Safety Evaluation of Bridge Type Wharf Structural System by Using Damage Index Method

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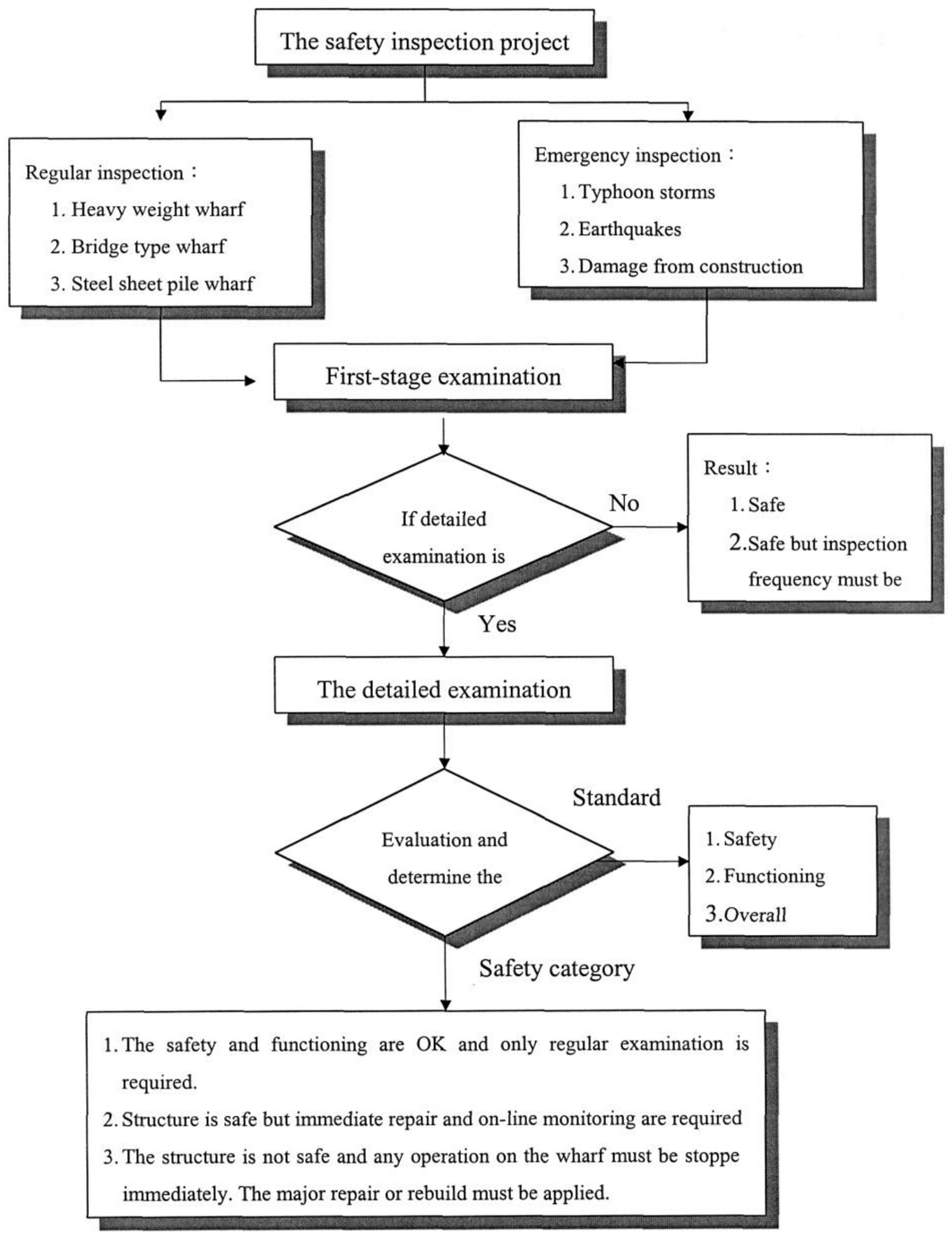
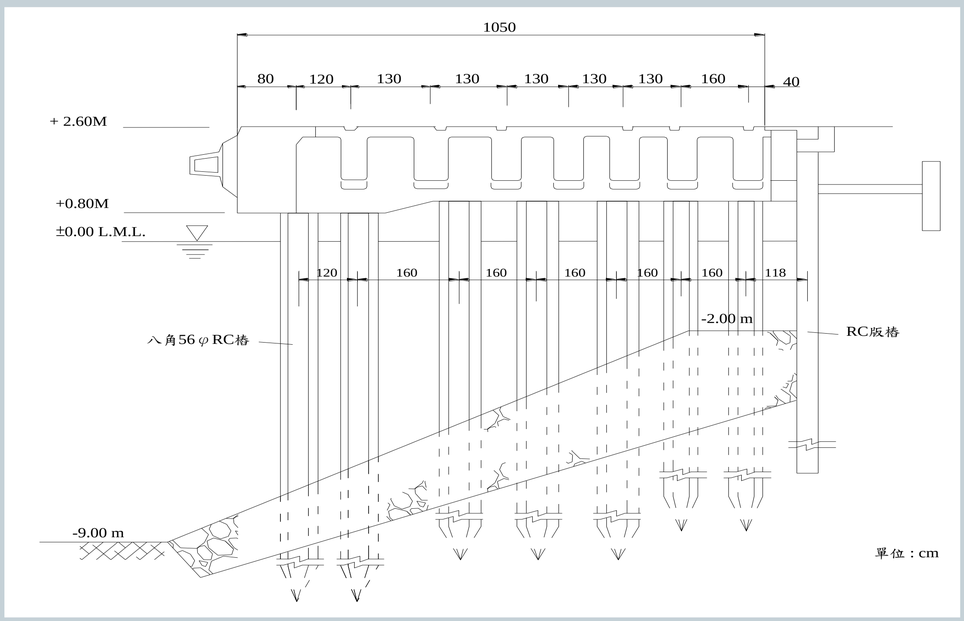
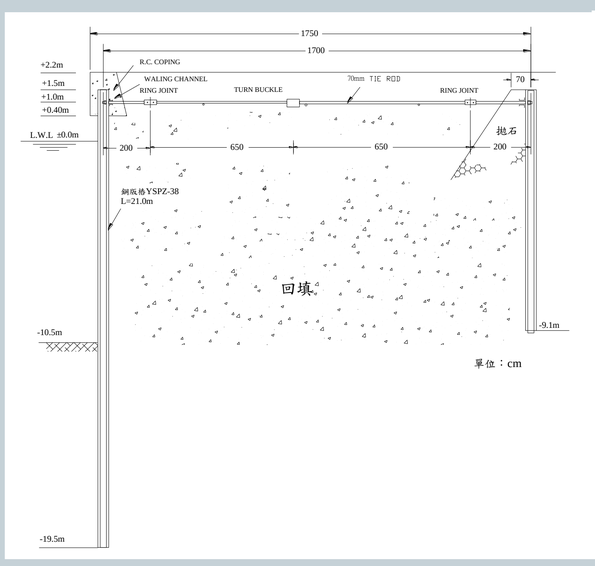
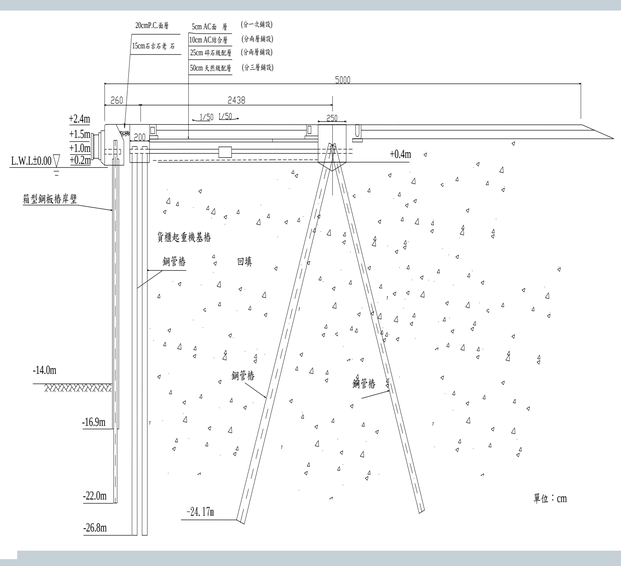


Pier (bridge) type wharf structural system



Steel-sheet pile type wharf structural system





Inspection for Bridge Type Wharf Structural System

The structural system of a bridge type may consists of decks, piers, girders and beams under the deck and function facilities on the deck. Under the water some embankment supporting structures may also be established to reinforce the piers.

