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TH32 - Concrete Degradation Part II:  
Perspectives on Radiation Effects on Structural Capacity of Nuclear Concrete Structures

# **Irradiation Effects on Concrete Strength**

**Masayoshi KOJIMA**

Regulatory Standard and Research Department,  
Secretariat of Nuclear Regulation Authority (S/NRA/R), Tokyo, Japan

NRA: Nuclear Regulation Authority, Japan  
\* NOTE: The content of this report does not represent official NRA positions.

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 **Contents**

1. Background
2. Objectives
3. Key Points
4. Tests on Coarse Aggregate
5. Tests on Concrete
6. Discussion
7. Conclusion

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 **1. Background**

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 **Background**

- Hilsdorf et al. pointed out the followings. \*
- ✓ Neutron fluence of **more than  $1 \times 10^{19} \text{ n / cm}^2$**  may have an effect on concrete strength.
- ✓ Radiation damage is mainly caused **by lattice defects in the aggregates** which cause a volume increase of aggregates and concrete.

\* Hilsdorf, Kropp, Koch, "The Effects of Nuclear Radiation on the Mechanical Properties of Concrete," ACI SP55 (1978)

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 **2. Objectives**

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 **Objectives**

- To investigate **the effects on strength reduction** of concrete by neutron irradiation.
- To investigate **the technical basis based on the scientific method** when there are the effects on strength reduction.

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### 3. Key Points

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**Key Points**

- $\alpha$ -quartz in aggregate expands 16 to 18% in volume by neutron irradiation.
- The crystal structure inside  $\alpha$ -quartz changes due to metamictization\* in a process of expansion of aggregate by neutron irradiation.



**Focusing on percentage of  $\alpha$ -quartz content in coarse aggregate**

Metamictization\*: A state in which a crystal lattice is destroyed by radiation and is regarded as amorphous like glass for both X-rays and visible light.

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### 4. Tests on Coarse Aggregate

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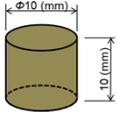
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**Specification on Coarse Aggregate Specimens**

- Specimen Size:  $\Phi 10\text{mm} \times 10\text{mm}$
- Neutron Fluence ( $E > 0.1\text{MeV}$ ): **4 Levels**  
**0.701, 1.28, 4.12, 8.25** ( $\times 10^{19}$  n/cm<sup>2</sup>)
- Quartz Content: **5 Levels**



| Specimen No. | Quartz Content (mass %) | SiO <sub>2</sub> Content (%) | Grain Size (mm) | Rock Type                 |
|--------------|-------------------------|------------------------------|-----------------|---------------------------|
| GA           | 91.9                    | 87.0                         | 0.1 - 0.3       | Tuff (Crushed Stone)      |
| GB           | 47.1                    | 74.7                         | 1.0 - 3.0       | Sandstone (Gravel)        |
| GC           | 39.7                    | 70.8                         | 2.0 - 5.0       | Sandstone (Crushed Stone) |
| GD           | 40.1                    | 74.1                         | 1.0 - 3.0       | Sandstone (Crushed Stone) |
| GE           | 23.5                    | 52.6                         | 0.5 - 1.5       | Sandstone (Crushed Stone) |

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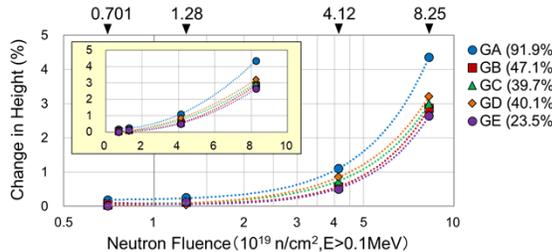
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**Relationship Between Neutron Fluence and Expansion**

- The expansion on height was proportional to the square of the neutron fluence.
- The quartz content of 23.5 to 47.1% showed no significant difference in height expansion.




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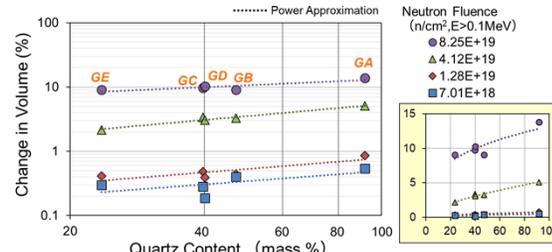
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**Relationship Between  $\alpha$ -Quartz Content and Expansion**

- The larger the  $\alpha$ -quartz content, the greater the expansion.
- The larger the neutron fluence, the greater the expansion.




