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

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The safety inspection project

First-stage examination

Emergency inspection:
1. Typhoon storms
2. Earthquakes
3. Damage from construction.

Regular inspection:
1. Heavy weight wharf
2. Bridge type wharf
3. Steel sheet pile wharf

Result:
1. Safe
2. Subsequent examination is needed.

Yes

Standard

Safety category
1. Safety
2. Functioning
3. Overall

Table of the Related Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Range</th>
<th>Definition</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>D_1</td>
<td>≥1.0</td>
<td>Damage index of individual member</td>
<td>Equation (1)</td>
</tr>
<tr>
<td>D_{var}</td>
<td>≤1</td>
<td>Parameter of data variation</td>
<td>[1] - data variation &gt; 0.95, =1 if data variation ≤ 5%</td>
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<tr>
<td>D_{duct}</td>
<td>≤1</td>
<td>Parameter of ductility loss</td>
<td>( \alpha_d = \beta_1 \cdot \beta_2 \cdot \beta_3 )</td>
</tr>
<tr>
<td>\beta_1</td>
<td>≤1</td>
<td>Reduction coefficient of cross-section of members</td>
<td>(1 - R_0)</td>
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<tr>
<td>\beta_2</td>
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Level 1: \( \Phi \geq 0.85 \). The safety and functioning of the wharf are OK and only regular examination is required.
Level 2: \( 0.85 > \Phi \geq 0.68 \). Structure is safe but immediate repair and on-line monitoring is required.
Level 3: \( \Phi < 0.68 \). 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.

The Damage Index of Individual Member

Evaluation of damage index for individual structural member

\[
D_i = \frac{\delta_i}{\delta_m} + \frac{\beta_i}{\beta_m} \sum E_i
\]

(1)

Based on the damage index for concrete beam subjected to cyclic loadings - 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:

\[
E_i = \sigma_i \delta_{ei}
\]

(2)

The Global Safety Index of Whole Structure

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

\[
\Phi = \frac{1}{M} \sum \delta_i
\]

(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

\[
\Phi = \frac{1}{M} \sum \delta_i
\]

(4)

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

Related Parameters from On-site Inspection

\[
\delta_i = \frac{1}{2} \left[ 1 - \frac{1}{\Delta} \left( \frac{R_i}{\delta_m} + \frac{\delta_i}{\delta_m} \right) \right]
\]

(5) and \( \alpha_{e} = \frac{1}{\alpha_{\delta} \cdot \alpha_{v}} \)

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Safety Evaluation for Bridge Wharf System

\[
S_s \leq S_c \cdot \Phi
\]

S_0 is the nominal strength of the material
S_s 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: \( \Phi \geq 0.85 \). The safety and functioning of the wharf are OK and only regular examination is required.
Level 2: \( 0.85 > \Phi \geq 0.68 \). Structure is safe but immediate repair and on-line monitoring is required.
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