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BIOLOGIC STEP STIFFNESS SIMULATION OF TANGENCY JOINTS ON SHEET PILE LOAD TRANSFER INTO WATERWAY BED

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The irrigation project of Abadan will supply fresh water through the three flat dams in the NW of the Persian Gulf. Circular cofferdam is located in the Bahmanshir River upstream in 2007. Cell dam and ship lock walls are constructed using sheet piling and Pipe-Pin-Micro (PPM) piles on the steel walls. Next step is required to design ship lock concrete bed. It should have compatible behavior with the sheet walls, micro piles and gelatin concrete. The main purpose is transfer the extra bending moment of waterway impact from sheet walls into the concrete bed. It is mentioned that steel walls and concrete bed will operate individually without any connections with each other. Also, tangency joints will resolve the problems such as structural bed connection and steel wall thermal enlargement. In addition the bed and walls must perform independently. Artificial intelligence design (AID) will introduce a new joint with variable stiffness to transfer the impact loads into the bed (Turk Joint, TJ). According to the exerted load function, stiffness may be varied. In the concrete bed, each part of members will be simulated to determine the divided forces into the steel bars, spiral stirrups and steel pipes by step stiffness method (SSM). Concrete Bed is free from any connection with sheet walls. Tangency joint could be installed to absorb the variable bending moments by double cane action.

Keywords: AID, Connection, Persian Gulf, Bahmanshir River, Thermal effects, Turk Joint.

1 INTRODUCTION

Circular cell cofferdam was built in 2007 on the Bahmanshir River that is near the three branches of the Karun River (Turk 2002, Turk 2003). It was built in order to control spring flood and divert the fresh water into the downstream of the Bahmanshir River. Distance from the Karun Three Branches (KTB) to Persian Gulf is 85 km. Two flat dams must be constructed on this part of Bahmanshir River. The first dam is fixed at KTB (+0.400 km) and the second may layout at +40 km before the Persian Gulf near the Choebdeh port. The first dam is constructed to transfer the waterway loads by RJ, sheet piles, and gelatin concrete (GC) (Turk 2004a). Ship lock sketch contains using the vertical sheet piles and GC inside the closed sheet piles. Waterway bed should be designed to carry out the vertical and lateral load of impact forces without any constrains on the sheet wall surfaces. Concrete bed will stable with the micro piles net injections. Also, sheet walls will be driven in depth (Puller 2003) by hydraulic hammer and PPM injections (Turk 2004b). There are different lengths of constrains for sheet piles L = 9 m at the level -3.0 m until

-12.0 m and for concrete bed foundation L = 6 meters at level -4.0 m until -10 m. The shape of Tangency joint is like a wooden cane that must transfer the exerted bending moment into the bed. The two opposite canes will be absorbed the impact load in the foundation at level -4.0 m (Turk 2005) when the soil and grout injection acts as a support in the river bed. Otherwise, force may apply in trapezoid stress form when the basement of foundation level is more than -3.0 m. This stiffener mechanism will share 40% - 50% of total bending moment of impact loads per span that is depended on the position level of canes and bed. Also, it acts as a damping shaft for sheet piles vibrations. Due to wide range of thermal elongation in SW area, touch connection will be an engineering and easy method to remove thermal effects on the concrete and steel structures under water. These joints shall be free from any displacement constrains and only has the frictional arms with the cane double action.

2 TANGENCY JOINT OPERATION (TURK JOINT)

Concrete bed is constructed by the three parts of materials. The first part is included 12 spans concrete box in length 25 m, width 4 m, and height 1 m. The second part will be executed by the steel pipes inside the concrete boxes. Finally the third part may complete through the steel spiral stirrups around the steel pipes. Each box will be filled by concrete mix and grouting in steel pipes. All boxes should be fixed by micro piles at -4 m to -10 m depth. Figure 1 demonstrates the place and layout of TJ. Figures 2 to 3 will represent the PPM and sheet piles walls.

