



GREEN CONCRETE CUBE COMPETITION 2023

American Concrete Institute Singapore Chapter and Temasek Polytechnic School of Applied Science, Centre for Urban Sustainability (CUS) have been playing a proactive role in the development of concrete technology through education, training, conferences, and short seminars. Its annual concrete cube competition also seeks to facilitate the progress of the local concrete industry toward high-performance sustainable concrete technology.

The competition is open to individuals, tertiary institutes, companies, and organizations.

Each tertiary institute, company, and organization is allowed to submit up to a **maximum of 2 entries** and be differentiated by different Team Names in each application. **Registration is Free.**

Rules and Regulations

1. The Concrete Cube Competition 2023 will be judged by the following 4 criteria:
 - i. **Criterion 1** - Ratio for average compressive strength to average concrete density (the higher the better).
 - ii. **Criterion 2** – Average Compressive strength (the higher the better)
 - iii. **Criterion 3** - Ratio for recycled waste material mass to total concrete mass. (To be declared in concrete mix design, computed up to 1% – the higher the better)
 - iv. **Criterion 4** – Write up (Maximum 3 pages in doc/docx format) on how the recycled waste material/s affects the compressive strength or the density or the positive impact towards the zero-carbon initiative.
2. The weightages for scoring for each of the criteria are **1st criterion (50%)**; **2nd criterion (30%)**; **3rd criterion (10%)** and **4th criterion (10%)**.
3. See below for an example of a scoring system:

Team A achieved an average compressive strength of 71.6 MPa and an average density of 1810 kg/m³ (both averages of 3 cubes). Team A also reported a ratio of 30% for Criterion 3 and had a score of 73% for the write-up (For Criterion 4 - awarded by the panel of judges).

Assumed 10 teams participating, Team A is 2nd for Criterion 1, 4th for criterion 2, 5th for criterion 3, and 9th for criterion 4:

In this scenario, Team A would have a score of $(9/10 \times 50\%) + (7/10 \times 30\%) + (6/10 \times 10\%) + (2/10 \times 10\%) = 74\%$



The team with the highest score will be the winner.

4. Tie-breaker – In the case of a tie-in score, the submission with the higher compressive strength wins the tie.
5. In each entry, the applicant shall submit **four (4) nos. of 100mm X 100mm X 100mm cube specimens**. These cube specimens shall be delivered to the appointed test laboratory on the testing date as specified hereunder.

One (1) of four (4) cubes will be selected randomly and split into two (2) halves to reveal the cross-sections. The judges would review (by observation) the cross sections. Photos of the cross sections will be taken for recording purposes.

The average density of the remaining (3) cubes will be computed. These three (3) cubes will be tested for compressive strengths and the average computed.

6. The minimum average compressive strength of the 3 cubes must be at least 40MPa.
7. The type of cement used **MUST** be the materials listed in Table 1 of SS 544: Part 2: 2019 Singapore Standard Concrete – Complementary Singapore Standard to SS EN 206 – Part 2: Specification for constituent materials and concrete – Amendment No. 1 dated May 2021 (**see the table 1 enclosed**).

However, recycled waste materials must **NOT** be any of the cementitious components mentioned in **table 1 enclosed**.

8. Recycled Waste materials like recycled concrete aggregates; and recycled materials such as plastic, glass, clay, etc. can be used.
9. The recycled waste materials to be used shall be **declared in the official entry form and must be approved by the judges** before casting the cubes. In the official entry form, **more than one recycled waste material can be submitted for approval**. The final selected recycled waste material/s used should be amongst the approved recycled waste material/s in the official entry form submitted.
10. The ratio of recycled waste material mass to total concrete mass shall be **at least 10%**.
11. **A photo/s of the recycled waste material/s** used is to be submitted together with the write-up.



12. Each contestant shall provide, together with the cubes submitted, a statement declaring/showing the following (see **sample form for concrete mix design** provided):
- i. The mix composition of the submitted concrete cubes.
 - ii. The type, strength class, and density of cement to be used.
 - iii. The type and density of Additions/Supplementary Cement Materials SCM to be used.
 - iv. The type and density of coarse aggregates to be used.
 - v. The type and density of fine aggregates to be used.
 - vi. The type of admixtures and/or additives to be used.
 - vii. The type and density of recycled waste material to be used.
 - viii. The date for the casting of the cubes.
 - ix. The method of curing.

