# VIBRATION OF THE SATHER TOWER.

By

**Professor C. Derleth, Jr.**

*With Plates* XXVII–XXVIII.

[The following excellent account of the construction and of the measurement of vibration of the Sather tower is a letter very kindly addressed to me under the date of Dec. 5th, 1918 by Professor C. Derleth, Jr., of the Civil Engineering Department of the University of California, and has been reproduced here on account of its great importance in connection with the problem of the vibration of high steel structures. As the period of vibration of the tower complete is 1.14 sec. we have here a case of "short column," whose natural period is not much longer than that of the destructive earthquake motion, and whose base is exposed to the maximum fracturing seismic force. F. Omori.]

I acknowledge with thanks your letter of Sept. 25 and under separate cover Vol. IX, No. 1 and Vol. IV, No. 3 of your Bulletins, referring respectively to the vibration of reinforced concrete chimneys and railway carriages.

By the same mail I am sending you a package containing the following:

a. Four photographs of the Sather Tower, being progress views showing the structure first when the steel frame was complete, then in various stages of the granite construction.

b. Three blue print sheets, Nos. 1, 101 and 102, to give you an idea of the structure as designed, including the foundation. You will note that the tower is very massive.

The structural steel in this tower weighs 501 tons. The total

weight of the monument on the foundation bed is 13,750,000 lbs., giving a uniform dead load pressure on the bed of foundation of 3 tons per sq. ft. A wind pressure of 30 lb. per sq. ft. vertical projection decreases the pressure on the foundation at windward toe to 2 tons and increases it to 4 tons per sq. ft. at the leeward edge.

From an examination of blue print sheet 102 you will note that X bracing occurs only in every other story. We have assumed that by the omission of X bracing the yielding quality of the frame would be increased. Of course the stout main columns somewhat offset this assumed advantage. You will recall that in our 1906 earthquake towers like that of our ferry building, in which there was complete X bracing, were badly shaken. The X bracing actually ruptured at joints or in the body of the X bracing.

This tower as an architectural monument is the design of Professor John Galen Howard, head of our Department of Architecture and Supervising Architect of our University buildings. I was associated with Mr. Howard as the consulting and designing engineer.

Through the courtesy of Professor E. E. Hall of our Department of Physics I was able to have an extensive number of vibration studies made upon the tower during the progress of its construction. Professor Hall used an apparatus very similar to the one described by him in Engineering News, Vol. 68, p. 198, August 1, 1912, in which article he discusses the results of studies made on the vibration of tall buildings in our San Francisco Bay region.

Professor Hall's vibration measurements were made on the following dates: March 5, June 18, August 1 and August 3, 1914; Feb. 8, October 4, 1915; December 28, 1917. On March

5, 1914, the steel frame was complete but no stone work had been begun; see photograph No. 1. On June 18, 1914, the granite walls and concrete floors had been built to the 80 ft. level from the ground surface. On August 1, 1914, the masonry work had been finished to level 130 ft.; see photographs 2 and 3. These photographs 2 and 3 do not show the masonry just as it was on the dates of June 18 and August 1, but are suggestive. On Feb. 8, 1815, the masonry work of the tower was practically complete but no clock, chimes or elevator had as yet been installed (except for the temporary workmen's elevator). On October 4, 1915, the tower was essentially complete without the chimes. The final record taken Dec. 28, 1917, is for the tower complete with chimes.

All vibration measurements were made with the recording instrument at the belfry floor level, elevation 234 ft. 2 in.; see blue print sheet 102; with the exception of the records taken on August 1, 1914, in which case the apparatus was installed at the 130 ft. 2 in. or fifth level; see sheet 102. In the following table the averages of all records made on the different dates are given. Column 2 shows the vibration period in seconds for the north-south components; that is, parallel to column line 1–2–3–4; see sheet 101. The third column gives the similar figures for the east-west components.

| Date. | Period, N-S Component. | Period, E-W Component. | Position of Recorder. |
|---|---|---|---|
| 1914, March 5. | 0.904 secs. | 1.02 secs. | Belfry floor. |
| June 18. | 0.746 | 0.874 | „ „ |
| August 1. | 0.693 | 0.844 | At 130 ft. level |
| August 3. | 0.692 | 0.863 | Belfry floor. |
| 1915, Feb. 8. | 1.064 | 1.045 | „ „ |
| Oct. 4. | 1.133 | 1.137 | „ „ |
| 1917, Dec. 28. | 1.137 | 1.136 | „ „ |

