EVALUATION ON APPARENT INSTANTANEOUS STIFFNESS DECREASE CONSIDERING THE EFFECT OF CREEP OF MASS CONCRETE BASED ON MEASUREMENT RESULTS OF ACTUAL STRUCTURES

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INTRODUCTION

Thermal cracks affect durability, water tightness, and appearance of concrete structures.

Thermal cracks must be evaluated as accurately as possible.

3-D FEM analysis can improve accuracy by using data based on actual construction

- Thermal analysis: Relatively high accuracy
- Stress analysis: Not well accuracy
INTRODUCTION

Examples of stress analysis results

Reflect measured values of temperature history, strength properties and thermal expansion coefficient.

Of the various factors, focus on the influence of the apparent instantaneous stiffness decrease with the effect of creep.

Purpose of the study

- Calculate the reduction coefficient of Young’s modulus from measurement result of several actual structures.
- Evaluate influence of the reduction coefficient of Young’s modulus on thermal stress analysis.
MEASUREMENT IN ACTUAL STRUCTURES

Outline of each structures

Structure-A (Wall Structure)
- Crack control joints was arranged at intervals 5.0m

Structure-B (Wall Structure)

Structure-C (Columnar Structure)

Temperature, total strain, non-stress strain and effective stress were measured.

Embedded strain meter

Embedded strain meter and non-stress container

Embedded concrete effective stress meter
Structure-A (Wall Structure)

- W/C 54.4% · C(BB) 315kg/m³ · Slump 12cm
- Concrete was placed in the end of May(ct:20°C)
- Cracking occurred only at crack control joints

Structure-B (Wall Structure)

- W/C 50.0% · C(BB) 300kg/m³ · Slump 8cm
- Concrete was placed in the beginning of May(ct:20°C)
- Cracking occurred only at crack control joints
2 MEASUREMENT IN ACTUAL STRUCTURES

Structure-C (Columnar Structure)
- W/C 47.2% · C(L) 339kg/m³ · Slump 12cm
- Concrete was placed in the end of December (ct: 11°C)
- Whether cracking has occurred is unknown

![Graphs showing temperature and effective stress over material age]

3 REDUCTION COEFFICIENTS OF YOUNG’S MODULUS

Calculation method
- Relationship between effective strain and effective stress
  ※Effective strain = total strain − non-stress strain

Effective Young’s modulus is obtained by dividing effective stress by effective strain
※Because plot-by-plot calculation has considerable variation,
  the slope was calculated for each section that obtain the straight line.

- Relationship between Young’s modulus and temperature-adjusted age of concrete

Calculate as static Young’s modulus from compressive strength of specimen and temperature measurement result of actual structure
※Use Equation shown in JCI guideline

Reduction coefficient is calculated dividing effective Young’s modulus by static Young’s modulus
3 REDUCTION COEFFICIENTS OF YOUNG’S MODULUS

Effective Young’s modulus

- Structure-A (Wall Structure)
- Structure-C (Columnar Structure)

This age is just matched the time when the measured effective stress changed from compressive to tensile.

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3 REDUCTION COEFFICIENTS OF YOUNG’S MODULUS

Reduction coefficient for Young’s modulus

- Structure-A (Wall Structure)
- Structure-C (Columnar Structure)

◆ It is considered that difference of effects of creep depended on the stress state and material age.

► Evaluation by average value each of stress state
  (Increasing compressive stress, decreasing compressive stress, and increasing tensile stress)
3 REDUCTION COEFFICIENTS OF YOUNG’S MODULUS

Average of reduction coefficient of Young’s modulus for each stress state

<table>
<thead>
<tr>
<th>Stress state</th>
<th>Structure</th>
<th>Average</th>
<th>Concrete Guideline</th>
<th>Previous literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in compressive stress</td>
<td>A: 0.56</td>
<td>B: 0.59</td>
<td>C: 0.48</td>
<td>0.42</td>
</tr>
<tr>
<td>Decrease in compressive stress</td>
<td>A: 0.67</td>
<td>B: 1.31</td>
<td>C: 0.61</td>
<td>0.86</td>
</tr>
<tr>
<td>Increase in tensile stress</td>
<td>A: 0.47</td>
<td>B: 0.28</td>
<td>C: 0.34</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Near the center value of JCI guidelines and previous literature, they tend to be larger than other stress states.

4 EFFECT OF THERMAL STRESS ANALYSIS

Analysis model

- W/C 53.0% · C(N) 330kg/m³ · Slump 12cm
- Thermal analysis is reflected measured values of temperature history.
- Stress analysis is reflected strength properties and thermal expansion coefficient, in addition to average value of reduction coefficient obtained in this study.

※ the crack control joints of length 5m
4 EFFECT OF THERMAL STRESS ANALYSIS

Comparison of stress analysis

![Graph showing stress analysis comparison.]

Analysis value (using average of structure A-C) is,
- For compressive stress, larger than actually measured value.
- For the tensile stress, as same as actually measured value.

Comparison of minimum thermal cracking index

![Graph showing minimum thermal cracking index comparison.]

- Analysis value (using average of structure A-C) is as same as measured value.
- Analysis value (JCI guideline) is more safe side evaluation.

※ Dividing estimated tensile strength by measured value of the effective stress
## CONCLUSION

- The reduction coefficient of Young's modulus with the effect of creep that obtained in this study may be smaller than the JCI guideline.
- It was confirmed that the reduction coefficient of Young's modulus differs depending on the stress state.
- Because the result was based on a limited amount of structures data, it is necessary to further accumulate data in the future.