Contestants are required to furnish additional details if requested by the panel of judges.

13. The **compressive strength** shall be recorded to the **nearest 0.1 MPa** and the **concrete density to 10 kg/m³**.
14. The **compressive strength-to-density ratio** shall be computed to the nearest **0.0001 MPa/(kg/m³)**.
15. The **compressive strength standard deviation shall not exceed 5 N/mm²**.
16. Prizes for winning teams will be as follows:
- Gold Award (\$800.00)
 - Silver Award (\$600.00)
 - Bronze Award (\$300.00)
 - Merit Award (\$200.00 each)
 - Commendation (\$100.00 each)

All winning and participating teams will be given a certificate of participation.

17. **THE DECISION OF THE PANEL OF JUDGES SHALL BE FINAL.**



Registration and Submission

1. All entries shall be emailed to:
Green Concrete Cube Competition Committee
ACI-Singapore Chapter (ACI-SC)
e-mail: desmond.low@concrete.org.sg
2. **Closing date for registration:** **3 Apr 2023 Mon**
Include request approval for recycled waste material/s to be used.
3. **Casting of cubes:** **Any date between 3 to 7 Jul 2023**
Photo/s of the four (4) cubes cast - showing cube labels stating:
 - **ACI CUBE COMPETITION**
 - *the date of casting and*
 - *cube numbering**to be emailed to the above e-mail address on the day of casting. The photo/s will be used for verification during cubes testing.*
4. **Date of submission of Concrete Mix Design:** **10 Jul 2023 Mon**
5. **Date of submission of Write-Up:** **10 Jul 2023 Mon**
Photo/s of Recycled Waste Material/s used to be enclosed.
6. **Date and time for cube testing (28 days from casting date) to be arranged accordingly. Cubes must be delivered to the testing lab on the testing day.**
7. **Test Laboratory Appointed: Temasek Polytechnic School of Applied Science at its Centre for Urban Sustainability (CUS) facilities.**



GREEN CONCRETE CUBE COMPETITION 2023
OFFICIAL ENTRY FORM
(Due Date: 3 Apr 2023 Mon)

NAME OF TEAM: _____

INDIVIDUAL / TERTIARY INSTITUTE / COMPANY / ORGANIZATION:

ADDRESS: _____

NATURE OF BUSINESS: _____

RECYCLED WASTE MATERIAL (1): _____ (Approved/Not Approved)

RECYCLED WASTE MATERIAL (2): _____ (Approved/Not Approved)

RECYCLED WASTE MATERIAL (3): _____ (Approved/Not Approved)

RECYCLED WASTE MATERIAL (4): _____ (Approved/Not Approved)

Person-in-charge: _____ Contact Tel No. : _____

Designation: _____ Email Address : _____

Date: _____

Signature



GREEN CONCRETE CUBE COMPETITION 2023
CONCRETE MIX DESIGN
(Due Date: 10 Jul 2023 Mon)

01 Cement

| | | | |
|---------------------------------------|--|--|--|
| Type (refer to Table 1 below) | | | |
| Content (kg/m ³) | | | |
| Strength Class | | | |
| Specific Density (kg/m ³) | | | |

02 Additions / Supplementary Cementitious Materials SCM

| | | | |
|---------------------------------------|--|--|--|
| Type (refer to Table 1 below) | | | |
| Content (kg/m ³) | | | |
| Specific Density (kg/m ³) | | | |

03 Coarse Aggregate

| | | | |
|---------------------------------------|--|--|--|
| Type | | | |
| Content (kg/m ³) | | | |
| Max Size (mm) | | | |
| Specific Density (kg/m ³) | | | |

04 Fine Aggregate

| | | | |
|---------------------------------------|--|--|--|
| Type | | | |
| Content (kg/m ³) | | | |
| Specific Density (kg/m ³) | | | |

05 Admixture/Additive/Others

| | | | | |
|---------------------------------------|--|--|--|--|
| Type | | | | |
| Name | | | | |
| Manufacturer | | | | |
| Specific Density (kg/m ³) | | | | |
| Dosage (litre/m ³) | | | | |



06 Recycled Waste Material

| | | | | |
|---------------------------------------|--|--|--|--|
| Type | | | | |
| Content (kg/m ³) | | | | |
| Name | | | | |
| Specific Density (kg/m ³) | | | | |

