis of varying *moisture content*. We therefore have the remarkable condition that while

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the granite is expanding by heat, at the same time the concrete backing is contracting by excessive *dryness* . . . and vice versa, as the seasons alternate. This reciprocative type of disharmonious dynamic action, within the statics of a tall-building structure, is the result of fallacious design theory. Consequently it is not only destructive of the structural fabric but grows progressively worse with time.

In the rainy cold winter months, when the outer granite facing (statically inorganic with its backing) is *contracting,* under the *temperature* factor of the atmosphere complex, the concrete backing absorbs

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humidity from the atmosphere and is expanding, through the operation of the *moisture factor* in the air. Thus the pounds per square inch of tension along granite and concrete *contact* surfaces becomes so great that nothing would keep them from sliding separation, one from the other — "Something must give in."

***Note:** Moisture, humidity, as a component of air, is a gas, and not simply small particles of water like a fine rain or fog. Therefore like a gas, it penetrates instantly any contiguous location holding a body of air, however small, if of lesser moisture content. That the concrete within the tower is "protected" from the outside air or "weather" has no appreciable effect on the hygroscopic index of the concrete. A hygrometer will accurately register a continuity of changing "relative humidity" except in a sealed off chamber.*

It is hard to say how this unnatural problem resulting from *built-in-dynamics* disrupting the normal statistics of building construction, could be rectified by modification. It is our opinion that this cannot be so accomplished. The only answer would seem to be removal of the entire granite surface. Then rebuild with an adequate inter-wall space between concrete and granite, together with ties so designed as to permit both lateral and vertical movement.

However, as the granite shell is at present self-supporting from base to bell platform, another major problem enters into evidence. Since the difference in horizontal expansion of granite against its backing amounts to some ½ inch in 30 feet. The difference in vertical expansion as between concrete and granite would be some 5 (five) inches in the distance from base to platform! How this very great movement could be compensated for, is indeed a puzzle. Perhaps by some system of individually supported units of outer wall assigned to each ten feet of tower height. These could perhaps rest on the steel and concrete structure properly strengthened to take the extra load and under provision of suitable expansion joints, at the ten foot intervals.

These horizontal expansion joints would of course plainly show and disclose unpleasantly that an inorganic and fallacious design is there taking place. Here indeed would be a situation of neither engineering nor aesthetic merit.

∴ REPAIRS NOT POSSIBLE ∴

Thus one faces a tour de force. The only adequate solution appears to call for the *complete* reorganization as to tower structure and a complete architectural restatement of the relations of such a tower, both with respect to its self-integrity as engineering and with respect to society as represented by the university.

One could scarcely find in architecture a more typical illustration of total frustration of a project and its objectives in every respect where the initiating thought under which it is conceived lacks all the nobility of simple candor flowing from an honest heart. Had the spiritual objectives of such a university tower been materialized with relation to all the basic engineering and the know-how of crafts, so easily available in 1914 —no such miscegenation of forms in their unending interrelative conflict could have resulted. False pride preceded this enterprise . . . and thus the big educational milepost of our time was marked for inescapable defeat. Here was a situation where the five technical arts should have been harmonized by the architect, but in 1914 no such ideal was in evidence in our profession and is still but feebly understood. Architecture revolts when straightjacketed by violators of natural laws.

JOHN A. JAGER, *A.I.A.*

This winter, during severe storms, pieces of stone, pushed out of the tower wall, have been windblown to considerable distances necessitating fencing off larger areas around the base of the tower directly in the path of maximum flow of campus pedestrian traffic. Nemesis did not omit a single factor of retribution in punishment for the defiance of the good earth's immutable laws.

JACOB STONE is a native of Minneapolis and there attended elementary school. After two years at the old Putnam High School in Newburyport, Massachusetts, he entered the architectural course at M.I.T. in Boston. Upon graduation in 1899, he

Mr. Stone and Friend

remained in Boston working for Shepley, Rutan and Coolidge before returning to Minneapolis.

He says: "In 1909, with Jerome Paul Jackson, we started the firm of Jackson and Stone. Paul was a classmate of mine at M.I.T., and we had a very pleasant association for many years, designing residences, a college gymnasium at Northfield, and libraries in Minneapolis and other Minnesota towns. World War One came along, and we both went into the Service. I spent two years in the U. S. Army as First Lieutenant, Engineers, half the time in France. I returned home in July, 1919, and again went into architectural practice. It was tough going, and it seemed only a brief period before World War Two. My twenty-seven year old son, Jacob Stone, 5th, volunteered, when he was suddenly cut down by Polio.

Early in 1943, I went to California to engage in engineering work at the Kaiser Shipyards. Soon my good wife and daughter joined me, and the latter has since married. Her three-year old boy, Jacob Stone Dickinson will carry on the tradition of my father, a well-known civic leader in Minneapolis fifty years ago."