# KIND DESIGNS

## Technical Specifications for Living Seawalls™

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# I. About Kind Designs

Kind Designs is a Miami-based Climate-Tech startup 3D-Printing Living Seawalls™. Living Seawalls™ fortify coastal areas from flooding and storm surges, while fostering marine biodiversity and collecting essential water quality data.

Concrete seawall panels are traditionally made using molds and are primarily flat. Living Seawalls™ are made using 3D-Printing technology, which enables Kind Designs to incorporate micro textures and macro designs to transform the structural panel into an artificial reef. The wet face biomimicry design offers shelter 60% more surface area than a traditional seawall, encouraging colonization of marine life.  The Living Seawalls™ design enhances biodiversity while also mitigating the impact of waves and tides, supporting a healthier and more secure coastal environment.

Kind Designs commitment to positive impact to its coastal community drives the creation of Living Seawalls™, which serve as a harmonious fusion of technology, design, and environmental stewardship in our precious coastal cities.

*Figure 1A: Conventional flat, precast concrete seawall panel*

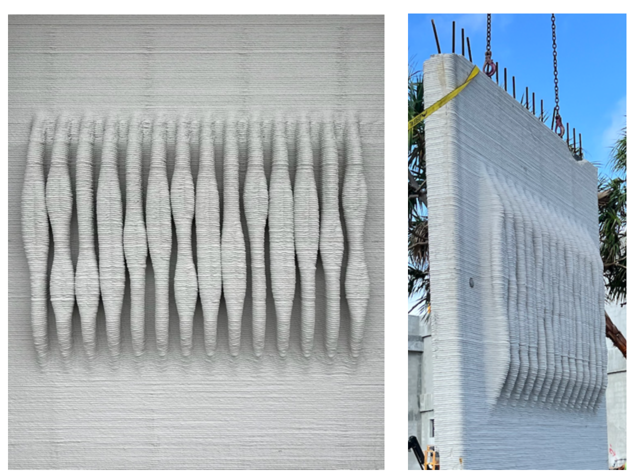

*Figure 1B & 1C: Kind Designs 3D-Printed seawall panel*

# II. 3D Printing Methodology

Kind Designs' Living Seawalls™ are structurally identical to conventional cast-in-place or precast concrete systems that have been used historically. Our panels are designed to be "plug & play" into existing seawall projects. With 3D printing technology we can customize our panels to meet exact specifications of already permitted seawall projects.

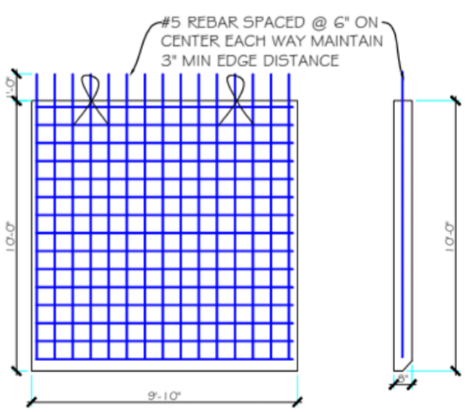


*Figure 2A: Engineering plans for 6431 Pine Tree Drive Circle, Miami Beach, FL 33143*

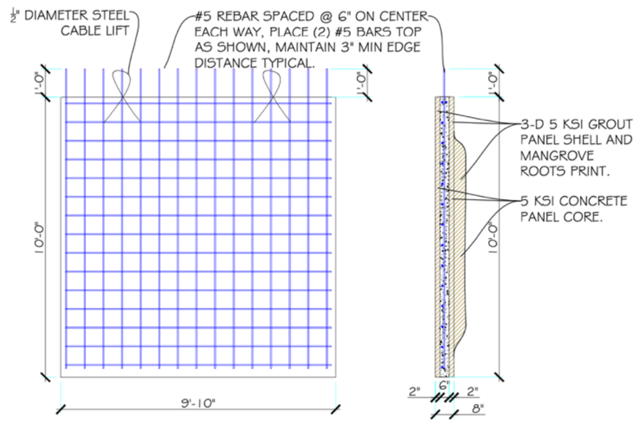


*Figure 2B: Kind Designs 3D-printed seawall panel shop drawing made to exact specifications detailed in plans for 6431 Pine Tree Drive Circle, Miami Beach, FL 33143*