07 **Total Ratio of recycled waste material/s mass to total concrete mass (Computed up to 1%):** _____

08 Water: _____ kg/m³

09 Design Strength: _____ MPa at 28 days

10 Slump/Slump Flow: _____ Class/mm

11 Date of Casting: _____

12 Method of Curing: _____

13 Cube Labels: _____

Person-in-charge: _____ Contact Tel No. : _____

Designation: _____ Email Address : _____

Date: _____

Signature



Table 1 – General purpose cements and combinations

Singapore Standard SS 544: Part 2: 2019
Amendment No. 1

| Type | Notation | Standard | Board designation | Grouping used in BRE SD1:2005 | |
|---|---|----------------------------------|-------------------|------------------------------------|---|
| Portland cement | CEM I | SS EN 197-1 | CEM I | A | |
| Sulfate-resisting Portland cements | CEM I-SR 0 | SS EN 197-1 | CEM I-SR 0 | G | |
| | CEM I-SR 3 | SS EN 197-1 | CEM I-SR 3 | G | |
| Portland silica fume cement ^{A)} | CEM II/A-D | SS EN 197-1 | IIA | A | |
| Portland limestone cement | CEM II/A-L | SS EN 197-1 | IIA | B ^{B)} or C ^{B)} | |
| | CEM II/A-LL | SS EN 197-1 | IIA | B ^{B)} or C ^{B)} | |
| Portland slag cements | CEM II/A-S | SS EN 197-1 | IIA | A | |
| | CEM II/B-S | SS EN 197-1 | IIB-S | A | |
| Portland natural pozzolana cements | CEM II/A-P | SS EN 197-1 | IIA | A | |
| | CEM II/B-P | SS EN 197-1 | IIB-P | A | |
| | CEM II/B-P+SR ^{C)} | SS EN 197-1 | IIB-P+SR | D | |
| Portland natural calcined pozzolana cements | CEM II/A-Q | SS EN 197-1 | IIA | A | |
| | CEM II/B-Q | SS EN 197-1 | IIB-Q | A | |
| | CEM II/B-Q+SR ^{D)} | SS EN 197-1 | IIB-Q+SR | D | |
| Portland fly ash cement | CEM II/A-V | SS EN 197-1 | IIA | A | |
| | CEM II/B-V | SS EN 197-1 | IIB-V | A | |
| | CEM II/B-V+SR ^{E)} | SS EN 197-1 | IIB-V+SR | D | |
| Portland composite cements ^{F)} | CEM II/A-M (S-L or LL) | SS EN 197-1 | IIA | B ^{B)} or C ^{B)} | |
| | CEM II/A-M (L or LL -S) | SS EN 197-1 | IIA | B ^{B)} or C ^{B)} | |
| | CEM II/A-M (P or Q-L or LL) | SS EN 197-1 | IIA | B ^{B)} or C ^{B)} | |
| | CEM II/A-M (L or LL-P or Q) | SS EN 197-1 | IIA | B ^{B)} or C ^{B)} | |
| | CEM II/A-M (V-L or LL) | SS EN 197-1 | IIA | B ^{B)} or C ^{B)} | |
| | CEM II/A-M (L or LL-V) | SS EN 197-1 | IIB-M | B ^{B)} or C ^{B)} | |
| | CEM II/B-M (S-L or LL) | SS EN 197-1 | IIB-M | B ^{B)} or C ^{B)} | |
| | CEM II/B-M (L or LL-S) | SS EN 197-1 | IIB-M | B ^{B)} or C ^{B)} | |
| | CEM II/B-M (P or Q-L or LL) | SS EN 197-1 | IIB-M | B ^{B)} or C ^{B)} | |
| | CEM II/B-M (L or LL-P or Q) | SS EN 197-1 | IIB-M | B ^{B)} or C ^{B)} | |
| | CEM II/B-M (V-L or LL) | SS EN 197-1 | IIB-M | B ^{B)} or C ^{B)} | |
| | CEM II/B-M (L or LL-V) | SS EN 197-1 | IIB-M | B ^{B)} or C ^{B)} | |
| | Blastfurnace cements | CEM III/A | SS EN 197-1 | IIIA | A |
| | | CEM III/A+SR ^{G)} | SS EN 197-1 | IIIA+SR | D |
| CEM III/B | | SS EN 197-1 | IIIB | A | |
| CEM III/B+SR ^{G)} | | SS EN 197-1 | IIIB+SR | F | |
| Pozzolanic cement | CEM IV/B(P) ^{H)} ^{I)} | SS EN 197-1 or BS EN 14216 | IVB-P | E | |



