Analysis about equivalent conversion of two dimensions for large cylinder structure

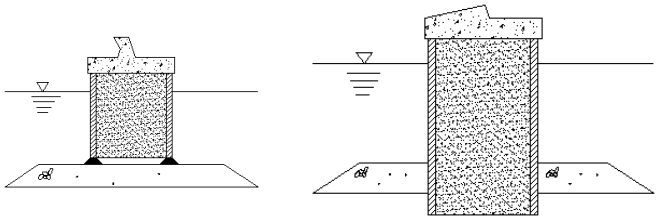
Guojun Feng[1, 2], Bo Song[1, 2]

1 School of Civil and Resource Engineering, University of Science and Technology Beijing, Beijing 100083, China.
2 Beijing International Cooperation Base for Science and Technology-Aseismic Research of the Rail Transit Engineering in the Strong Motion Area, Beijing 100083, China.
Corresponding author: fgjshx@126.com

Abstract. There was practical engineering of large cylinder structure used in China. Elastic mechanics problems of large cylinder structure quay wall were space problems. Sometimes we needed to transform space problem of large cylinder structure into plane problem of it. Circular section of signal large cylinder structure was converted into rectangular one by using the same bending stiffness and section area for breakwater.

1. Introduction

Large cylinder structure is the abbreviation of large diameter thin-walled cylinder structure, and it usually refers to shell structure of over six meters in the diameter, bottomless, no internal partition and thin-walled cylinder. Large cylinder structures mostly were made of reinforced concrete or steel. According to the characteristics of port engineering, large cylinder structure could be roughly divided into two types of bedding and embedded, and the embedded could be divided into shallow and deep buried. The large cylinder structure was shown in Fig. 1.



(a) bedding (b) embedded

FIGURE 1. Types of large cylinder structure.

Hydraulic structures began to apply large cylinder structure in the 1940s. the structure of new type was at the beginning of 50s in France for the construction of the port at first, and quay wall of large cylinder structure also was used in the Soviet Union, Spain, Britain, Denmark, Canada, Japan and other countries , large cylinder structures were introduced to China in the 1980s.

Many test and engineering practice works of large cylinder structure were done in China. Through the relevant scientific research institutes, universities, design consulting and construction enterprises according to the working mechanism, model and physical model test, design method and construction

technology of large cylinder structure were carried out. A lot of research topics had made many remarkable achievements, and practical engineering was used in the project. Advances and Characteristics of large cylinder structure were studied[1], and new design approach of it were analyzed[2]. Some parameters of large cylinder structure in China were shown in the Table 1.

TABLE 1. Some parameters of large cylinder structure.

Type	Parameters			Material
	diameter	height	thickness	
bedding	7	4.75	0.6	reinforced concrete
embedded	12	17.1	0.28	reinforced concrete
bedding	16	14.4	0.3	reinforced concrete
bedding	8		0.25	reinforced concrete
bedding	8.36	7	0.18	reinforced concrete
bedding	14	13/11.2	0.3	reinforced concrete
embedded	15	25～26	0.28	reinforced concrete
bedding	15	13	0.35	reinforced concrete
embedded	10	12	0.2	reinforced concrete
bedding	10	12	0.2	reinforced concrete
bedding	14	13	0.3	reinforced concrete
embedded	13.5	13～34	0.014 0.012	steel
embedded	22	40～50	0.016	steel

2. Two dimensions theory of equivalent conversion

Elastic mechanics problems of large cylinder structure are space problems. when we will transform space problem of large cylinder structure into plane problem of it, the analysis and calculation of the workload will be reduced, and the results of it also can meet the practical engineering requirements on the accuracy[3] [4]. Diagram of plane stress is shown in Fig. 2.

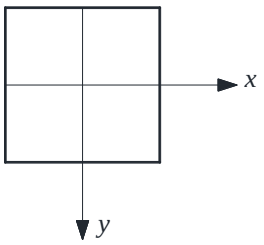


FIGURE 2. Diagram of two dimensions.