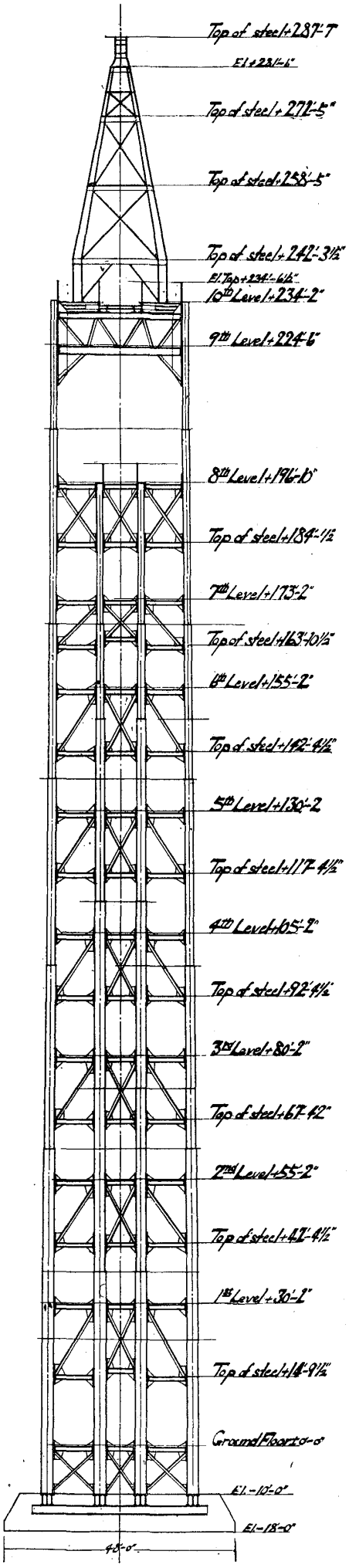


Fig. 1.

The Sather Tower,

showing the Steel Frame Construction.

# The Sather Tower.

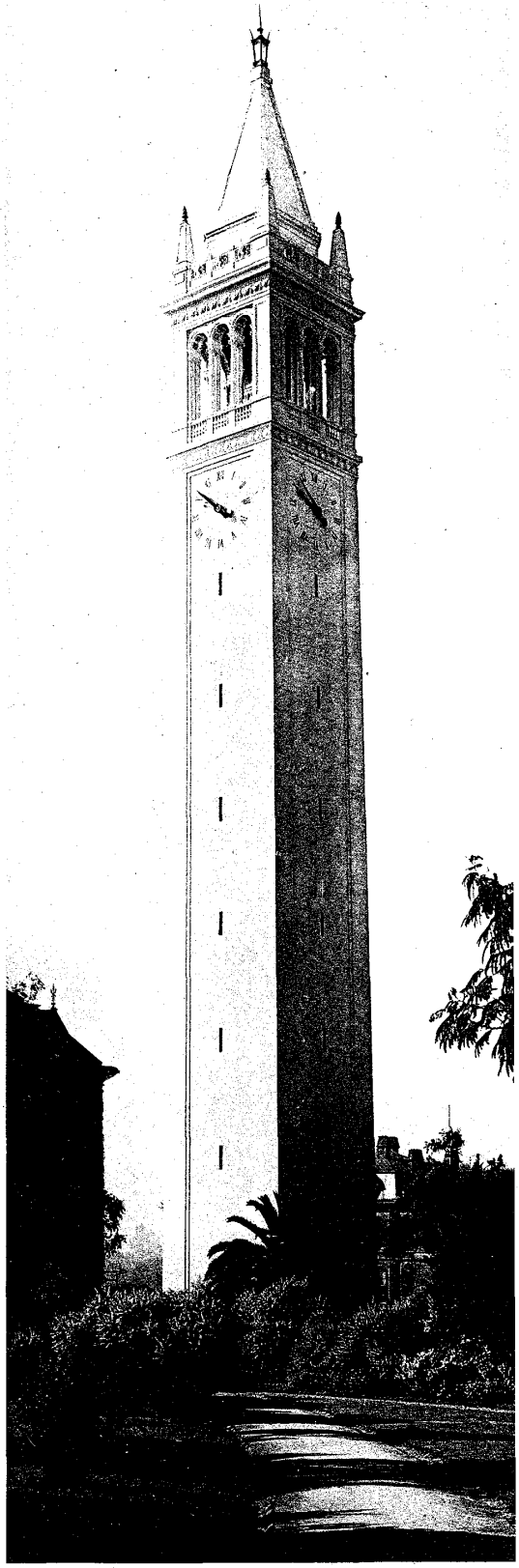

Fig. 3. The Tower Complete.

