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# CIRCULAR CELL COFFER DAM SHEET PILES INSTALLATION AND DESIGN: THE IRANIAN METHOD

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## ABSTRACT

Use of steel sheet pile makes it perfect for shore, water engineering, dams, river dams, inaccessible land, water sea, pump stations side dam’s, and installation of these piles needs more technically specialized engineering because of complex and accurate locks.

Steel sheet piles were installed first by an Iranian contractor in the south of Iran (The Persian gulf) in 1998. The original layout was designed by Soeico (Sweden Company) consulting engineering in 1975, after some years with some modification, it was approved again for installation. There is a difference between foreign and Iranian method in installation workshop. The longest sheet pile (R500J12.5) is 18 m, and Iranian method (A.TURK 2001 method) will produce comfort action of templates and cells. In this article we will describe new formulation and design method I.D.I.C (Iranian Method of Design and Installation for Circular Cell 1998).

## KEYWORDS

Circular Cell Cofferdam, Sawlike, Sawing Installation ,Qult Criterion, Shear Control

## 1. INTRODUCTION

Cellular cofferdam in 202 workshop. Notification on as-built map can show number (64) of steel sheet pile driven. Cells could stable individual against adjacent cells and it is possible cells to contact each other with Arcs. It is mentioned that a small deviation in driving operation and installation operation may it out of standard rang. Therefore the body of the cell turns unsymmetrical. For halting the turning, we should use tem-plats; those pictures we will present in the body of the article. Tem-plats could guarantee safety and vertical driving. The most importance factor is junctions that make conforming cells and Arcs. 90˚ or 120˚ junctions are used in Circular cells, more detail attached in the text. Sheet piles have mechanical locks producing friction and tension stresses. More care needs for loading and stacking of steel sheet piles. If workers in loading do not take care, warping in sheets may be created, these sheets could not be used in driving. One problem that occurred in the project was the level of plate form. This problem comes from the original map suggesting that excavation and installation must be under natural level. Excavating operation should be started on the earth with 1:4 slope and it needs a crane with long boom about 40m.

Specifications of tem-plat.

1- Rigidity

2- Light weight

3- Transmissibility

## 2. INSTALLATION OPERATION

One of the civil engineering activities is circular cell building, which could keep the standard movement of the whole structure. If the structure has not suitable displacement, we will see vertical deviation and inclined cutting steel sheets on land. The maximum tension stresses exerted upon the locks is about %60 of 300 t/cm and it will not get this value, because of the technical cell shape stabilizes in the depth of mud and water. Depth of cell driving could be designed by information of dead and live load, water pressure, earthquake force, lateral forces, bearing and resistance property of compaction material inside the cell and circular cell radius. The new method would discuses designing of main parameter, driving depth, steel sheet thickness and displacement criterion. As it is mentioned in 202 workshop, installation is the same as foreign countries. The compulsory condition forced us to use a simple method in 202. For example, loaders, sawlike sheet and splicing are used. Both contractor and consulting engineer had not any expertise in the field of circular cells. Besides, installation was a new civil work in Iran and it invites designers, engineers, to challenge new project in foreign countries.

Poor expertise changed cells cofferdam in 201 workshop into straight sheet piles. After 1 month, anchorage and tie-rods collapsed by extra tension stresses exerted upon them. Tem-plat installation and design are the most important driving steps.

Circular cell dam execution in 202 workshop:
1- Draws plan of dam (circumference line) on the earth by surveying.
2-Use of thin concrete layer helps to produce horizontal surface, before sheets are installed.
3-Tem-plat had used 4 piece (90˚ sector); each piece was a sector of cylindrical structure.

They could assemble together in three forms. In form No.1 one piece stood on top of the other piece. Form No.2 consisted of two forms No.1. Form No. 3 was each piece gets a place to produce a disk shape, Fig .3.

It is possible to install sheets in 3 forms of sector individual tem-plats. An engineer should survey measuring of errors and movement in complete cell. Assembled cell deviations must be drawn by a computer to measure the total movement of a sheet tip in the require depth. If the total movement is bigger than the standard value, supervisor engineer should regulate the sheets by replacement and tension.

First assembled cell has 64 sheets in complete cell. After driving, sheet numbers convert to 65 sheets. The 65 sheets are fixed into 64 sheets by lateral tension exerted upon the skin of the cell, in the end, small movement is rejected in the body of the cell. All sheets could get three turning deviations and three small displacements in a cell.

