Vibration

1st December 1952

During the past month considerable wind has been encountered at Kole Kole. Steady velocities up to 40 mph for many hours have been observed. Upon top of building where anemometer is, the wind is quite steady without gusts, at the surface of hill around base of framework the wind is quite gusty. However the mean velocity is much lower. It seems improbable from qualitative observations that the gusts exceed the mean free velocity above the hill.

Under these conditions the framework has been observed and inspected repeatedly. There is no evidence of failure anywhere but vibration is quite bad because some of the members are too long and slender. Vibration was considered too great if member could be seen to vibrate from a distance of 30 feet. This meant the amplitude was greater than ± 0.1 inches if the eye has a resolution of 1' of arc. Amplitudes less than this were considered satisfactory. Experience showed that

(1) 12" pipe, .135" wall, 56.45' long was much too long when merely supported at ends. this is a full side of turntable.

(2) Same pipe supported at middle was satisfactory, this is a half side of turntable.

(c) Same pipe supported at one end and continuous at other was a bit too long at 40'. This is radius of turntable.
(d) The column #3,27 vibrated considerably. It is 28 ft long and 8×8 at center with 3/4" wall made of redwood. It is supported at both ends. To be acceptable the column should be at least 10×10 and of thinner wall construction
(e) The column #4,27 vibrated very badly. It is 41 ft long and 9 1/2×9 1/2 at center with 3/4" wall made of redwood. Also supported at both ends. To be acceptable it probably should be only half as long or else twice as wide.
(f) Truss #3,19 was satisfactory. It was 27 ft long and 2 ft square at center. Corners made of 2×2 with 1×1 battens.
(g) Truss #4,19 was just passable. It would vibrate when other members induced it to. It probably should be about 3 ft square at center, Corners made of 2×2 with 1×1 battens. This truss 40 ft long. #3,19 + #4,19 made of redwood and supported at ends.
(h) One of the 28 ft and one of the 41 ft hollow redwood columns had developed long cracks in the widest center board. This is not primarily due to vibration but rather the drying of the lumber which was not well cured. None of the smaller pieces show cracking. The 2×2 and 1×1 of trusses seem satisfactory. Obviously, if large hollow columns are to be built they should be made of plywood as wide boards are most susceptable to cracking.
(i) Truss on parapet of Wheaton mirror was 22 ft long and 1 ft × 1 1/2 ft at center, 3/4×1 1/2 corners and 3/8×1 1/4" battens. It was satisfactory.

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The following may be deduced as reasonable design ratios giving satisfactory performance at 40 mph winds.

(1) Steel pipe 12" O.D., .135" wall 25' long supported at ends
$l/d = 25$

(2) Same steel pipe 35' long continuous at one end
$l/d = 35$

(3) Same steel pipe 45' long continuous at both ends
$l/d = 45$

(4) Hollow wooden columns 28' long, 12" at center, supported at ends
$l/d = 28$

(5) Hollow wooden columns 41' long, 18" at center, supported at ends
$l/d = 27$

(6) Open truss 27' long 2' at center, supported at ends
$l/d = 13.5$

(7) Open truss 41' long 3' at center, supported at ends
$l/d = 13.7$

(8) Open truss 22' long 1' x 1½' at center, supported at ends
$l/d = 17.6$

Apparently hollow wooden columns of tapered construction should have l/d about 25 or 30. Steel columns of uniform crossection about same. Open trusses $l/d = 15$. All these good for 40 mph wind. Vibration will probably be unacceptable at velocities above these such as 60 mph and up.

It is obvious that a member can be designed to be amply safe and still be objectionable in a wind due to vibration. Vibration is bad because whole structure shakes and various antenna wires get out of line or else break. Also bolts loosen and some members may tend to crack or split.

A structure should be designed to be vibration proof at the highest wind velocity which will be encountered for 95% of total time. The remaining 5% will be high wind conditions and some vibration may be expected. If structure is vibration proof it will automatically be so strong it will have strength to resist largest wind loads encountered.

At Kole Kole the structure should be vibration proof at 40 mph.

From above it is apparent that bamboo would never do as it is much too slender - Good thing I never got mixed up far into the bamboo business -