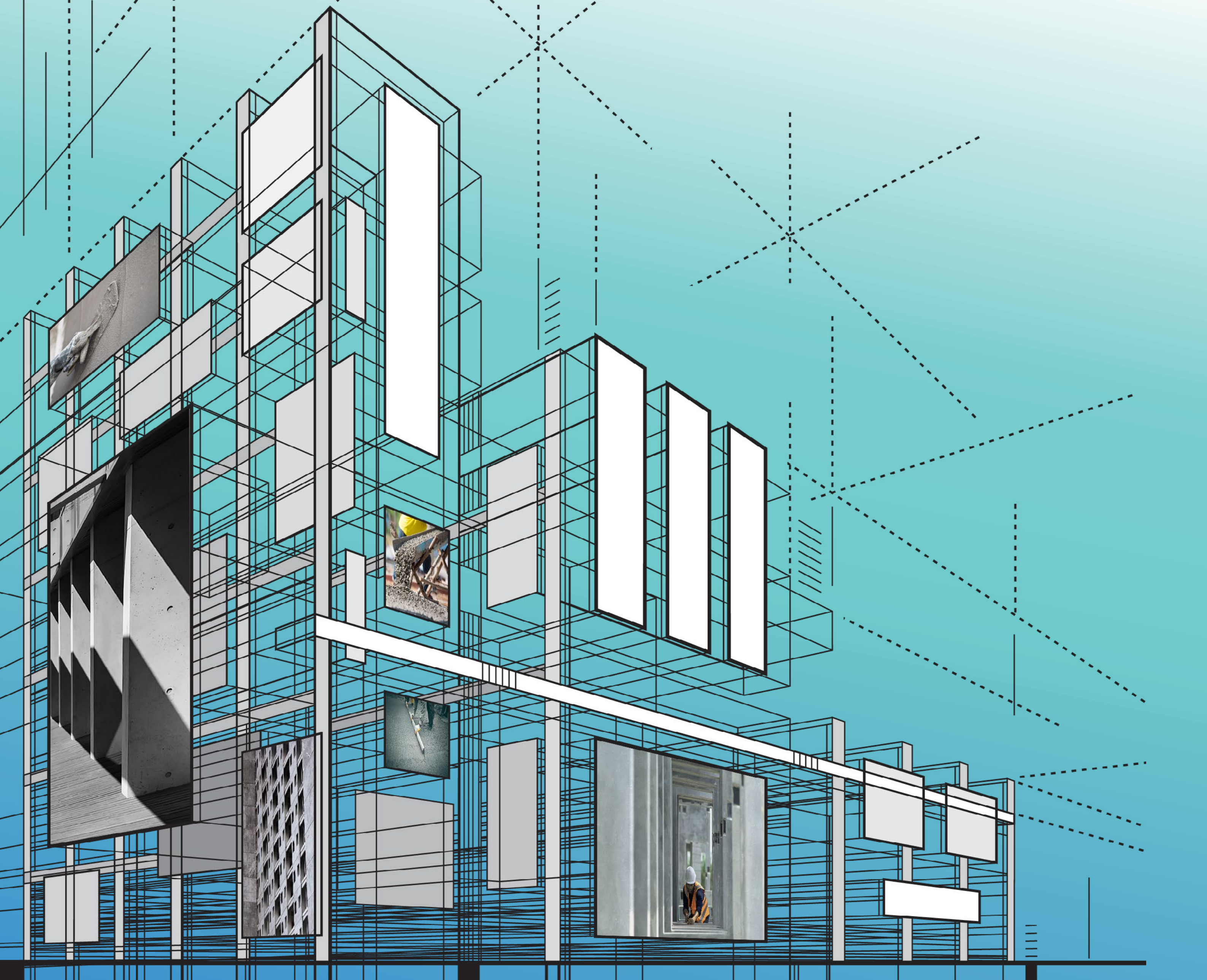
Building and Construction Authority

BuildSG

eResource for DEPLOYING INNOVATIVE CONCRETE SOLUTIONS in Singapore

Version February 2025

Pre-release



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COMMON TERMS AND ACRONYMS USED IN SINGAPORE

1. **Institute of Higher Learning (IHL)** refers to the institutes that offer tertiary or post-secondary level academic education in Singapore's context, i.e., the universities or polytechnics.

2. **Qualified Person** refers to: (i) an architect under the Architects Act who has in force a practising certificate issued under that Act, or (ii) a professional engineer under the Professional Engineers Act who has in force a practising certificate issued under that Act.