$\theta x$ $\theta y$ $\theta z$ turning
$\Delta x$ $\Delta y$ $\Delta z$ displacement

Movement more than standard value could increase rise the exerted tension in locks and this tension could drop the sheets in the depth. Finally, it is not possible to drive Arcs and cells, which are connected with main cells. Installation of junction should be very accurate as for place and deviation. Error in junction installation makes it difficult to drive the Arc between cells. Arcs driving will start when two adjacent cells are completed. Two complete cells with the Arcs between them produce a main collection. Repeating the main collection follows project to end. In 202 workshop, steel sheets cut to stood sawlike with symmetrical length to reduce the slenderness of the sheets and the costs due to making tem-plat.

The following lines describe the advantages of this method:

A-use of limited instruments and machines in workshop.
B-effective utilization of sector disk tem-plat instead of great rigid tem-plat which needs a separate workshop.
C-cells separator - two cells with ½ weight.
D-safety of sheets plumb-line.
E-psychological effects due to finishing the work.

Cutting (sawlike) and non cutting method comparison:

A-weakness of shear resistance in cut line (sawing zone).
B-adding splice plates cost to improve shear resistance.
C-time and economical consideration for extra welding in sawing place.
D-the need for dry plate form –sawing method does not suggest in water zone.
E-vertical direction controlling is very difficult in sawing method.

Cells have done in form of original map and it was made with some small differences. Installation of cells have been done without consideration for interaction of soil and concrete wall of pump station. Where the first Arc and concrete wall start, number of sheet of connection Arc changed from 3 sheets into 18 sheets. These variation increased lateral earth pressure on sheets, concrete wall and long steel connection plat. After driving the first Arc, long plate connection was detached by extra tension. This tension is based on two views:

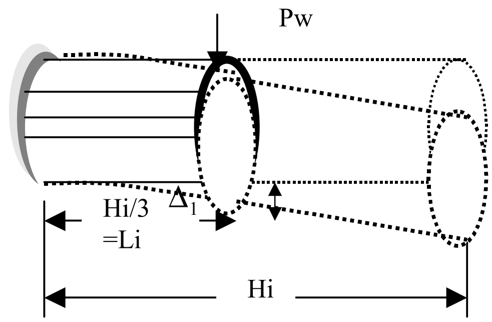
The first view suggests that, the root of long plate may not satisfy the tensions.
The second view suggests that, two main problems occurred to the structure.
I-original deviation had remained in sheets and extra movement was converted to tension.
II-changing the numbers of sheets could exert as much as six times earth pressure value, upon the sheets and long steel connection (18sheets/3sheets=6 times).

Four methods are suggested for improving the miss-fit of connection Arc:

A-match on original map, before revision.
B-a steel sheet put in the outside margin of pump station concrete wall to reduce tensions.
C-keep vertical plumb-line in driving operation.
D-making a cell with curved circumference (first cell).

Extra standard movement is shown in fig .4. Which remains in the body of circular cells.

## 3. STIFFNESS FORMULA OF CIRCULAR CELL AND FILL MATERIAL




$$\Delta_1 = \frac{Pw_1 L_1^3}{3(EI)_1}$$

$$\Delta_2 = \frac{Pw_2 L_2^3}{3(EI)_2}$$

**Figure.1**

$Pw_1$= share of steel cell , tons
$Pw_2$= share of fill material, tons
$\Delta_1$= displacement of steel cell at exerted force , cm
$\Delta_2$= displacement of fill material at exerted force , cm
$L_1$, $L_2$ = length of resistance part

Suppose $\Delta_1=\Delta_2$ :

$$Equation.1 \qquad \frac{Pw_1 L_1^{\ 3}}{3(EI)_1} = \frac{Pw_2 L_2^{\ 3}}{3(EI)_2}$$

$$Equation\ 2 \qquad P_{w1} + P_{w2} = P_w$$

$$Eq.1\ \&\ Eq.2 \Rightarrow Pw_1 = \frac{EI_1}{EI_2} Pw_2 \qquad \Rightarrow Pw_2 = \frac{EI_2}{EI_1 + EI_2} Pw \qquad and \qquad Pw_1 = \frac{EI_1}{EI_1 + EI_2} Pw$$

$$E_{steel} = 2.1E6 \ \frac{kg}{cm^2} \qquad and \qquad E_{fill\ material} \cong 1500 \frac{kg}{cm^2}$$

