A LARGE REINFORCED CONCRETE STANDPIPE.

The details of the design of the 300,000-gallon reinforced concrete standpipe which was recently constructed in the town of Penetanguishene, Ontario, are shown herewith in Fig. 1. This tank is described in a recent issue of Engineering and Contracting. As will be noted from the drawings, the tank is 50 ft. in diameter and 21 ft. deep. The side walls are of 1:1:2 concrete, 12 ins. thick at the base and 8 ins. thick at the top. The walls are made thicker than necessary for strength in order to prevent the formation of a thick ice crust. The tank is covered by a reinforced concrete dome of a height of 1/10 of the diameter. It is 4 ins. thick and is reinforced by ⅜-in. bars 12-in. on centres.

The tank was built in about six weeks during October and the early portion of November of 1912. It was filled the latter part of December, and did not show a leak or sweating at the first filling nor thereafter.

The reinforcement of the shell was figured by a method not ordinarily used in the United States. If we consider a a shell alone and assume that it is not connected with the bottom, it will increase in size as shown by curve A of Fig. 2. Inasmuch as the shell is connected with the bottom, and besides rests on the ground, it cannot elongate at the bottom, and if a proper connection is made between the side walls and bottom, the lowest portion of the shell cannot even change its directions at the bottom; or, in other words, it is fixed at the bottom. Hence, the real deformation of the shell will be a line somewhere as shown by curve B in Fig. 2. It clearly depends on the thickness and height of the shell where the deviation from the ideal line of deformation stops.

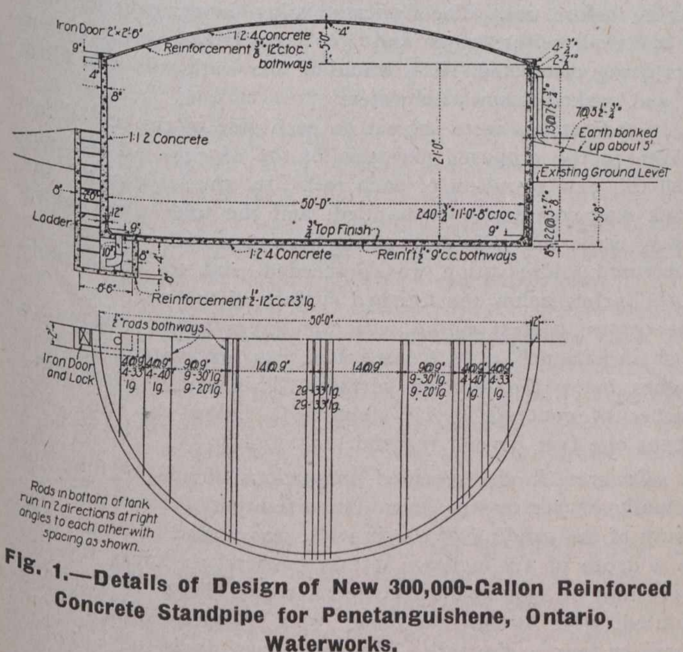

Fig. 1.—Details of Design of New 300,000-Gallon Reinforced Concrete Standpipe for Penetanguishene, Ontario, Waterworks.

This problem was first investigated by Professor Grashof, and published in his book on "Theory of Elasticity" in 1878. The differential equations governing the conditions are, however, of a high order, and even in the simplest case where the walls are of uniform thickness, the equations for the elastic curve are expressed in periodical functions and it takes several days' labor to solve a single problem. The equation cannot be solved for walls of various thicknesses, as the integrals of the differential equations are unknown up to this day. However, the elastic equations clearly show that the shape of the elastic curve is a function of $\frac{h^2}{rt}$, wherein h is the height of the tank, r the radius of the tank, and t the thickness of the shell at the base, all being expressed, of course, in the same unit.

In the present case $\frac{h^2}{rt}$ equals 16 and the elastic curve for this case only starts to deviate abruptly from the ideal deformation at the point of 4/10 h above the base, as shown in Fig. 2, curve B. This means that the water pressure corresponding to the shaded portions is not taken up by the ring action but by the cantilever action of the connection of base and shell. After a little consideration, it will be clear that there must be acting on the ideal beam, for this case a force above the 4/10 h point, which tends to bend it back into the

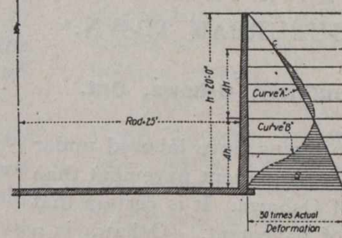

Fig. 2. Deformation Diagram.

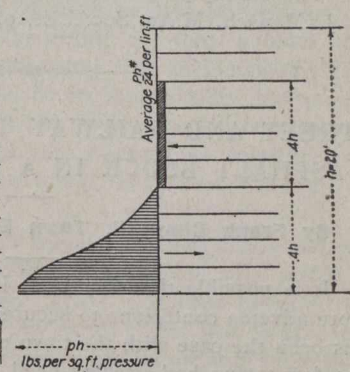

Fig. 3. Loading on Ideal Beam.

line formed by the ideal deformation of the ring sections, as the cantilever would tend to bend the top portion further out and the deformation on top must be zero from the nature of the case. This force is nearly a uniform load also for a height of 4/10 h in this case and equals approximately $\frac{ph}{24}$ in this case. Now, if a beam is assumed which is acted upon by the forces as shown in Fig. 3, we can find the elastic curve from the equation $\frac{d^2y}{dx^2} = -\frac{M}{EI}$, wherein M is the moment at any section x feet from the top, E the modulus of elasticity and I the moment of inertia at the section x. If the assumption of the form and position of curve B of Fig. 2 is correct, the elastic curve obtained by the foregoing general equation must be identical with curve B. This agreement can be reached after a few trials.

It is also clear that there exists beside the negative moment at the bottom of the shell on the inside, a positive moment higher up on the outside of the shell. The maximum value of this positive moment occurs where the shear passes through the zero value. The shear at the bottom of the shell can also be obtained from Fig. 3. This shearing stress governs the reinforcing of the bottom of the tank. The moment at the bottom of the shell, in this case is about

$$\frac{ph^3}{66} = \frac{62.5 \times 20^3}{66} = 7{,}600 \text{ ft.-lbs. per lin. ft.}$$

The reinforcing here adopted is more than ample. The positive moment on the outside of the shell is $\frac{ph^3}{217}$, which can be taken up by the concrete without reinforcing. If the reinforcement at the bottom of the shell be omitted, the tank will first crack on the inside of the shell at the junction with the bottom, and then a larger bending moment will appear on the outside of the tank $= \frac{ph^3}{163}$ in this case. This