3. **Specialist** refers to a person with expert knowledge in the relevant field. This can be an academic or practitioner with extensive experience and is skilled in concrete technology, such as concrete structural design, repairs, etc. They should preferably have excellent track records such as being a member of relevant technical workgroups or committees, and have publications in prestigious journals like Magazine of Concrete Research, etc.

4. Singapore's public organisations and their functions:
   - **Building and Construction Authority (BCA)** is a statutory board under the Ministry of National Development that champions the development and transformation of the built environment sector to improve Singapore's living environment. BCA oversees areas such as safety, quality, inclusiveness, sustainability and productivity, all of which, together with our stakeholders and partners, help to achieve our mission to transform the Built Environment sector and shape a liveable and smart built environment for Singapore.

   - **Housing and Development Board (HDB)** is a statutory board under the Ministry of National Development and is Singapore's public housing authority. HDB plans, develops Singapore's housing estates, and provides affordable homes of quality and value to Singaporeans; transforming towns to create a well-planned, vibrant and sustainable towns and providing a quality living environment for all.

   - **JTC Corporation (JTC)**, as a government agency under Singapore's Ministry of Trade and Industry, is paving the way forward for Singapore's industrial landscape with sustainable, green, and smart estate master plans such as one-north, Seletar Aerospace Park, Jurong Innovation District, and Punggol Digital District. JTC's estates attract new investments and foster collaborative ecosystems that strengthen Singapore's position as an advanced manufacturing hub. JTC also drives innovation in the Built Environment sector by piloting new construction technologies.

   - **Land Transport Authority (LTA)** is a statutory board under the Ministry of Transport. LTA spearheads land transport developments in Singapore. LTA plans, designs, builds, and maintains Singapore's land transport infrastructure and systems.

   - **National Environment Agency (NEA)** is a statutory board under the Ministry of Sustainability and the Environment. NEA is the leading public organisation responsible for ensuring a clean and sustainable environment for Singapore. Its key roles are to improve and sustain a clean environment, promote sustainability and resource efficiency, maintain high public health standards, provide timely and reliable meteorological information, and encourage a vibrant hawker culture. NEA works closely with its partners and the community to develop and spearhead environmental and public health initiatives and programmes. It is committed to motivating every individual to care for the environment as a way of life, in order to build a liveable and sustainable Singapore for present and future generations.

   - **PUB, Singapore's National Water Agency** is a statutory board under the Ministry of Sustainability and the Environment. It is the national water agency, which manages Singapore's water supply, water catchment, and used water in an integrated way.

PREFACE

The refreshed Built Environment (BE) Industry Transformation Map (ITM) was launched in September 2022. The ITM takes a building lifecycle approach towards the transformation of the BE sector, via the three key transformation areas of (i) Integrated Planning and Design; (ii) Advanced Manufacturing and Assembly; and (iii) Sustainable Urban Systems. Innovation is key to pushing the boundaries as part of our industry transformation efforts.

