MODEL-SIZED AND FULL-SCALE DYNAMIC PENETRATION TESTS ON DAMPING CONCRETE

Robert Scheidemann, Eva-Maria Kasparek, Karsten Müller, Bernhard Droste, Holger Völzke

BAM Federal Institute for Materials Research and Testing
Berlin, Germany

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MODEL-SIZED AND FULL-SCALE DYNAMIC PENETRATION TESTS ON DAMPING CONCRETE

Robert Scheidemann, BAM, Germany
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Introduction

**Shock absorbing footings**
- material called ‘damping concrete’
- used in loading areas of interim storage facilities
- reduces loads applied to cask body
- FE material model is needed for a comprehensive evaluation of hypothetical accident scenarios
- determination of material parameters under different loading conditions

**Damping concrete**
- concrete-polymer composite
- polystyrene parts are admixed to concrete matrix
- parts have a spherical shape with a diameter of about 1.5 mm
- manufactured by HOCHTIEF Construction AG
**Mechanical behavior**
- analyzed by laterally constrained compression tests on cubic specimen
- nonlinear elastic-plastic behavior
- large volume change at plateau zone at nearly constant stress level
- pronounced compacting after the plateau zone
- stress-strain curve affected by load velocity

**Scope of work**
- further experimental investigations
- characterization of mechanical behavior under shear stress
- penetration tests on damping concrete
  - different sizes and configurations of specimen
  - varying indenters

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**Stress-strain curves for cubic specimen**

Specimen before and after lateral constrained compression test, edge length = 100 mm
# Overview experimental investigations

## Experimental matrix of penetration tests

<table>
<thead>
<tr>
<th>Phase</th>
<th>Type</th>
<th>Specimen</th>
<th>Parameters</th>
<th>Front geometry</th>
<th>Lateral friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>model-sized displacement driven</td>
<td>100 x 100 x 100</td>
<td>--</td>
<td>plane</td>
<td>with / without</td>
</tr>
<tr>
<td>2</td>
<td>model-sized drop test</td>
<td>1200 x 400 x 500</td>
<td>Joint pattern: - config. A - config. B</td>
<td>plane</td>
<td>with / without</td>
</tr>
<tr>
<td>3</td>
<td>full-scale drop test</td>
<td>2400 x 2400 x 500</td>
<td>--</td>
<td>plane</td>
<td>with</td>
</tr>
</tbody>
</table>
Experimental investigations

Phase 1: Model-sized penetration tests

- Specimen
  - cubic size 100 x 100 x 100 mm³
- Indenters
  - consists of base and penetration element
  - penetration element
    - plane and hemispherical front
  - base element
    - with and without lateral friction
- Test setup
  - specimen holder to ensure lateral constraint
  - loading rate 0.5 mm/s
  - penetration depth 70 mm
  - measuring displacement, forces parallel and perpendicular to load
Experimental investigations

Phase 2: Model-sized dynamic penetration tests

- Specimen
  - size 1200 x 400 x 500 mm³
  - two mortared layers of damping concrete bricks
  - two configurations of joint patterns:
    - drop on tile spacer resp. on one brick
- Indenters
  - consists of base and penetration element
  - base element with and without lateral friction
  - penetration element:
    - plane
    - hemispherical

Indenter configurations

Config. A

Config. B
Experimental investigations

Phase 2: Model-sized dynamic penetration tests

- Test setup
  - drop test machine for guided drop tests
    - \( m = 1,100 \text{ kg} \)
    - \( h = 6.0 \text{ m} \)
  - steel frame to ensure lateral constraint of specimen
  - three penetration positions

Test setup of drop test machine for guided drop tests

Steel frame configurations
Results

Phase 2: Model-sized dynamic penetration tests

- Effect of indenter on penetration depth

- Effect of joint pattern on force
Experimental investigations

**Phase 3: Full-scale penetration test**

- Verification of FE-model
  - comparison of numerically and experimentally determined penetration depth
- Specimen
  - size 2400 x 2400 x 500 mm³
  - two mortared layers of damping concrete bricks
  - stiff steel frame to ensure lateral constraint
- Indenter
  - full-scale cylindrical cast iron indenter
  - total weight $m = 23$ Mg
  - penetrating part $d = 1100$ mm, $h = 200$ mm
  - plane front
Experimental investigations

Phase 3: Full-scale penetration test

- Test setup
  - drop height $h = 5.0$ m
  - four accelerometers circularly on top
  - high-speed camera recording

- steel frame mortared with grout onto unyielding IAEA target

Damping concrete footing with full-scale indenter before drop test and in drop position

Penetration sequences and imprint of indenter
Results

Phase 3: Full-scale penetration test

- experimentally determination of penetration depth
- calculated by
  - deceleration data
    => $s_{\text{max}} = 132 \text{ mm}$
  - optical tracking
    => $s_{\text{max}} = 131 \text{ mm}$
- penetration depth vs. time curves coincide

- comparison with numerical calculation
  => $s_{\text{max}} = 134 \text{ mm}$

(Qiao, L., et al.: Development of a Finite Element Model for Damping Concrete under Severe Impact Loads; PATRAM 2013)
Conclusions

- development of FE material model for shock absorbing damping concrete
- information about characteristics of failure process under shear stress needed
- penetration tests were conducted
  - variations of specimen size and indenter configuration
- effect of joint pattern as well as indenter geometry was determined in dynamic model-sized penetration tests
- comparison of numerically and experimentally determined penetration depth in a full scale test show very good agreement
- additional tests in particular penetration tests are needed to get more information about complex failure process

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Tests were performed in course of the research project ENREA funded by the German Federal Ministry of Education and Research (no. 02S8588) and in cooperation with WTI GmbH.
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