*Figure 2C: 3D-printed component with fiberglass reinforcement*

*Figure 2D: 3D-printed component filled with interior core concrete fill and wire lifting hooks*

# III. CyBe Materials

## a. CyBe Overview and Material Specifications[1]

Kind Designs partnered up with Cybe Construction to manufacture its 3D-Printers. CyBe Construction is an award-winning tech company, established in the Netherlands in 2013. CyBe provides hardware, software, and material to simplify the complex building processes, and guides the industry through education, certification, and business development of 3D-Printing houses. Kind Designs has an exclusivity agreement with Cybe to apply their technology to 3D-Printing seawalls.

Cybe Construction produces CyBe Mortar, which is used for architectural, structural, industrial, and design projects regarding 3D concrete printing applications. It is a high-performance, single purpose material, and **durable in all environments.** Additionally, it is **non-metallic, and contains trace amounts of chloride and sulphate**. The material was specifically designed for 3DCP, together with their partner Korodur.

The use of CyBe Mortar with their 3D concrete print technology produces high durability objects where low shrinkage is desired. Their material sets rapidly allowing a fast and efficient printing process, a reduction of costs, and sustainable results.

*Table 1: Mortar Technical Specifications[3]*

| Type of Test | Result | Optimal Range | Testing Standard |
|---|---|---|---|
| Grain Size | 0-3mm | 0-5mm | DIN/BS EN 933-1 |
| Layer Thickness<br>*****Changes based on nozzle* | .5in *h* x 1.5-2in *w* | | |
| Setting Time | Initial set approx. 3 min<br>Final set approx. 5 min | | DIN/BS EN 196-3 |
| Load Bearing | After 60 min | | |
| Compressive Strength ($f_{ck}$) | After 5h:<br>approx. 20 N/mm$^2$<br>(approx. 2901 psi)<br>After 1d:<br>approx. 25 N/mm$^2$<br>(approx. 3626 psi)<br>After 7d:<br>approx. 30 N/mm$^2$<br>(approx. 4351 psi)<br>After 28d: | after 28d:<br>approx. 34 N/mm$^2$<br>approx. 5,000psi | DIN/BS EN 12390-13<br>DIN/BS EN 1015-11<br>DIN/BS EN 12504-1 |

| | | | |
|---|---|---|---|
| | approx. 40 N /mm² (approx. 5802 psi) | | |
| Tensile Bond Strength ($f_{ctm}$)<br>**Parallel to layer: //*<br>**Perpendicular to layer: ⊥* | After 1d:<br>// approx. 2.4 N/mm² approx. 348 psi<br>⊥ approx. 2.4 N/mm² approx. 348 psi<br>After 28d:<br>// approx. 4 N/mm² approx. 580 psi<br>⊥ approx. 2.4 N/mm² approx. 580 psi | After 28d:<br>approx. 3.4 N/mm²<br>approx. 500 psi | DIN/NEN EN 1542<br>CUR Aanbeveling 20 |
| Flexural strength (psi)<br>**Identical in different orientations perpendicular and parallel to layer* | After 5h:<br>approx. 4 N/mm²<br>approx. 580 psi<br>After 1d:<br>approx. 4 N/mm²<br>approx. 580 psi<br>After 7d:<br>approx. 5 N/mm²<br>approx. 725 psi<br>After 28d:<br>approx. 6 N/mm²<br>approx. 870 psi | After 28d:<br>approx. 6 N/mm²<br>approx. 870 psi | DIN/BS EN 1015-11<br>DIN/BS EN 13892-2 |
| Density ($p$) | Hardened:<br>approx. 2100-2200 kg/m³<br>approx. 137 lbs/ft³ | approx. 2070kg/m³<br>approx. 137 lbs/ft³ | DIN/EN 12390-13<br>DIN/EN 12390-7<br>DIN/BS EN 12504-1 |
| Flow | approx. 160mm<br>approx. 6.3in | Variable by mixing method or design | ASTM C1437-01 |
| Air void content | approx. 5.3 Vol.-% | | DIN/BS EN 1015-7; Method A |
| Static stabilized secant E-modules (Ecm) | approx. 26.000–28.000 N/mm² | Variable based on material | DIN/EN 12390-13; Method B<br>DIN/EN 13412 |
| Thermal resistance<br>**At mean temperature 35 °C* | 0,054 (m²*K)/W | Variable based on material | ASTM C177:10 |
| Thermal conductivity (λ)<br>**At various temperatures, based on corresponding standard* | 0,781^(1^ –0,979 ^(2^W/(m.K)<br>*^(1^ Performed on 3D printed specimen*<br>*^(2^ Performed on densified lab specimen* | Variable based on material | DIN 52612 |
| Specific heat capacity (c) | 1.10 J/(g*K) 3 0.06 | Variable based on material | Determined with Macro-DSC |
| Thermal expansion coefficient ($\alpha_m$) | 15,0 * 10-6/K | Variable based on material | DIN EN 1770 |
| Depth of water penetration | approx. 23 mm (approx. 1 in) | Variable based on material | DIN EN 12390-8 |
| pH value | 12 | Variable based on material | |
| Sulfate resistance<br>*According to W. Wittekindt* | Requirement fulfilled; *high chemical resistance* | Variable based on material | According to W. Wittekindt<br>From: ZKG, Zement, Kalk, Gips - 1960 |
| Fire classification | Class A1: non-combustible | | DIN EN 13501-1; acc.to EN ISO 1182 and EN ISO 1716 |