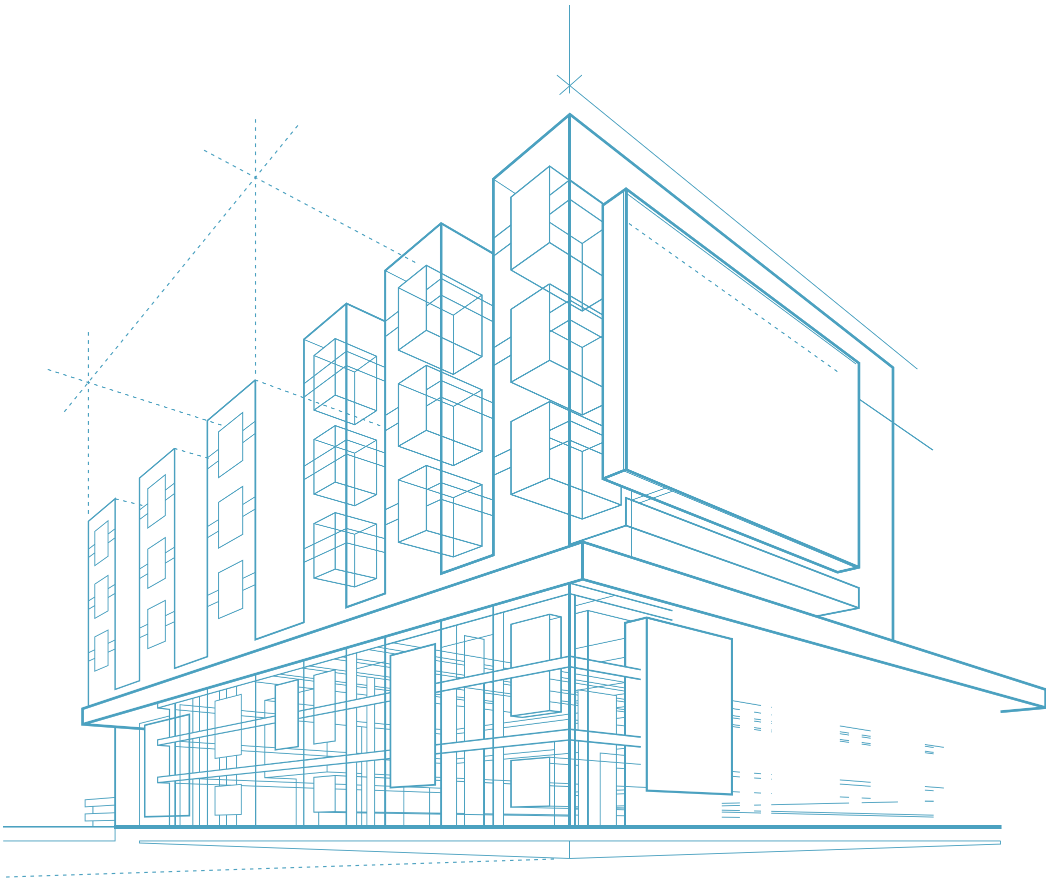
There are growing demands for construction materials that are (i) sustainable and environmentally friendly, to support decarbonisation efforts, (ii) high-strength and lightweight, to support higher construction productivity and reduce volume of materials used, and (iii) durable and low maintenance that are climate-resilient, to reduce long-term maintenance needs.

Underpinned by this demand, there has been an increase in innovative materials and material production technologies for building and construction applications in recent years. Local and overseas innovators and solution providers may face uncertainties as to how to gain industry acceptance for such innovative concrete materials. This eResource was initiated to facilitate this process, by providing a reference on the types of property and performance validation tests required and the test standards, codes and regulatory requirements to comply with in Singapore.

ACKNOWLEDGEMENT

BCA would like to express gratitude to our partners from both the public and private sectors for their support and contributions to the development of this eResource:

- American Concrete Institute (Singapore Chapter)
- Alliance Concrete Singapore Private Limited
- Association of Consulting Engineers Singapore
- CAST Laboratories Private Limited
- Centre of Innovation for the Built Environment – Advanced Materials (COIBE-AM)[1]
- Element Construction Testing (S) Private Limited
- EnGro Corporation Limited
- Housing and Development Board
- Island Concrete (Private) Limited
- JTC Corporation
- Land Transport Authority
- Nanyang Technological University
- National University of Singapore
- Pan-United Concrete Private Limited
- Samwoh Corporation Private Limited
- Setsco Services Private Limited
- Singapore Green Building Council
- TUV SUD PSB Private Limited



[1] A collaborative effort of Republic Polytechnic, Singapore Polytechnic and Temasek Polytechnic

DISCLAIMER

This eResource is intended for reference and does not purport to be exhaustive or applicable to all situations.

The Building and Construction Authority disclaims any liability (including any liability arising from negligence) arising in respect of any matter and the consequences of any act done or not done by any person in reliance on anything in or omitted from this eResource.

Readers should take note of the limitations in coverage and scope, despite utmost efforts to make the eResource as comprehensive and relevant as possible. Additionally, readers should not interpret the information presented in the eResource as an endorsement of any specific material or technology by the Building and Construction Authority.

The tests, standards, and codes for the test methods listed in this eResource are not exhaustive and are accurate at the time of publication. Readers are encouraged to refer to the latest standards. For undated standards, the latest published edition (including amendments) will be applicable.

Qualified Persons of construction projects in Singapore (typically a registered Architect or Professional Engineer) and solution providers should ensure that the design and performance of the new materials or solutions align with the latest relevant standards, even if not explicitly listed in the eResource. They should also comply with the prevailing building regulations, codes of practice, and product specifications.

This eResource may be updated or amended from time to time. Please refer to the website of the Building and Construction Authority: www.bca.gov.sg for the latest version of this eResource.

