CO₂ Emissions from Concrete Sector (billion ton)

- Material production: 3.012
  (cement, reinforcement, aggregate)
- Concrete production: 0.810
- Execution: 1.144
- Repair and retrofitting while in service: ?
- Demolition and recycling: 0.085

Total = 5.051 (17.4% of total CO₂ in 2007)
Tools for Low-Carbon Concrete

- CCS Technique
- Low-carbon cement production
- Use of supplementary cementitious materials
- Use of high performance chemical admixtures
- Combination of each tool
Purpose of Study

- To examine the effect of fly ash and blast-furnace slag on fresh properties and hardened properties of concrete.
- To clarify the effect of fly ash and blast-furnace slag on the reduction of CO$_2$. 
Replacement Ration of Fly Ash and Slag, and Mix Proportions

- **Replacement ratio**
  - Fly Ash: 0, 10, 20
  - Slag: 0, 10, 20, 30, 40

- **Mix proportion**
  - \( W/(C+FA+BS) = 0.4 \)
  - \( s/a = 0.46 \)
  - 13 mixtures
Experiments

- **Tests on fresh Concrete**
  - Air content, bleeding, and setting

- **Tests on hardened concrete**
  - Compressive strength, splitting tension, autogeneous shrinkage, and drying shrinkage
Unit Water

BS replacement ratio (%)

Unit water (kg/m³)

FA0%
FA10%
FA20%

(12.5)
(12.3)
(12.9)
(10.2)
(11.3)
(10.2)
(10.3)
(10.0)
(10.7)

(10.5)
(10.3)

(12.5)
(12.5)
(10.7)

(12.0)
(9.5)
Amount of AE Admixture

![Graph showing the relationship between BS replacement ratio and amount of AE admixture.](image-url)

- Amount of AE admixture (kg/m³)
- BS replacement ratio (%)

Key:
- FA0%
- FA10%
- FA20%

Note: ( ) : air cement (%)

Sample data points:
- (4.5): 1.4
- (5.0): 1.2
- (5.4): 1.0
- (5.5): 0.8
- (5.3): 0.6
- (5.1): 0.4
- (5.2): 0.2
- (5.4): 0.0
- (4.1): 0.0
- (3.6): 0.0
Setting Time

![Diagram showing the effect of BS replacement ratio (%) on setting time (min) for different FA percentages. The graph compares initial and final setting times for FA0%, FA10%, and FA20% conditions.](image-url)
Compressive Strength

- Compressive strength (N/mm²)
- BS replacement ratio (%)
- Age (days)
  - 28
  - 7
  - 3

Graph showing compressive strength for different BS replacement ratios (FA0%, FA10%, FA20%) over various ages.
Change in Compressive Strength

Age: 3 days

Age: 28 days
Splitting Tensile Strength

![Chart showing splitting tensile strength in relation to BS replacement ratio and age (days)].

- **BS replacement ratio (%)**
- **Splitting tensile strength (N/mm²)**
- **Age (days)**
  - 28
  - 7
  - 3

The chart illustrates the splitting tensile strength for different ages and BS replacement ratios. The data is grouped by age (28, 7, and 3 days) and BS replacement ratios (0%, 10%, and 20%).
Change in Splitting Tensile Strength

Age: 3 days
- FA0%
- FA10%
- FA20%

Age: 28 days
Autogeneous Shrinkage Strain

![Graph showing the shrinkage strain over time for different materials.](image)

- **BS0%**
- **BS10%**
- **BS20%**
- **BS30%**
- **FA 10%**
Autogenous Shrinkage Strain

![Graph showing Autogenous shrinkage strain vs BS replacement ratio (\%) at Time 550hrs.](image)

- **Autogenous shrinkage strain (\(\mu\))**
- **BS replacement ratio (%)**
- **Time 550hrs**

Legend:
- FA0%
- FA10%
- FA20%
Drying Shrinkage Strain
Drying Shrinkage Strain

![Graph showing the relationship between BS replacement ratio and drying shrinkage strain. The graph includes lines for FA0%, FA10%, and FA20% replacement ratios.](image)
### Unit-Based CO₂ Emission in Each Material
(JSCE recommendation of environmental performance verification for concrete structures, 2005)

<table>
<thead>
<tr>
<th>Materials</th>
<th>Unit-based CO₂ emission (kg-CO₂/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland cement</td>
<td>765.5</td>
</tr>
<tr>
<td>Fly ash</td>
<td>17.9</td>
</tr>
<tr>
<td>Blast furnace slag</td>
<td>26.5</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>3.7</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>2.9</td>
</tr>
<tr>
<td>High-range water-reducing AE agent</td>
<td>187.5</td>
</tr>
</tbody>
</table>
Amount of CO₂ Emission

![Bar chart showing the amount of CO₂ emission for different BS replacement ratios (FA0%, FA10%, FA20%)](image)

- **Y-axis:** Amount of CO₂ emission (kg/m³)
- **X-axis:** BS replacement ratio (%)
CO₂ Emission per Unit Compressive Strength

The graph illustrates the relationship between BS replacement ratio (%) and the amount of CO₂ emission (kg/m³) per unit compressive strength (N/mm²) for different fractions of FA (FA0%, FA10%, FA20%). The age (days) is indicated as 3, 7, and 28. The graph shows a downward trend in CO₂ emission with increasing BS replacement ratio for all fractions at different ages.
Conclusions (To be cont’d)

- The use of both fly ash and blast-furnace slag allows significant reductions in the unit water content but increases the amount of an air-entraining agent.

- The use of both fly ash and blast-furnace slag affects the amount of bleeding but scarcely affects the setting times of concrete.
Conclusions (To be cont’d)

The use of both fly ash and blast-furnace slag reduces the compressive and splitting tensile strengths of concrete by 54% and 55%, respectively, at the maximum at 3 days, but these losses are reduced to 19% and 14%, respectively, at the maximum at 28 days.
Conclusions (Cont’d)

- The use of both fly ash and blast-furnace slag reduces the autogeneous shrinkage strain and drying shrinkage strain.
- The use of both fly ash and blast-furnace slag decreases the amount of CO$_2$ emission per 1N/mm$^2$ of concrete compressive strength.
Thank You……