* *See Appendix A for definition of testing standards and their ASTM equivalent, if applicable*

## b. Cement in CyBe mortar[1]

Cybe Mortar uses Belite Calcium sulfoaluminate (B-CSA) instead of calcium aluminate cement (CAC). B-CSA cements operate on a totally different chemistry than CAC. In the B-CSA system, the aluminum is present as a calcium sulfoaluminate C4A3S, which hydrates into ettringite first (for rapid strength gain). The rest of the cement is mostly composed of belite, the same major phase that is found in Portland cement. B-CSA cements DO NOT undergo strength regression.

Comparison with Type II Portland Cement (most used in seawall construction):

i. Early Strength:

C3S, or “alite” is the compound responsible for early strength development in Type II Portland. C3S contributes strength in the first 1-3 days. In B-CSA cement the C3S is replaced by C4A3S, which hydrates much faster, developing strength in 1-3 hours.

ii. Long Term Strength:

C2S, or “belite” is the compound responsible for long-term strength gain in Portland cement. It hydrates slowly, developing strength from about 7 days, continuing for long periods of time, up to many years.

That is why some portland cements are very high in C2S, it is made for large structures and mass pours like dams, developing strength (and generating heat) slowly. B-CSA cement has an even higher C2S content than most portland cements, meaning it has the highest potential of long-term strength gaining ability.

iii. Sulfate Resistance:

C3A is the compound in portland cement that reacts with sulfates in water and soil, causing late age expansion that can damage the concrete. To limit this damage, special sulfate resistant Portland cements are limited to a maximum of 5% C3A. B-CSA cement has zero detectable C3A, giving it absolute sulfate resistance.

### c. Aggregates[1]

The sieve analysis determines the gradation and uniformity of particle sizes, which are critical factors in determining the workability and strength of concrete.

Well-graded aggregates lead to higher packing density in cementitious mixes. When particles of various sizes are present, they can fill the voids between each other more effectively, resulting in a denser and more cohesive mixture. Properly graded aggregates help minimize the risk of segregation and bleeding in cement, which can compromise the quality and durability of the product. Proper distribution of particle sizes contributes to the overall strength and durability of the product. A well-graded aggregate ensures a more homogenous mix, reducing the likelihood of weak zones or areas of poor interlocking between particles.