Damage inspections for structural members of pier wharf:

- **Deck: pilling, cracks, corrosion of reinforcement, material degradation**
- **Piers: corrosion of steel pile, cracks, material degradation, disposition or displacement of pile**
- **Girders and beams: pilling, cracks, corrosion of reinforcement, material degradation**
- **Embankment: variation of water depth, deformations, unusual holes**

The Damage Index of Individual Member

Evaluation of damage index for individual structural member

$$D_e = \frac{\delta_{Me}}{\delta_{ue}} + \frac{\beta_e}{pQ_{ye}\delta_{ue}} \sum_i^p \mathrm{E}_i^e \qquad (1)$$

Based on the damage index for concrete beam subjected to cyclic loadings - Park and Wen (Park and Wen, 1986)

The accumulated energy of member "*e*" before failure is assumed to be from "p" cross-sections of the individual beam that was under damage inspections as:

$$\mathrm{E}_i^e = \sigma_{ri}\delta_{est.i} \qquad (2)$$

The Global Safety Index of Whole Structure

The global safety index for the whole wharf structural system is presented as:

$$\Phi = \frac{2}{M}\sum_e^M [\frac{\phi_r}{\phi_l} \cdot \delta_e^{\alpha_e}] \qquad (3)$$

where various types of members are taken into accounts in terms of their design loading factors and strength reductions for the material

If the connected members are same type of structural elements the global safety index is simplified into

$$\Phi = \frac{1}{M}\sum_e^M [\delta_e^{\alpha_e}] \qquad (4)$$

where M: number of members, loading factor, = strength reduction factor

Related Parameters from On-site Inspection

$$\delta_e = \frac{1}{2}\left[1 - \frac{\sum E_i}{\Delta} + \frac{\delta_{Me}}{\delta_{ue}}\right] \qquad (5) \quad \text{and} \quad \alpha_e = \frac{1}{\alpha_{le}\alpha_{ve}} \qquad (6)$$

It is noticed that these two parameters are most import for the global safety index and they are based on on-site inspection data such as

Δ: Ductility parameter, maximum = 5 for concrete material

α_{ve} **= (1- data variation %): Variation parameter due to data difference**

α_{le} **: Parameter of cross-section loss and cracks**

Table of the Related Parameters

Parameters	Range	Definition	Formula
De	≥1.0	Damage index of individual member	Equation (1)
α_{ve}	≦ 1	Parameter of data variation	(1–data variation%)/0.95, =1 if data variation≦5%
α_{le}	≦ 1	Parameter of ductility loss	$\alpha_{le} = \beta_1 \cdot \beta_2 \cdot \beta_3$
β_1	≦ 1	Reduction coefficient of cross-section of members	$(1\text{-}R_{sl})$
β_2	≦ 1	Degradation coefficient of material	$(1\text{-}R_{dl})$
β_3	≦ 1	Brittle coefficient	$(1\text{-}R_{al})$

Safety Evaluation for Bridge Wharf System

$$S_d \le S_n \cdot \Phi$$

S_n is the nominal strength of the material

S_d is the design strength

If the material is concrete and 0.85 nominal strength has been used for design then the following criteria are suggested:

Level 1： $\Phi \geqq 0.85$. The safety and functioning of the wharf are OK and only regular examination is required.

Level 2： $0.85 > \Phi \geqq 0.68$. Structure is safe but immediate repair and on-line monitoring is required.

Level 3：$0.68 > \Phi \geqq 0.50$. The structure is not safe and all operations on the wharf must be stopped immediately. The major repair work or rebuild must be applied after overall estimation including the cost analysis.