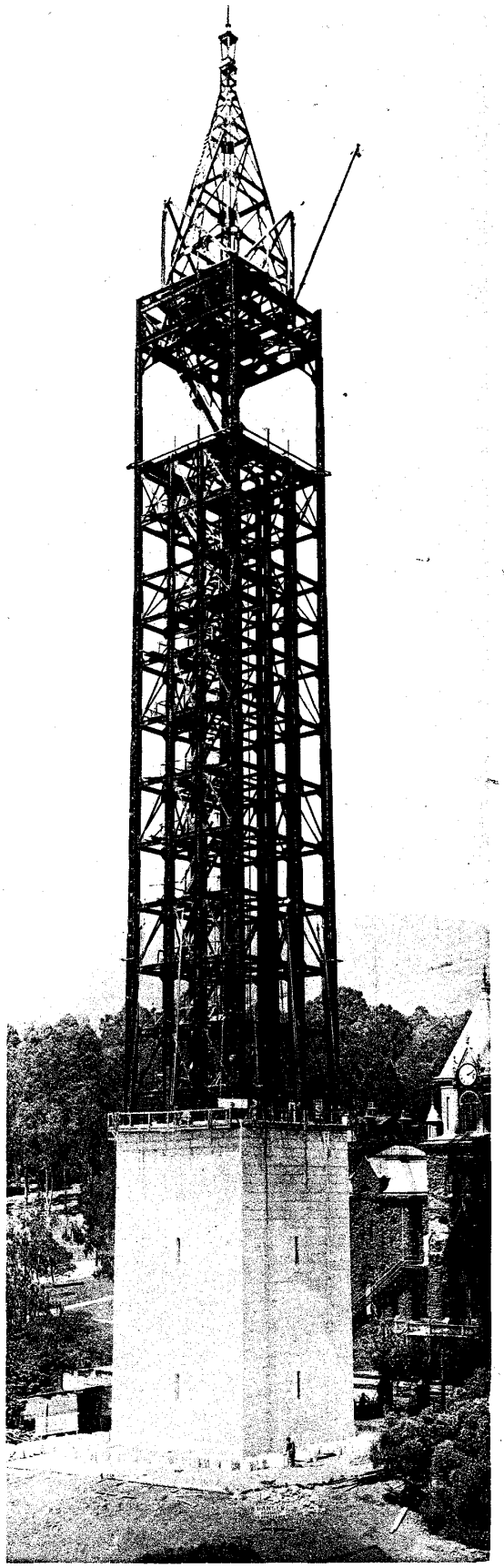

Fig. 2. The Tower in Construction.

As is to be expected, the period was about 1 sec. for the steel frame unloaded with masonry (March 5, 1914). The period gradually decreased as the masonry was added to about August 1914. Then the period increased again as the mass of masonry was attached to the top of the tower.

While maximum double amplitudes were measured on all of the dates, in all cases they were small, first because of the great stiffness of the tower, and second because no violent winds were blowing. For example, on August 3 the maximum double amplitude (east-west) due to swinging the temporary stairways (by man power) was 0.86 mm. On Feb. 8, 1915, the maximum double amplitude obtained by several men shaking the tower together was 0.5 mm. On Oct. 4, 1915, four men shaking the tower by impulses in tune with the tower's period produced a maximum double amplitude of 0.7 mm. On this same day the double amplitude due to wind gusts was about 0.1 mm.

On Dec. 28, 1917, during the playing of the chimes, tremors were recorded, the frequencies of which varied between the limits of 6.1, 103 vibrations per second. The double amplitude of these tremors varied from 0.0004 mm. to 0.0027 mm. for the vertical component and from 0.0004 to 0.0004 mm. for the east-west horizontal component.

The center of gravity of the complete tower is about 102 ft. above the foundation bed, elavation−18 ft.; see sheet 102; that is about 4 ft. above the third level.

Very truly yours,

C. Derleth, Jr.

Professor of Civil Engineering.