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## 5. Tests on Concrete

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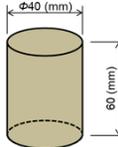
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### Specification on Concrete Specimens

- Specimen Size: **Φ40mm × 60mm**
- Neutron Fluence (E>0.1MeV): **3 Levels**  
**0.778, 1.41, 4.58 ( ×10<sup>19</sup> n/cm<sup>2</sup>)**
- Quartz Content: **2 Levels**



| Specimen No. | Coarse Aggregate |                    |           | Water-Cement Ratio |
|--------------|------------------|--------------------|-----------|--------------------|
|              | No.              | Quartz Content (%) | Size (mm) |                    |
| <b>Con-A</b> | GA               | <b>91.9</b>        | 5 - 13    | 0.50               |
| <b>Con-B</b> | GB               | <b>47.1</b>        | 5 - 13    | 0.50               |

- Cement: High-Early-Strength Portland Cement
- Fine Aggregate: Pit Sand (SiO<sub>2</sub> ≈ 76%)

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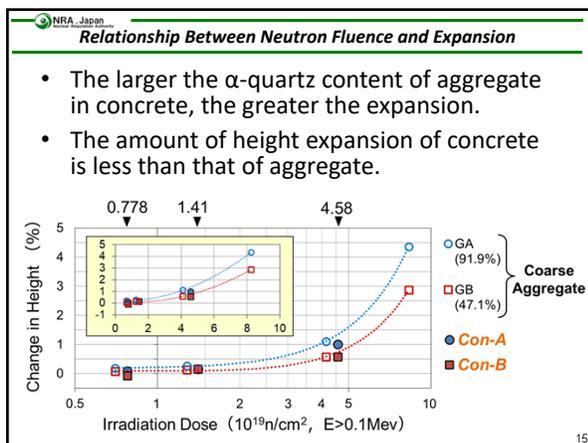
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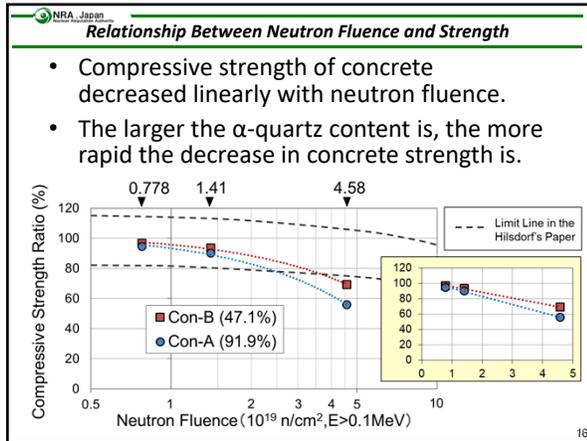
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## 6. Discussion

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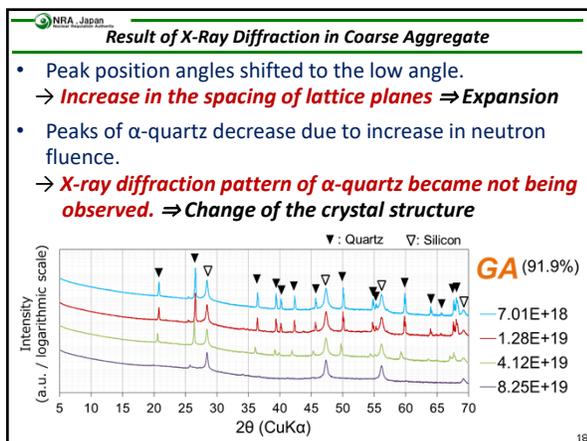
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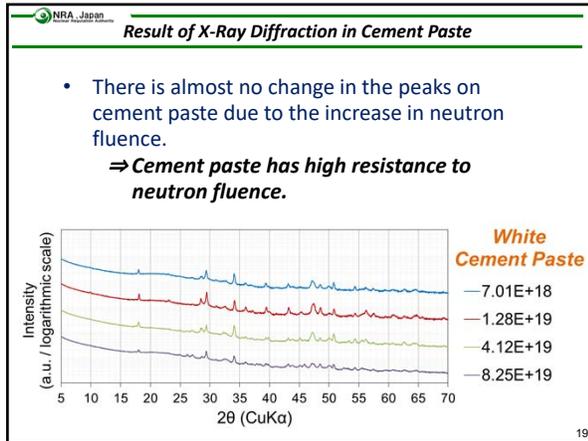
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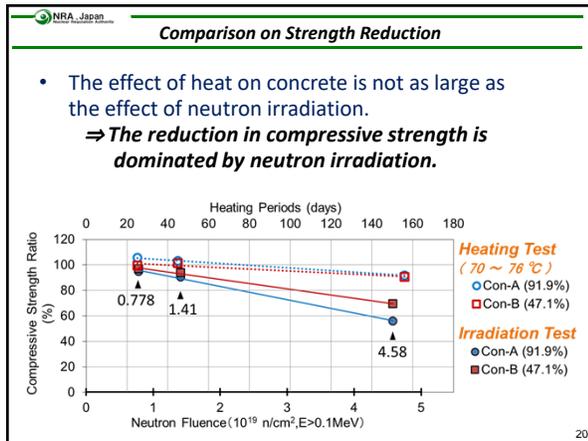
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**7. Conclusion**

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**The Effects of Concrete by Neutron Irradiation**

- **Concrete expands by neutron irradiation.**  
→ The larger the  $\alpha$ -quartz content in the coarse aggregate, the greater the expansion of concrete.
- **Compressive strength of concrete is decreased by neutron irradiation.**  
→ The larger the  $\alpha$ -quartz content in the coarse aggregate is, the more rapid the decrease in concrete strength is.



Mechanism: **Increase in the spacing of lattice planes** and **disappearance of X-ray diffraction pattern on  $\alpha$ -quartz** in the coarse aggregate of concrete by neutron irradiation.

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**Thank you very much.**



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