*Table 2a: Sieve Analysis of Aggregate Distribution in Mortar – Sand[1]*

| Bagging line | Amount (%) | Amount (g) |
|---|---|---|
| Quarz 0-0.2 mm | 16.57 | 331.40 |
| Quarz 0.1-0.5 mm | 20.82 | 416.40 |
| Quarz 0.5-1.0 mm | 46.06 | 921.20 |
| Quarz 1-3 mm | 16.55 | 331.00 |

| | |
|---|---|
| Amount of powder (g) | 2,000.0 |

*Table 2b: Sieve Analysis of Aggregate Distribution in Mortar – Powder[1]*

| Mesh size (mm) | Mass retained (g) | Mass retained (%) | Cum. Mass retained (%) |
|---|---|---|---|
| <0.09 | 4.45 | 0.22 | 0.22 |
| <0.25 | 345.50 | 17.28 | 17.50 |
| <0.50 | 391.00 | 195.5 | 37.05 |
| <0.63 | 120.50 | 6.03 | 43.07 |
| <1.00 | 616.00 | 30.80 | 73.87 |
| <20.0 | 274.65 | 13.73 | 87.61 |
| <3.15 | 245.00 | 12.5 | 99.86 |
| >3.15 | 29.0 | 0.15 | 100.00 |

## d. CyBe Sustainability Statement

*Table 3: CyBe Mortar Statement/Sustainability*[1]

| | |
|---|---|
| Product Description | CyBe Mortar is a ready to use, cementitious dry mortar on the basis of a high-performance fast setting cement for printing processes. |
| Production Facility | KORODUR Werk Bochum-Wattenscheid<br>44866 Bochum |
| Recycled Content | Recycled Content Post Consumer: 0%<br>Recycled Content Pre-Consumer: >12% |
| Origin of Resources | Average transport distance of primary resources 70% < 100 km<br>20% not specified |
| Carbon Footprint | Approx. 32 % lower in comparison to Portland Cement |
| EPD | Modified mineral mortars, group 1<br>EPD-FEI-20160017-IBG1-EN<br>** "Declaration of Conformity for Products with Model EPD" attached |
| Emission of VOC | Volatile Organic Content < 1 % |

## e. Producer of CyBe Mortar[2]

[2]Korodur International is the manufacturer of CyBe Mortar. Since 1936 KORODUR has been a specialist in the production of mineral hard aggregates for cementitious heavy-duty industrial floors. On international scale, more than 750 million square meters of KORODUR industrial floors have been installed.

KORODUR is known not only thanks to its high-quality industrial floors, but also specializes in:

- MICROTOP® – shotcrete mortar for drinking water reservoirs
- 3D Concrete Printing

KORODUR

## Manufacturer's Statement – CyBe Mortar

As of 02/2024

CyBe Mortar is a high-performance material used for 3D concrete printing and is durable in all environments. It is only to be used with a 3D concrete printer to produce objects with high durability and low shrinkage.
CyBe Mortar is a fast setting material. It sets in 3 minutes and achieves structural strength in 1 hour.

We hereby confirm:

CyBe Mortar is suitable for use underwater.

Contact with water has no effect on objects produced using CyBe Mortar.

CyBe Mortar does not contain any metallic elements, chlorides or sulfates.

A change in pH, if present at all, is to be evaluated like in normal concrete.

**KORODUR International GmbH**

Frank Sander
Technical Director

*Image 2: Korodur International Sustainability Statementy[2]*

# IV. Reinforcement

We can fabricate our panels with any type of reinforcement bar (rebar) per customer request or as required to meet project specifications.

Steel #5 Rebar

- Grade: 60 ksi
- Follows ASTM A615/A615M-22 standard

*Table 4: A615 SCH40 Mechanical Information*[3]

| | Strength (psi) |
|---|---|
| Ultimate Tensile Strength | 90,000 |
| Yield Tensile Strength | 60,000 |