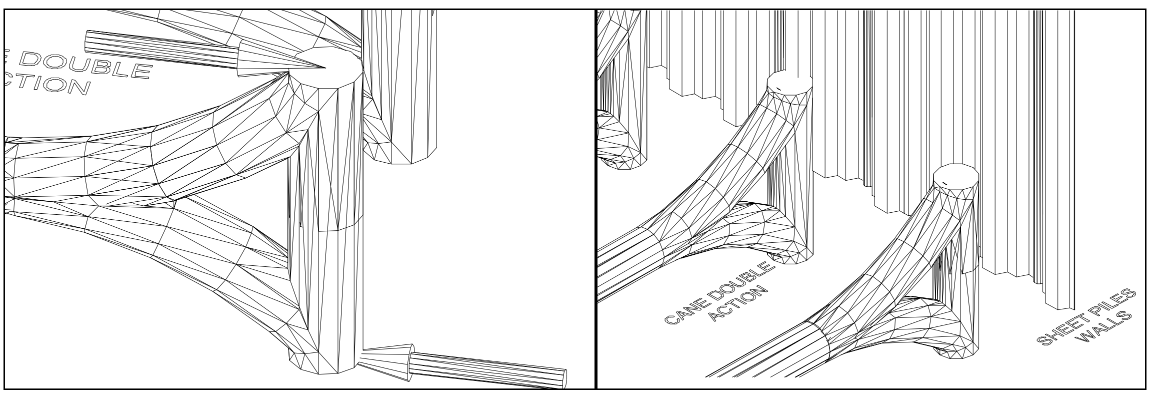

Figure 1. Cane double action (single forces) converted (bending moment) on the sheet piles.

Figure 2. PPM and Installation of sheet piles walls near the cell dam workshop (Turk 2004).

2.1 Formulation of Tangency Joint

The axe of waterway is X-X direction and EI stiffness can be computed through Eq. (1) to Eq. (11) that refer in Table 1. It is mentioned that modules of elasticity will consider the gelatin concrete materials (one third of concrete). Eq. (12) to Eq. (18) will describe the TJ forces to apply on the cane double action by impact load of barges in waterway structure.

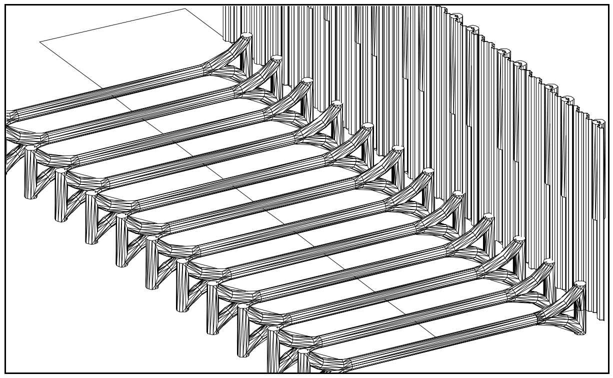

Figure 3. Composite PPM sheet piles and TJ.

In Table 1, the Relative K values should consider to compare the sheet pile (Eq. (6)) vs. the cane and span materials (Eq. (8), Eq. (9), and Eq. (18)). This comparison shows Relative K achieve to ten times in Table 1 in the row (V). It interprets to transfer the waterway forces into the bed by axial stiffness of span materials. Vibration forces of impact loads can only damps through the compression of span elements. It means that bending force will convert to axial loads. Eq. (15) to Eq. (30) may explain the deferential equation of wavy exerted loads.

Table 1. Bending stiffness of sheet piles and TJ (Turk 2005).

Row	Materials	EI (kg.cm^2)	K (kg/cm)	Equations	Relative K	L(cm)
I	Sheet piles	128E+12	2.4E+7	Eq. (6)	I/I=1	800
II	Cane 1	2.0E+6	5.0E+5	Eq. (9)	I/II=40	150
III	Cane 2	2.0E+6	5.0E+5	Eq. (9)	I/III=40	150
IV	Cane 1,2	4.0E+6	10.0E+5	Eq. (8)	I/IV=20	300
V	span	5.0E+9	2.0E+6	Eq. (14)	I/V=10	2500

$$EI_{WATERWAY} = EI_{SheetPile} + EI_{GC} \tag{1}$$

$$EI_{WATERWAY} = \underbrace{\underbrace{\underbrace{t \times b}_{Area} \times h^2}_{Ah^2} \times 2 \times \underbrace{E_S}_{SteelElasticity}}_{I_{X-X}} + \underbrace{\underbrace{E_{GC}}_{GelatinConcrete\ E} \cdot \left(\frac{b \times h^3}{12} \right)}_{I_{X-X}} \tag{2}$$

$$EI_{WATERWAY} = \underbrace{1 \times 400 \times 200^2 \times 2 \times 2 \times 10^6}_{SheetPile} + \frac{1}{3} 10^5 . \left(\frac{400 \times 400^3}{12} \right) = 128 \times 10^{12} \left(kg.cm^2 \right) \tag{3}$$