If we take this values, t=12.5mm(R500J12.5) and R=10m radius of cell, force will separate to this relations:

$$\Rightarrow (cell \quad share) Pw_1 = \frac{7}{8} Pw \qquad and \qquad (fill \quad material) Pw_2 = \frac{1}{8} Pw$$

The low root length of steel sheet does not satisfy the condition of rigid support, therefore the ratio 7/8 never applies to steel cell. We could use a criterion for maximum and minimum of action of steel in circular dam. Stable and curved shape of the cell makes the cell to be the main structure skeleton and the cell will devote at all time, more of the moment and force.

## 4. DISPLACEMENT CRITERION

$$Allowable \quad moment \qquad : M_{all} = \frac{2EI}{L}\left(\frac{3}{2}\Delta / l - 3\Delta / l\right) = -3\frac{EI}{l^2}\Delta_{all}$$

$$\Rightarrow \Delta_{all} = M_{all} \frac{l^2}{3EI}$$

### 4.1 Over Turning Criterion

Over turning control with displacement criterion and bearing stress of cell toe (Fig .2.):

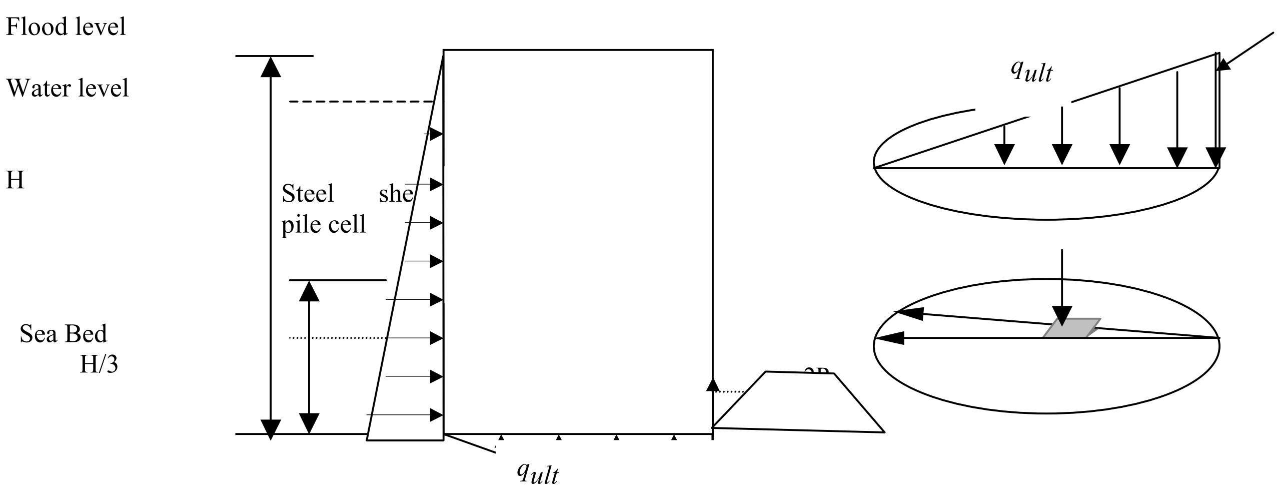



**Figure 2: Stress Diagram**

$$bearing \quad stress \quad on \quad toe:$$

$$q = (q_{ult} - \frac{q_{ult}}{2R} r)$$

$$dM = q.dA.r = q.rd\theta.dr.r$$

$$\int dM = \int_{\theta=0}^{\theta=\pi} \int_{r=0}^{2R} (q_{ult}.r^2 - \frac{q_{ult}}{2R} r^3).dr.d\theta \Rightarrow \int dM = \pi.q_{ult}.R^3 (\frac{8}{3} - 2) = \frac{2}{3}\pi.q_{ult}.R^3$$