**See Appendix A for definition of testing standards*

FIBERGLAS™ Rebar

*Table 5: Physical & Mechanical Properties*[4]

| NOMINAL DIAMETER | | | NOMINAL CROSS SECTIONAL AREA | | UNIT WEIGHT/ LENGTH | | GUARANTEED ULTIMATE TENSILE FORCE | | GUARANTEED ULTIMATE TENSILE STRENGTH | | ULTIMATE TENSILE STRAIN | MEAN TENSILE MODULUS OF ELASTICITY | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bar Size | in | mm | $in^2$ | $mm^2$ | lb/ft | kg/m | kip | kN | ksi | MPa | % | Msi | GPa |
| #2 | 0.25 | 6 | 0.05 | 32 | 0.05 | 0.07 | 6.76 | 30.08 | 138.0 | 951 | 2.03% | 6.80 | 46.88 |
| #3 | 0.375 | 10 | 0.11 | 71 | 0.11 | 0.16 | 15.07 | 67.03 | 137.0 | 945 | 2.01% | 6.80 | 46.88 |
| #4 | 0.500 | 13 | 0.20 | 129 | 0.18 | 0.27 | 26.90 | 119.66 | 134.5 | 927 | 1.98% | 6.80 | 46.88 |
| #5 | 0.625 | 16 | 0.31 | 199 | 0.32 | 0.47 | 40.30 | 179.26 | 130.0 | 896 | 1.91% | 6.80 | 46.88 |

| MEAN TRANSVERSE SHEAR STRENGTH | | BOND STRENGTH | | FIBER MASS CONTENT | MOISTURE ABSORPTION IN 24 H AT 50°C (122°F) | MOISTURE ABSORPTION TO SATURATION AT 50°C (122°F) | MEAN GLASS TRANSITION TEMPERATURE (DSC) | |
|---|---|---|---|---|---|---|---|---|
| ksi | MPa | psi | MPa | % | % | % | °F | °C |
| ≥19 | ≥131 | ≥1100 | ≥7.6 | ≥70 | ≤0.25 | <1.0 | ≥212 | ≥100 |

## V. Interior Concrete Fill[5]

The core of our panels is filled with standard concrete used in marine applications throughout South Florida. A standard, 5,000psi, 3/6” pumpable, Ready-Mix concrete produced locally. Our Design allows for the use of other mixes based on project requirements.

Components[5]:
10%-15% cement
60%-75% aggregate
10%-15% water
3%-5% Entrained air

| | | |
|---|---|---|
| Designed Slump: | 6.5” +/- 1.5” | Optimal range 4” to 8” |
| Designed Unit Weight: | 139.1 lbs/cu.ft | |
| Design Air: | Entrapped | |
| Designed W/C Ratio: | 0.40 | |

# VI. Ongoing Technical Tests

1. In-field destructive testing
2. 3-point load testing – University of Miami
3. Modeling wave dissipation capacity of Living Seawalls™ modeling – University of Florida (UF)
4. Modeling Erosion and resuspension prevention by Living Seawalls™ - UF
5. Monitoring Ecological Enhancement of Living Seawalls™ - Florida International University (FIU)
6. Measure Carbon Sequestration of Living Seawalls™ - FIU

# Appendix A[3,6]

*(in order of appearance in document)*

DIN/BS EN 933-1 - The Standard for Tests for geometrical properties of aggregates - Determination of particle size distribution.

- ASTM equivalent: ASTM C136 - Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates

DIN/BS EN 196-3 - specifies the methods for determining standard consistency, setting times and soundness of cements.

- ASTM equivalent: ASTM C151 - autoclave expansion test (AET)

DIN/BS EN 12390-13 - Methods for the determination of the secant modulus of elasticity in compression of hardened concrete on test specimens which can be cast or taken from a structure.
Method B - method B is for determination of stabilized modulus only.

- ASTM equivalent: ASTM C469 - Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression

DIN/BS EN 1015-11 - Methods of test for mortar for masonry determination of flexural and compressive strength of hardened mortar

- ASTM equivalent: ASTM C109 - Standard Test Method for Compressive Strength of Hydraulic Cement Mortars

DIN/BS EN 12504-1 - Method for taking cores from hardened concrete, their examination, preparation for testing and determination of compressive strength.

- ASTM equivalent: ASTM C42/C42M-20 - Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.