Chapter 1

The importance of performance testing

Concrete is the most commonly used building material worldwide. Recently, there has been growing interest in innovations that enhance its performance or reduce its carbon footprint. Materials like supplementary cementitious materials (e.g., ground granulated blast-furnace slag and silica fume), fibres, and carbon dioxide can be added to traditional concrete to improve its properties.

To assess the impact of these new materials, testing is essential. These tests help determine the materials' properties and ensure they are safe for local construction needs. To this end, in Singapore, testing regimes are put in place to ensure adequacy and continued compliance of the material for structural applications. For such material tests, they are to be done by facilities accredited by the Singapore Accreditation Council (SAC); the concrete produced for structural applications must also come from plants certified by SAC-accredited certification bodies. Tests are conducted according to international standards, and the results can be compared with benchmark values or other materials for verification. Besides proving performance, solution providers can use these test results to gain recognition under industry certification schemes, which help their innovations gain acceptance.

The following chapters will guide solution providers on the appropriate tests to demonstrate the different material properties and their performance to meet regulatory requirements, as well as the local testing facilities providing these tests. Annexes A and B provide detailed information on these tests. In addition to the common tests, some adopters may request additional tests to meet specific needs. Annex C will cover the available commercial and institutional testing facilities in Singapore.

Beyond verifying performance through testing, solution providers should promote their innovations to the industry to build awareness and acceptance. Sharing the solution's safety and quality benefits with key stakeholders — such as developers, design consultants (Qualified Persons or QPs), and builders — can build confidence. Some ways solution providers can engage these stakeholders include organising exhibitions, seminars, and conferences.

Chapter 2

Singapore's standards and test requirements for concrete solutions

Test requirements and procedures are documented in international standards, such as those from the American Society for Testing and Materials (ASTM), British Standards European Norms (BS EN), Singapore Standards (SS), and Singapore Standards Eurocode (SS EN). These standards ensure that recognised testing methods are followed. However, while they often cover similar concrete properties, different standards may require different testing methods. Standards can also include country-specific parameters. For example, in Singapore, supplementary SS standards complement SS EN 206.

In Singapore, the required testing standards for compliance are based on the Eurocodes and are performance-based. SS EN or BS EN standards take priority unless there is no relevant standard for a particular test method, in which case other reference standards, like ASTM, can be used. Likewise, in general, test laboratories are commonly accredited by SAC for test methods based on the SS EN or BS EN standards. However, these commercial test laboratories are not likely to be accredited for new test methods if such tests are envisaged. Notwithstanding that, the results of such tests can be considered for acceptance, if carried out by a recognised IHL.

When designing and constructing buildings or infrastructure, the performance requirements in the Building Control Regulations and the Approved Document (aligned with the Building Control Act) must be followed. The Approved Document lists "acceptable solutions" — if a building or structure is designed and constructed using these solutions according to the prescribed codes and standards, it is deemed to satisfy the Building Control Regulations.

For solutions that are not listed within the Approved Document, a performance-based design approach known as "design assisted by testing" can be used. This approach allows new materials or methods to be accepted if they meet the required performance requirements. Under Singapore's regulatory framework, solutions may be approved if they meet the following criteria:

- Compliance with Eurocodes,
- Certified performance by a specialist, or
- Verification through:
    - Standards not listed in the Approved Document
    - Technical publications or guidelines
    - Credible laboratory test results and reports
    - Evidence of the material's successful use elsewhere

One example of performance-based design using "design assisted by testing" is steel fibre reinforced concrete. Since there is no design standard[2] for this material in the Eurocodes and no listed acceptable solutions, international standards such as TR-36/67, ACI-544, FIB Model Code, and NFP 18-710 were used. Steel fibre reinforced concrete was accepted after demonstrating its performance through tests and by studying its use in projects, both overseas and locally.

[2] The Singapore Standard SS 674: 2021 Fibre concrete – Design of fibre concrete structures has now been published and is based on Swedish standard SS 812310: 2014.

Chapter 3

Types of tests for concrete solutions

Concrete tests are generally grouped into three main categories:

1. Tests for raw material properties
2. Tests for the properties of the concrete product
3. Tests for the structural behaviour of reinforced concrete

Figure 3.1 gives an overview of these categories and the scope covered in this eResource.