Singapore Standard SS 544: Part 2: 2019
Amendment No. 1

| Type | Notation | Standard | Board designation | Grouping used in BRE SD1:2005 |
|------|-----------------------------|----------------------------------|-------------------|-------------------------------|
| | CEM IV/B(Q) ^{J)K)} | SS EN 197-1 or BS EN 14216 | IVB-Q | E |
| | CEM IV/B(V) ^{L)} | SS EN 197-1 or BS EN 14216 | IVB-V | E |

Combinations conforming to Annex A are manufactured in the concrete mixer. They may be combinations of Portland cement and natural pozzolana, natural calcined pozzolana, high reactivity natural calcined pozzolana, fly ash, ggbs or limestone fines. They may also be combinations of CEM II/A-L or CEM II/A -LL cement with either natural pozzolana, natural calcined pozzolana, high reactivity natural calcined pozzolana, fly ash or ggbs

| | | | | |
|--|-----------------------------------|----------------------|-------------------|--|
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 6% to 20% of combination of limestone fines conforming to BS 7979 | CIIA-L CIIA-LL | SS 544-2, Annex A | IIA IIA | B ^{B)} or C ^{B)} B ^{B)} or C ^{B)} |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 6% to 20% of combination of ggbs conforming to SS EN 15167-1 | CIIA-S | SS 544-2, Annex A | IIA | A |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 21% to 35% of combination of ggbs conforming to SS EN 15167-1 | CIIB-S | SS 544-2, Annex A | IIB-S | A |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 6% to 20% of combination of natural pozzolana conforming to BS 8615-1 | CIIA-P | SS 544-2, Annex A | IIA | A |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 21% to 35% of combination of natural pozzolana conforming to BS 8615-1 | CIIB-P CIIB-P+SR ^{C)} | SS 544-2, Annex A | IIB-P IIB-P+SR | A D |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 6% to 20% of combination of natural calcined pozzolana to BS 8615-1 or high reactivity natural calcined pozzolana conforming to BS 8615-2 | CIIA-Q | SS 544-2, Annex A | IIA | A |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 21% to 35% of combination of natural calcined | CIIB-Q CIIB-Q+SR ^{D)} | SS 544-2, Annex A | IIB-Q IIB-Q+SR | A D |



Singapore Standard SS 544: Part 2: 2019
Amendment No. 1

| Type | Notation | Standard | Board designation | Grouping used in BRE SD1:2005 |
|--|---|-------------------|-------------------|------------------------------------|
| pozzolana to BS 8615-1 or high reactivity natural calcined pozzolana conforming to BS 8615-2 | | | | |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 6% to 20% of combination of fly ash conforming to BS EN 450-1 | CIIA-V | SS 544-2, Annex A | IIA | A |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 21% to 35% of combination of fly ash conforming to BS EN 450-1 | CIIB-V CIIB-V+SR ^{E)} | SS 544-2, Annex A | IIB-V IIB-V+SR | A D |
| CEM II/A-L or LL conforming to SS EN 197-1 with a mass fraction of 6% to 29% of combination of ggbs conforming to SS EN 15167-1, and where the mass fraction of Portland cement clinker of combination is not less than 65% | CIIB-M (S-L or LL) ^{F)} CIIB-M (L or LL-S) | SS 544-2, Annex A | IIB-M | B ^{B)} or C ^{B)} |
| CEM II/A-L or LL conforming to SS EN 197-1 with a mass fraction of 6% to 29% of combination of fly ash conforming to BS EN 450-1, and where the mass fraction of Portland cement clinker of combination is not less than 65% | CIIB-M (V-L or LL) ^{F)} CIIB-M (L or LL-V) | SS 544-2, Annex A | IIB-M | B ^{B)} or C ^{B)} |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 36% to 65% of combination of ggbs conforming to BS EN 15167-1 | CIIIA CIIIA+SR ^{G)} | SS 544-2, Annex A | IIIA IIIA+SR | A F |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 66% to 80% of combination of ggbs conforming to SS EN 15167-1 | CIIBB CIIBB+SR ^{G)} | SS 544-2, Annex A | IIIB IIIB+SR | A F |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 36% to 55% of combination of natural pozzolana conforming to BS 8615-1 | CIVB-P ^{I)} | SS 544-2, Annex A | IVB-P | E |
| CEM I cement conforming to BS EN 197-1 with a mass fraction of 36% to 55% of combination of natural calcined | CIVB-Q ^{K)} | SS 544-2, Annex A | IVB-Q | E |