DIN/NEN EN 1542 - Products and Systems for The Protection and Repair of Concrete Structures - Test Methods - Measurement of Bond Strength by Pull-Off

- ASTM equivalent: ASTM C1583-13 - Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method)

DIN/BS EN 1015-11 - Method for determining the flexural and compressive strength of molded mortar specimens. This document is applicable to cement/air-lime mortars, air-lime mortars, mortars with hydraulic binders and retarded mortars.

- ASTM equivalent: ASTM C348-21 - Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars

DIN/BS EN 13892-2 - Methods of test for screed materials determination of flexural and compressive strength

- ASTM equivalent: ASTM C348-02 - Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars

DIN EN 12390-7 - Testing hardened concrete - Density of hardened concrete.

- ASTM equivalent: ASTM C642-21 - Standard Test Method for Density, Absorption, and Voids in Hardened Concrete

ASTM C1437-01 - Standard Test Method for Flow of Hydraulic Cement Mortar

DIN/BS EN 1015-7; Method A - methods for determining the air content of fresh mortars including those containing mineral binders and both dense and lightweight aggregates. Method A "The pressure method."

- ASTM equivalent: ASTM C231-09a - Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

DIN/EN 13412 - specifies two methods for determining the modulus of elasticity in compression for repair products and systems.

- ASTM equivalent: ASTM C469 - Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression

ASTM C177:10 - Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

DIN 52612 - Testing of thermal insulating materials; This standard gives the procedure to be followed to obtain from the measured values of thermal conductivity by means of the guarded hot plate apparatus; conversion of the measured values for building applications.

- ASTM equivalent: The ASTM C177-19 - Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus.

DIN EN 1770 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of the coefficient of thermal expansion

- ASTM equivalent: ASTM E831-19 - Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis

DIN EN 12390-8 - method for determining the depth of penetration of water under pressure in hardened concrete which has been water cured.

- ASTM equivalent: ASTM C803/C803M-18 -Standard Test Method for Penetration Resistance of Hardened Concrete

DIN EN 13501-1 - the fire classification specified in each of the product standards that enable products to be CE Marked, as required by The Construction Products Regulation (EU) No 305/2011.
acc.to EN ISO 1182 - Reaction to fire tests for products — non-combustibility test; and EN ISO 1716 - method for the determination of the gross heat of combustion (QPCS) of products at constant volume in a bomb calorimeter.

- ASTM E136-22 - Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750 °C
- ASTM D240-19 - Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (gross heat combustion).

ASTM A615/A615M-22 - Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.

# Glossary

1. Compressive Strength - the capacity of concrete to withstand loads before failure.
2. Concrete Slump Test - measures the plasticity of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows.
3. Entrained Air - microscopic air bubbles intentionally incorporated into concrete during mixing, usually by use of a surface-active agent.
4. Entrapped Air - Naturally occurring air pockets, or irregularly sized air voids, spread throughout the concrete.
5. Flexural Strength - the maximum stress in a material just before it yields in a bending test.
6. Flow - indicates the workability and consistency of a cementitious material. A higher flow value signifies a more fluid and workable mixture, while a lower value implies a stiffer and less workable mixture.
7. Gradation- The distribution of aggregate particles, by size, within a given sample.
8. Density - Higher density correlates to higher strength
9. Modulus of Elasticity of Concrete - the ratio of stress applied on the concrete to the respective strain caused.
10. Soundness - describes cement paste specimens that do not exhibit cracks, disintegration, or other flaws, that result from excessive volume change.
11. Specific Gravity - the ratio of the density of a substance to the density of some substance (as pure water) taken as a standard when both densities are obtained by weighing in air.
12. Specific Heat Capacity - measures the ability of a material to absorb thermal energy.
13. Tensile Bond Strength - the strength developed when a tensile load is applied normal to the bonded faces. The ability of a material to resist loads under stress or deformation, without failure.
14. Thermal Conductivity - Indicates how effectively the material conducts heat.
15. Thermal Resistance - Signifies the material's ability to resist heat flow.

# References

[1] Data provided by CyBe Concrete

[2] Data provided by KORODUR International GmbH

[3] Data & information provided by ASTM International

[4] Data provided by Owens Corning Infrastructure Solutions

[5] Data provided by Ready-Mix Vendor

[6] Information Provided by BSI GROUP