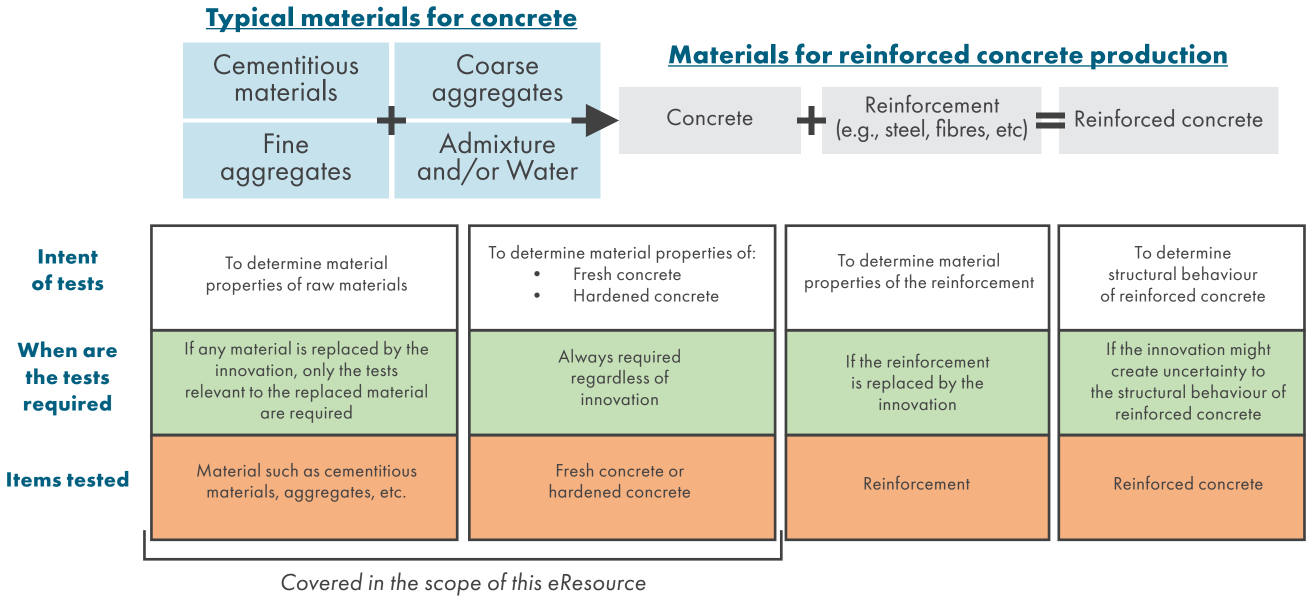


Figure 3.1: Composition of concrete, intent of different tests, and the need for such tests

1. Tests for raw material properties

Raw material tests focus on the constituents of concrete, such as cementitious materials, aggregates, admixtures, and water. These tests are performed when an innovation partially or fully replaces one or more of the constituents in concrete production. The goal is to understand the properties of the replacement constituent, its interaction with the other concrete constituents and how it affects the concrete.

Rather than testing every material in the mix, only tests relevant to the material being replaced should be conducted. For instance, if Ordinary Portland Cement is replaced by an innovative material, only tests related to cementitious materials are necessary. However, additional tests may be needed to examine how the new material impacts other properties, such as cement setting time which depends on the chemical reactions involved, as well as the application of the eventual concrete product.

Table 3.1 lists the common material property tests and standards for concrete raw materials, which are crucial for the quality and performance of concrete. More details on these tests can be found in Annex A.

Table 3.1. Typical tests conducted for raw materials

Raw material	Material property test	Standards adopted in Singapore
Cement	Autogenous shrinkage	ASTM C1698
	Cement compressive strength	SS EN 196-1
	Chemical analysis	BS EN 196-2
	Conformity of cement	SS EN 197-1 and 2
	Conformity of fly ash	BS EN 450-1 and 2
	Conformity of ground granulated blast-furnace slag	SS EN 15167-1 and 2
	Conformity of silica fume	BS EN 13263-1 and 2
	Drying shrinkage	ASTM C157
	Fineness test	BS EN 196-6
	Heat of hydration	BS EN 196-11
Aggregates	Setting time, soundness, consistency	BS EN 196-3
	Aggregates crushing value, fragmentation/impact resistance	BS EN 1097-2
	Angularity	BS 812-1
	Bulk density, voids, and bulking	SS EN 12620 and BS EN 1097-3
	Chemical properties of aggregates (eg. sulphate, chloride, sulphur, etc)	BS EN 1744-1, 5, and 6
	Drying shrinkage	BS EN 1367-4
	Elongation	ASTM D4791
	Fineness modulus/sieve analysis	BS EN 933-1
	Flakiness	SS EN 12620 and BS EN 933-3
	Particle density and water absorption	SS EN 12620 and BS EN 1097-6
	Particle shape and texture	SS EN 12620 and BS EN 933-4
	*Potential alkali reactivity[#] of aggregates by mortar bar method *To be conducted if the innovation is susceptible to alkali reaction	ASTM C1260
	^Potential alkali reactivity[#] of aggregates by petrographic examination ^To be conducted if the innovation is susceptible to alkali reaction	ASTM C295/C295M
Mixing water	Properties and quality of water	BS EN 1008
Admixtures	Common requirements and conformity of admixtures	SS EN 934-1 and 2

[#]Refer to Annex A.2.h for more details on measures to mitigate Alkali-Silica Reaction.