Singapore Standard SS 544: Part 2: 2019
Amendment No. 1

| Type | Notation | Standard | Board designation | Grouping used in BRE SD1:2005 |
|---|----------|-------------------|-------------------|-------------------------------|
| pozzolana to BS 8615-1 or high reactivity natural calcined pozzolana conforming to BS 8615-2 | | | | |
| CEM I cement conforming to SS EN 197-1 with a mass fraction of 36% to 55% of combination of fly ash conforming to BS EN 450-1 | CIVB-V | SS 544-2, Annex A | IVB-V | E |

A) When IIA or IIA-D is specified, CEM I and silica fume may be combined in the concrete mixer using the k-value concept; see BS EN 206:2013+A1:2016, 5.2.5.2.3.

B) The classification is B if the cement or combination strength is class 42.5 or higher and C if it is class 32.5.

C) With a minimum proportion of natural pozzolana of 25%. The performance of CEM II/B-P cement and its equivalent combination CIIB-P are not covered by BRE SD1:2005 [2] but are categorized as 'D' on the basis that the performance of natural pozzolana in concrete is assumed to be similar to fly ash.

D) With a minimum proportion of natural calcined pozzolana or high reactivity natural calcined pozzolana of 25%. The performance of CEM II/B-Q cement and its equivalent combination CIIB-Q are not covered by BRE SD1:2005 [2] but are categorized as 'D' on the basis that the performance of natural calcined pozzolana or high reactivity natural calcined pozzolana in concrete is assumed to be similar to fly ash.

E) With a minimum proportion of fly ash of 25%.

F) Within the brackets the constituent listed first is the constituent with the highest proportion, e.g. (LL-S) means the proportion of limestone is greater than the proportion of ggbs and (V-L) means the proportion of siliceous fly ash is greater than the proportion of limestone.

G) Where the alumina content of the slag exceeds 14%, the tricalcium aluminate content of the Portland cement fraction shall not exceed 10%.

H) CEM IV/A cement with natural pozzolana should be classified as either CEM II/A-P (6%–20% natural pozzolana) or CEM II/B-P (21%–35% natural pozzolana).

I) The performance of CEM IV/B(P) cement and its equivalent combination IV/B(P) are not covered by BRE SD1:2005 [2] but are categorized as 'E' on the basis that the performance of natural pozzolana in concrete is assumed to be similar to fly ash.

J) CEM IV/A cement with natural calcined pozzolana or high reactivity natural calcined pozzolana should be classified as either CEM II/A-Q (6%–20% pozzolana) or CEM II/B-Q (21%–35% pozzolana).

K) The performance of CEM IV/B(Q) cement and its equivalent combination IV/B(Q) are not covered by BRE SD1:2005 [2] but are categorized as 'E' on the basis that the performance of natural calcined pozzolana or high reactivity natural calcined pozzolana in concrete is assumed to be similar to fly ash.

L) CEM IV/A cement with siliceous fly ash should be classified as either CEM II/A-V (6%–20% siliceous fly ash) or CEM II/B-V (21%–35% siliceous fly ash).



GREEN CONCRETE CUBE COMPETITION 2023

**Format for Write-Up (Criterion 4)
(Due Date: 10 Jul 2023 Mon)**

Report Content:

- i. Introduction
- ii. Description and Explanations
- iii. Diagrams/Illustrations
- iv. Interpretation of concepts with examples
- v. Conclusion
- vi. List of references (if applicable)

Requirement: Photo/s of recycled waste materials to be enclosed.

Report Format:

- i. Report not exceeding 3 pages (exclude photo/s of recycled waste materials)
- ii. Line Spacing 1.5
- iii. Font size 12