

perimeter at 155 feet, 1,483,250 pounds, or a little less than 750 tons. The form of the caisson was such that the starlings braced themselves, and the only pressure which had to be carried by interior braces was that on the opposite long walls, the total strain on the braces being equal to the pressure on 55 feet, the length of one of these sides, or 483,300 pounds. This would have been carried by twenty-five braces, each eight inches square, with a strain scarcely exceeding 300 pounds on the square inch; but to avoid all possibility of accident, nearly double this strength of bracing was used. No other caisson was pumped out to nearly this depth; the round tub used at Pier No. 2, from its circular form, withstood the strains upon it without the aid of interior bracing.

### SAND PRESSURE AND FRICTION ON SIDES OF CAISSONS.

The pressure of the sand was considered the same as the thrust of a bank of earth, the particles of which have no mutual cohesion and computed by the formula:—

$$P = \frac{wh^2}{2} \tan^2 \frac{\alpha}{2} * \quad (a.)$$

in which  $P$  denotes the total pressure on each horizontal foot;  $w$ , the weight of a cubic foot of the earth or other material;  $h$ , the height of the bank in feet, and  $\alpha$ , the angle which the natural slope of the material makes with a vertical line, being the complement of the angle of repose and determined by the relation:—

$$\text{Cot. } \alpha = \text{coefficient of friction of material on itself.}$$

The application of this formula becomes somewhat complicated when the earth or sand is submerged. The action of the water is threefold: 1st, it gives buoyancy to the mass, thereby diminishing the weight; 2d, by acting as a lubricator on the surfaces in contact, it reduces the friction and increases the value of  $\alpha$ ; 3d, the pressure due to its weight is added to the thrust of the bank. The two first of these are simple and easily provided for by making the proper changes in the values of  $w$  and  $\alpha$ ; the latter is of a more complicated nature, dependent largely on the character of the material. If the bank

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\* This formula is taken from Claudel, Aide Memoire, etc. 7ieme Edition, p. 1252. It is also found in a slightly modified form in Rankine's Civil Engineering, 4th Edition p. 322 (11.)