$$\Rightarrow Equation.3 \qquad M_{Allow} = \frac{2}{3}\pi.q_{ult}.R^3$$

$$Equation.4 \qquad S.F = \frac{M_{all}}{M_{\circ}}$$

**4.2 Inter Lock Tension and Shear**

If soil in the cell acts elastically and there tension is under allowable stress ($q_{ult}$), shear force could be obtained by below formula ( BOWLES) and we must consider the positive and negative triangular stress which will change into linear positive triangular and this control is subcategory of displacement criteria. Lateral pressure coefficient $K_a'$ can be produce by Bowles Equation and combined with another formula, another criterion for shear could controls the dimension and force upon the cell. Shear force in soil on width of cell diameter:

$$K_a' = \frac{\cos^2\phi}{2 - \cos^2\phi} \qquad ; \qquad F_S = \frac{1}{2}\gamma.H_c{}^2.K_a'.\tan\phi$$

$$dV = dA.\tau \qquad , dA = dx.dy$$

$$\tau = \frac{\tau_{\max}}{R} y \to dV = \frac{\tau_{\max}}{R} y.dx.dy$$

$$V = \int_{x_1=0}^{x_2=R} \int_{y_1=0}^{y=\sqrt{R^2-X^2}} ydy.dx = \tau_{\max}\frac{R^2}{3}$$

$$\tau_{\max} = \frac{M_{\circ}}{S} = \frac{M_{\circ}}{\pi\frac{R^3}{4}}; \qquad S = \frac{I}{C} = \pi R^3/4$$

$$\Rightarrow V = \frac{8}{3\pi(2R)} M_{\circ} = 0.85\frac{M_{\circ}}{D}; D = 2R: \qquad V = F_S$$

$$Equation.5 \qquad S.F = F_S \frac{D}{0.85M_{\circ}}$$

## 5. THE SHEETS PENTRATION DEPTH

When soil is cohesiveness with C parameter , Equation.6. currently used for determination of penetration depth. Passive and active force should be equal when the cell is being turn. Therefore the horizontal equilibrium must be interned between passive and active force.

$$\sigma_p - \sigma_a = 2c - (\bar{q} - 2c) = 4c - \bar{q}$$

$$\Rightarrow \quad \frac{4c}{S.F} \leq \bar{q}$$

$$Equation\ .\ 6 \qquad \bar{q} = \gamma_{effetive} \times H_{cell} \quad in \quad turning\ \ zone$$

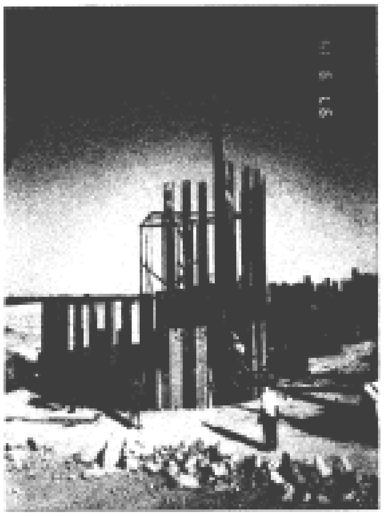


**Figure 3: Tem-plat Installation**

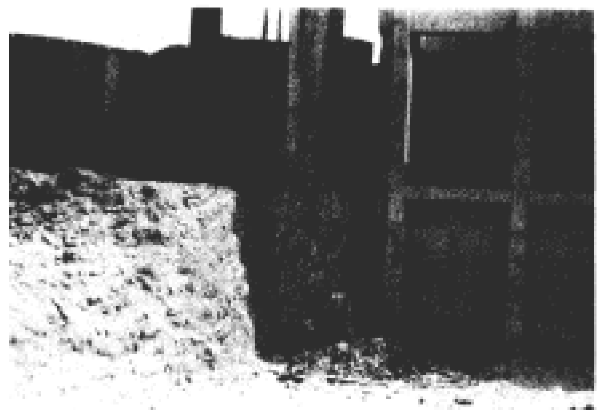


**Figure 4:Extra Standard Movement in Cell**

**Figure 5: Installation of Circular Cell Cofferdam**

## 6. CONCLUSION

Based on Equation.3., the critical case will happen in this criterion. We could take the value of maximum moment by Equation.3; it is mentioned that the maximum bearing stress on toe cell could not increase more than $q_{ult}$ of soil. The maximum bearing stress in toe is qult and the minimun of bearing stress is zero when the cell was turned about axial turning of the cell. We could draw a line from $q_{ult}$ ( max bearing stress) on soil to zero stress of the cell body, this part likes to separate the cell from the soil.

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