Note on the Form of Japanese Castle Walls.

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With Plate VII.

The curved form of a large stone *ishigaki*, or dry masonry retaining wall, is a feature peculiar to the Japanese castle building not to be found in the architecture of China, Chosen and other countries. Its origin was probably in the idea of making the stone wall earthquake-proof. Thus, in an old manuscript relating to castle building written in the winter of 1707, the year of the great Hōei earthquake which devastated the whole south-western portion of Japan from Kyushu to Tōkaido, is recommended a method for rendering the *ishigaki* strong and earthquake-proof, which is called " ōgi-kobai " from the resemblance of the curve to the open form of an *ōgi* or folding Japanese fan, the batter at the different heights being as follows :—

Vertical Height	Batter.
1st 1 ken (= 6 feet)	1 foot
2nd „	2 feet
3rd „	3 „
4th „	4 „
⋮	⋮
nth „	n „

The curve thus formed is in reality not a circular arc like an

open *ōgi*, but constitutes a parabola, as shown in the annexed figure. Now a column whose wall is parabolic has the property of being seismically uniform in strength, namely, of possessing a stability

Diagram showing the Parabolic Form of an *Ishigaki*
(Stone Retaining Wall), according to Equation (1).

1, 2, 3·····represent the successive 6 feet height intervals.
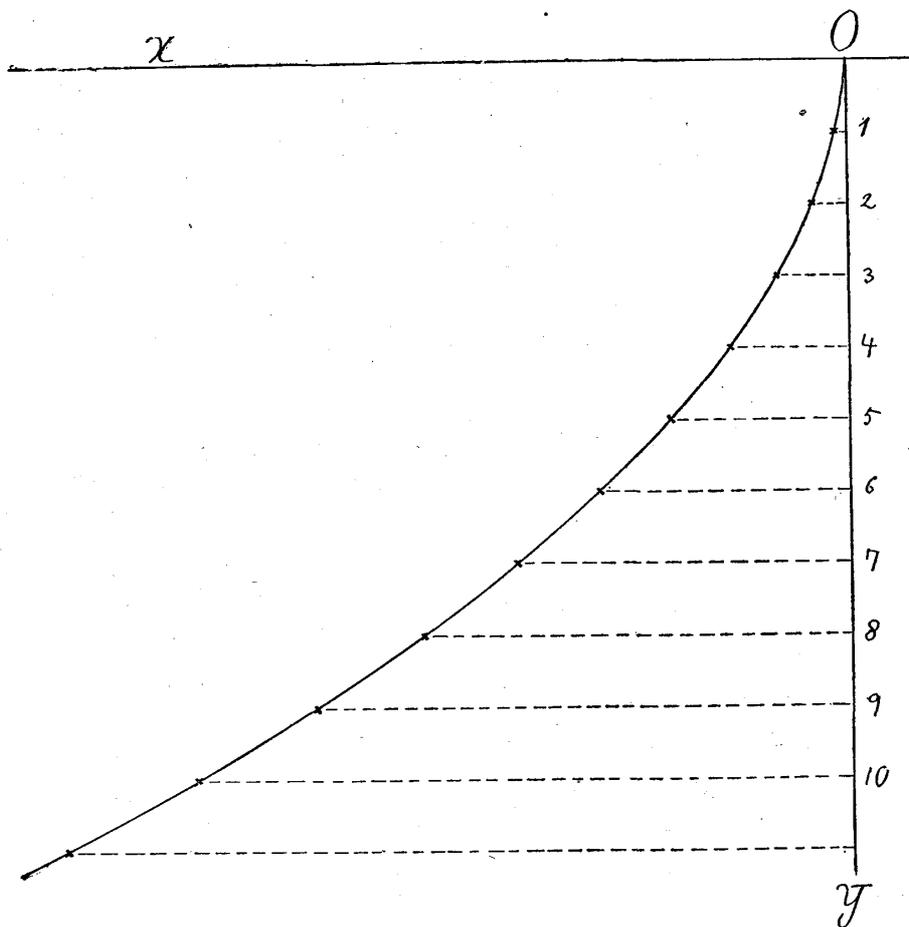
against the earthquake shock which remains constant for the different horizontal sections. A stone retaining wall with a parabolic form is thus free from the defect of being weakest at the base, thereby lessening the risk of the production of the *marginal vibration*, which may result in the formation of cracks along the upper edge and the sliding down of the side surface. As no

cementing material was used in the construction of the stone castle walls, the old Japanese civil engineers had evidently to give the *ishigaki* a form calculated to possess in itself a sufficient strength and stability,

Denoting by y the height of the *ishigaki* measured downwards and by x the horizontal distance, or the total batter corresponding to y, the form of the curve constructed according to the rule above indicated may be represented by the following equation :—

$$72\,x^{ft}=y^{ft}(6+y^{ft}) \quad\quad\quad\quad (1)$$

in which x and y are expressed in foot. More generally an *ishigaki* curve may be represented by the equation:

$$2\,k^2x=hy\,(k+y) \quad\quad\quad\quad (2)$$

in which h and k are constants such that h, $2h$, $3h$,....are the batters, or increments of x, corresponding to the successive height intervals, each equal to k; x and y being expressed in any length unit. If $h=1$ and $k=6$, then (2) reduces to (1).

Pl. VII shows the *ishigaki* of the Yedo (Tokyo) castle, whose vertical height is 60 feet. The batter of the wall is somewhat smaller than that prescribed by the equation (1); the literal fulfilment of the latter being in practice not easy.

Pl. VII.

Ishigaki, or Dry Masonry Retaining Wall,
of the Yedo (Tokyo) Castle.