$$S.F = 2 \qquad \Rightarrow EI_{WATERWAY} = 64 \times 10^{12} \left(kg.cm^2 \right) \tag{4}$$

$$K_{WATERWAY} = \frac{3EI_{WATERWAY}}{L^3} \tag{5}$$

$$K_{WATERWAY} = \frac{3(64\times10^{12})}{800^3} = 2.4\times10^7 \quad \left(\tfrac{kg}{cm}\right) \tag{6}$$

$$K_{Cane} = \frac{3EI_{Cane}}{L^3} = \frac{3E\frac{\pi}{4}r^4}{L^3} \tag{7}$$

$$2K_{Cane} = 2\frac{3(2\times10^6)\frac{\pi}{4}20^4}{150^3} = 2\times50\times10^4 = 10^6 \quad \left(\tfrac{kg}{cm}\right) \tag{8}$$

$$K_{Cane} = \frac{3(2\times10^6)\frac{\pi}{4}20^4}{150^3} = 50\times10^4 = 5\times10^5 \quad \left(\tfrac{kg}{cm}\right) \tag{9}$$

$$SSM = \frac{K_{WATERWAY}}{2K_{Cane}} = \frac{2.4\times10^7}{10^6} \rangle\ 20 \tag{10}$$

All Eq. (7) to Eq. (10) try to demonstrate the bending stiffness of waterway structures at single span 4 m. Also Eq. (11) to Eq. (14) can compute the bending stiffness of the two canes inside the gelatin concrete. It seems that in the Eq. (10) the SSM (PEYKAV 1997, Turk 2001, NOFAN 2002, Turk 2005) is more than 20. It interprets weak stiffness of canes versus the waterway (Ulritch 2004). Thus, the cane's performance must be as the axial stiffness behavior, seeing all Eq. (7) to Eq. (10). The coefficient C in Eq. (15) and Eq. (16) defines as radial momentum of span mass. Impact load will be a vibration force that may compute by Eq. (27) to Eq. (30) in elapsing time $\Delta t = 0.20$ sec.

$$K_{Pipe} = \left(\frac{EA}{L}\right)_{Pipe} = 2\times\left(\frac{10^6\times\frac{\pi}{4}d^2}{2500(cm)}\right) = 10^5 \quad \left(\tfrac{kg}{cm}\right) \tag{11}$$

$$K_{GC} = \left(\frac{EA}{L}\right)_{GC} = \frac{\frac{1}{3}E_C\times a.b}{2500(cm)} = \frac{1}{3}\frac{2\times10^5\times100\times400}{2500(cm)} = 10^6 \quad \left(\tfrac{kg}{cm}\right) \tag{12}$$

$$\left(\frac{EA}{L}\right)_{SteelStirrupSpiral} = \frac{E_S\times(2a+2b).t}{2500(cm)} = \frac{2\times10^6\times2(100+400)\times1.2}{2500(cm)} = 10^6\left(\tfrac{kg}{cm}\right) \tag{13}$$

$$K_{Span} = \sum_{\lambda=i}^{iii}\left(\frac{EA}{L}\right)_{\lambda} = 10^5 + 10^6 + 10^6 = 2.1\times10^6 \left(\tfrac{kg}{cm}\right) = 2\times10^9 \left(\tfrac{N}{m}\right) \tag{14}$$

$$\left(M\ddot{Y} + C\dot{Y} + KY\right)_{Span} = F(t)_{WaterWay} \quad (N), \quad C = M\omega \tag{15}$$

$$M\omega = M\sqrt{K/M}., \quad M = 2\times10^5 kg \tag{16}$$

$$\left(\ddot{Y} + \sqrt{K/M}\,\dot{Y} + K/M\,Y\right)_{Span} = F(t)_{WaterWay}/M \tag{17}$$

$$K/M = 10^4\left(\tfrac{1}{Sec^2}\right), \quad \sqrt{K/M} = 100 \quad \left(\tfrac{1}{Sec}\right) \tag{18}$$

$$\left(\ddot{Y} - 10^2\dot{Y} - 10^4 Y\right)_{Span} = F(t)_{WaterWay}/2\times10^5 \rightarrow Y_{1,2} = 50\left(1\pm\sqrt{5}\right) \tag{19}$$

$$C.F: \quad Y = \alpha.Exp\left(50\left(1+\sqrt{5}\right)t\right) + \beta.Exp\left(50\left(1-\sqrt{5}\right)t\right) \tag{20}$$