2. Tests for the properties of the concrete product

Concrete product tests are performed on the concrete after all its constituents have been mixed, both in its fresh and hardened states. Any innovation involving new materials added to the mix can affect the final product's properties, so these tests are necessary for all new materials. The tests focus on two key areas: the properties of fresh concrete right after mixing, and the properties of hardened concrete after it has set. Fresh concrete tests also help determine quality control measures required to ensure subsequent batches can meet the required specifications.

More information about common concrete product tests and their significance can be found in Annex B, while Table 3.2 provides a list of typical fresh concrete tests based on current standards.

Table 3.2. Typical tests conducted for fresh concrete

Fresh concrete property	Standards adopted in Singapore
Bleeding of concrete	BS EN 480-4
Concrete setting time	ASTM C403/C403M
Workability by slump test	BS EN 12350-2#
Workability by Vebe time	BS EN 12350-3
Workability/slump flow of self-compacting concrete	BS EN 12350-8

Refer also to SS 544-1 which defines workability as expressed by consistence class

Test results of hardened concrete are used as key performance indicators. For instance, they help assess the strength development of the concrete, which can provide an indication to project parties as to whether the concrete has gained sufficient strength such that the formwork and other supporting structures can be removed. These results also help to inform the long-term mechanical and durability performance of the concrete, under different environmental conditions (classified as exposure classes in SS EN 206 and SS 544).

Table 3.3 lists common tests for hardened concrete properties that assess its mechanical and durability performance based on current standards.

Table 3.3. Typical tests conducted for hardened concrete

Mechanical property test	Standards adopted in Singapore
Compressive strength of concrete cubes at different ages	SS EN 206 and BS EN 12390-3
Compressive strength of concrete cylinder at different ages	BS EN 12390-3
Concrete density	BS EN 12390-7
*Creep	BS EN 12390-17
Concrete shrinkage	BS EN 12390-16
Flexural strength	BS EN 12390-5
Permeable voids	ASTM C642
Static modulus of elasticity	BS EN 1352 and BS EN 12390-13
Tensile strength (splitting test)	BS EN 12390-6
Durability property test	**Standards adopted in Singapore**
Acid resistance	ASTM C267
Carbonation	BS EN 14630 BS 1881-210 (accelerated test)
Chloride diffusivity	ASTM C1202^
Rebar corrosion	BS EN 48014
Sulphate resistance	ASTM C1012/C1012M
Water absorption	BS 1881-122
Water permeability	BS EN 12390-8

*Conduct when creep is a concern
^This test is also commonly referred to as the rapid chloride permeability test (RCPT)

Reinforced concrete contains reinforcement materials, such as steel reinforcement bars or fibres, embedded in the concrete. Testing reinforced concrete helps determine how it behaves structurally under applied loads, as well as its long-term durability. The specific tests needed depend on the intended use of the reinforced concrete and whether the innovation introduces any uncertainty in its behaviour.

These test results give construction professionals, like QPs, a clearer understanding of the reinforced concrete's performance, ensuring the structural design meets Eurocode standards. For example, adding steel fibres to reinforced concrete may affect its physical properties, so tests are conducted to understand how these fibres influence the concrete's structural behaviour. This allows QPs to adjust designs accordingly, compared to traditional reinforced concrete.

This eResource does not cover structural tests for reinforced concrete, as the required tests and conditions are project-specific. The type of structural tests and specific test conditions should be determined by the QP of the project adopting a new solution. Whenever possible, field trials should be conducted to evaluate the performance of the concrete mix under real conditions over time. Non-destructive tests, like the rebound hammer or Ultrasonic Pulse Velocity, or testing on cored samples, can be used to monitor the concrete's mechanical performance under actual loads and different environmental conditions.