In the process of elastic mechanics analysis, three equations are established by considering the three aspects of statics, geometry and physics. The relation between the stress component and the physical component in the plane problem can be obtained by the equilibrium differential equation in the plane problem, and the relation of it was shown in formula 1.

$$\left.\begin{aligned}\frac{\partial\sigma_x}{\partial x}+\frac{\partial\tau_{yx}}{\partial y}+f_x=0\\ \frac{\partial\sigma_y}{\partial y}+\frac{\partial\tau_{xy}}{\partial x}+f_y=0\end{aligned}\right\} \tag{1}$$

When the physics of the plane problem were considered, the relationship between the deformation component and the stress component is derived, and the relationship is the physical equation in the plane problem. Because of $\sigma_z=0$, physical equations of plane stress problems are shown in formula 2. because of $\varepsilon_z=0$, physical equations of plane stain problems are shown in formula 3.

$$\left.\begin{aligned}\varepsilon_x&=\frac{1}{E}\left(\sigma_x-\mu\sigma_y\right)\\ \varepsilon_y&=\frac{1}{E}\left(\sigma_y-\mu\sigma_x\right)\\ \gamma_{xy}&=\frac{2\left(1+\mu\right)}{E}\tau_{xy}\end{aligned}\right\} \tag{2}$$

$$\left.\begin{aligned}\varepsilon_x&=\frac{1-\mu^2}{E}\left[\sigma_x-\frac{\mu}{1-\mu}\sigma_y\right]\\ \varepsilon_y&=\frac{1-\mu^2}{E}\left[\sigma_y-\frac{\mu}{1-\mu}\sigma_x\right]\\ \gamma_{xy}&=\frac{2\left(1+\mu\right)}{E}\tau_{xy}\end{aligned}\right\} \tag{3}$$

Where x is the direction of the horizontal axis, y is the direction of the Vertical axis, σ is the normal stress, τ is the shear stress, f is the body force, ε is the linear strain, E is the Elastic modulus, μ is the poisson ratio and γ is the Shear strain.

3. Equivalent conversion for section

According to Technical Standards and Commentaries for Port and Harbour Facilities in Japan[5] and interpretation of the harbor facilities, when the number of large cylinder breakwater is connected with the arc plate, the equivalent width of the wall is calculated according to equivalent conversion in Fig. 3 by formula 4.

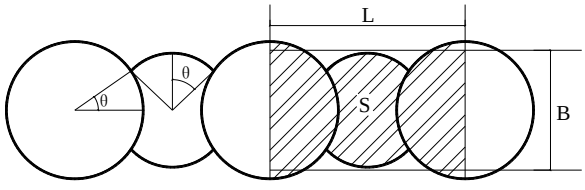


FIGURE 3. equivalent conversion for section.

$$B=S/L \tag{4}$$

Where B is the width of conversion wall, L is the length of conversion wall and S is the area of section.

The embedded steel cylinder structure is used on the breakwater. The breakwater consists of a series of steel cylinders, and the steel cylinders are connected through concrete membrane bags. A typical section of breakwater is shown in Fig. 4.

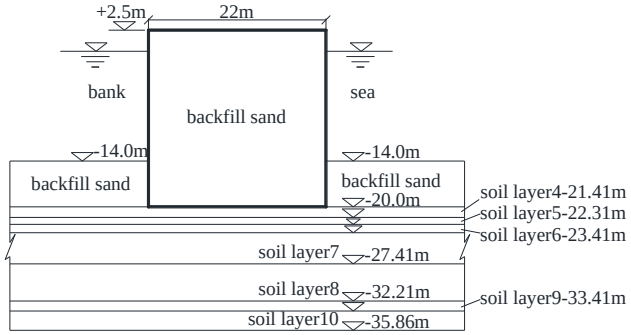


FIGURE 4. Diagram of a typical section for breakwater

Circular section is converted into rectangular one (Fig. 5) by using the same bending stiffness and section area of breakwater for signal large cylinder structure. In addition, the width (B) and length (L) of rectangular section are converted using formula (5) and (6). The plane strain model of steel cylinder breakwater can be established according to Fig. 5.

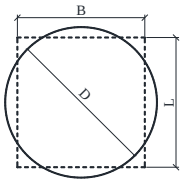


FIGURE 5. equivalent conversion for section.

$$A = \frac{\pi D^2}{4} = B \times L \tag{5}$$

$$I = \frac{\pi D^4}{64} = \frac{B^3 \times L}{12} \tag{6}$$

Where A is the section area, I is the inertial moment of section, and D is the diameter of steel cylinder.

4. Equivalent conversion for section

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Acknowledgments

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