$$P.I: \quad \left(D^2 - 10^2 D - 10^4\right)v = F_{\circ}Sin(\omega_w t)/M_{Span} \tag{21}$$

$$\omega_w = \sqrt{K_W/M_W} = \sqrt{\frac{2.4\times10^{10}}{2.56\times10^5}} \cong 300\left(\tfrac{Rad}{S}\right) \tag{22}$$

$$P.I: \quad v = A.Sin(300t) + B.Cos(300t) \tag{23}$$

$$A = -F_{\circ}\tfrac{10^{-6}}{180}, \quad B = -F_{\circ}\tfrac{10^{-9}}{60} \tag{24}$$

$$Y(t) = \alpha.Exp\left(50\left(1+\sqrt{5}\right)t\right) + \beta.Exp\left(50\left(1-\sqrt{5}\right)t\right) - -F_{\circ}\tfrac{10^{-9}}{60}\left(\tfrac{1}{3}Sin(300t) + Cos(300t)\right) \tag{25}$$

$$F.\underbrace{(t_1 - t_{\circ})}_{\Delta t} = \underbrace{M}_{ShipMass}.\underbrace{[v_1 - (v_2)]}_{\Delta V} \tag{26}$$

$$F_{\circ}.\left(\underbrace{0.2-0.0}_{\Delta t\,(\sec)}\right) = \underbrace{400'000(kg)}_{shipCapasity}.\left[+\underbrace{1.2\left(\tfrac{m}{\sec}\right)}_{impact\,velocity\,(v_1)} - \left(\underbrace{0.20\left(\tfrac{m}{\sec}\right)}_{return\,velocity\,(v_2)}\right)\right] \tag{27}$$

$$F_{\circ}(\Delta t = 0.2\sec) = 400'000(kg)\times1.0\left(\tfrac{m}{s}\right)\times\frac{1}{\Delta t(\sec)} = 400/\Delta t = 2'000(KN) \tag{28}$$

$$Y(0.20) = 8.75\times10^{-18}\left(e^{(161.8t)} - e^{(-61.8t)}\right) - 3.3\times10^{-5}\left(\tfrac{1}{3}Sin(300t) + Cos(300t)\right) \tag{29}$$

$$Y(t,\Delta t) = 8.75\times10^{-18}\left(e^{(161.8t)} - e^{(-61.8t)}\right) - 6.66/\Delta t \times10^{-6}\left(\tfrac{1}{3}Sin(300t) + Cos(300t)\right) \tag{30}$$

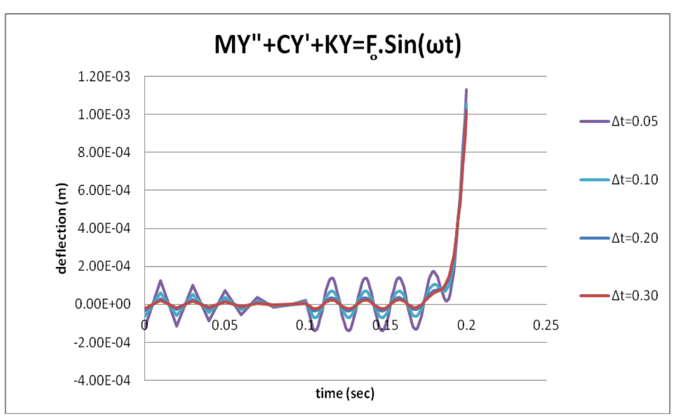

Figure 4. Deflection of span shows at elapsed time, 0.05, 0.10, 0.20, 0.30sec, (Ymax = 0.001 m).

2.2 Deflection Index Y by SSM

The maximum deflection of each span can be computed by the Eq. (30) that is the best index for resistance capability of span materials. It is included the pipe, spiral stirrups, and gelatin concrete. The Y index refers to the second order differential equations. It can be determined the maximum values of span deflection and possible exerted loads. According to the previous Dam study, (Turk 2007, Turk 2008), accurate instrumentation of Karkheh reservoir earth dam is used to interpret the SSM behavior of filter and clay embankments. Many lost data in vertical inclinometers were found to analyze by SSM.

3 CONCLUSIONS

Tangency joints could be introduced to develop usages in civil engineering, steel works where the thermal effects would be a sensitive character. In this area the range of temperature is varied between the +4.0 until +57.0 centigrade degree. Also, it is easy and simple method to obtain the responding impact loads and distribution of stiffness. This paper tries to show the behavior of combination material such as concrete, soil interactions and sheet piles.

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