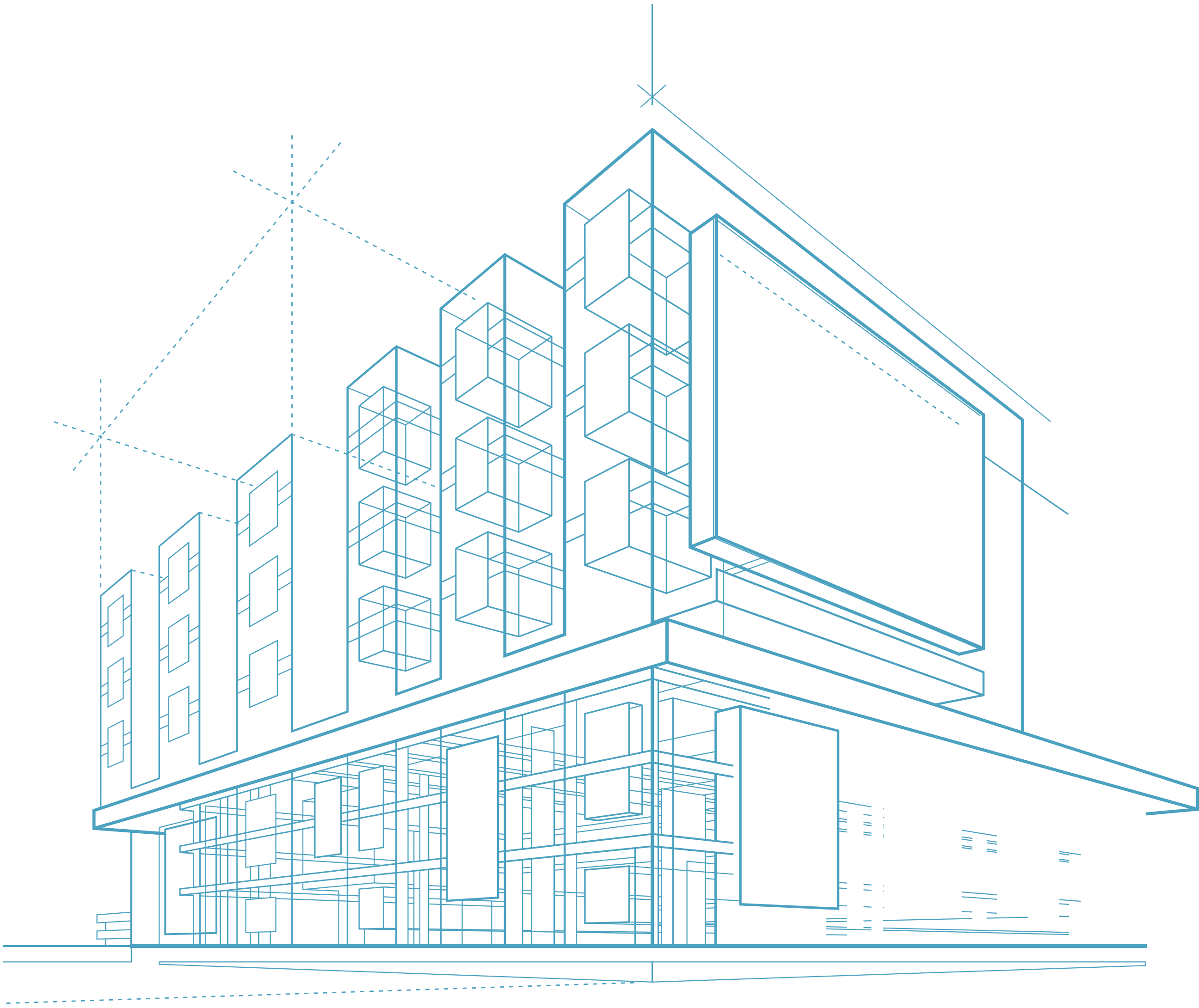
Chapter 4

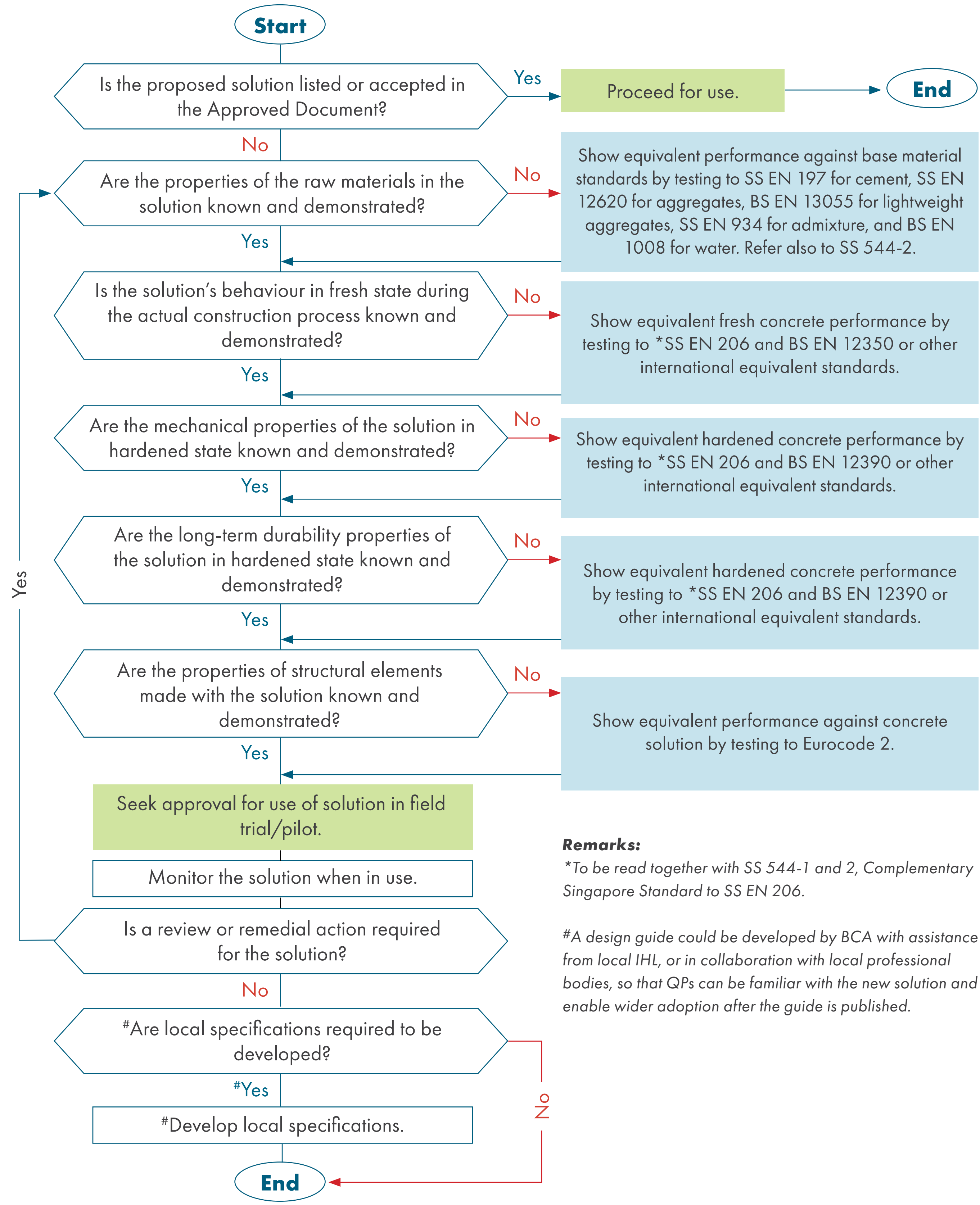
Process of design assisted by testing

When introducing a new solution in Singapore, it is essential for the solution provider to first consult a specialist who is familiar with local testing standards. This specialist will guide the provider through the necessary steps for conducting tests and obtaining regulatory approval.

Depending on the application, the concrete solution may need additional tests to meet the requirements of other relevant authorities, such as JTC, LTA, NEA, and PUB.

Figure 4.1 outlines the "design assisted by testing" process, with key questions to help determine which tests are needed, based on whether the new solution's properties are already known and proven. Case studies following this section provide examples on how to apply the flowchart in Figure 4.1.





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Remarks:

**To be read together with SS 544-1 and 2, Complementary Singapore Standard to SS EN 206.*

#A design guide could be developed by BCA with assistance from local IHL, or in collaboration with local professional bodies, so that QPs can be familiar with the new solution and enable wider adoption after the guide is published.

Figure 4.1: Flowchart for performance-based design via "design assisted by testing"

The subsequent case studies illustrate how "design assisted by testing" is applied in identifying the necessary tests to be conducted for a new solution.

Case Study 1 – Use of carbon mineralisation technology in concrete

1. Details of new solution

a) What is the innovation involved?
The injection of carbon dioxide into fresh concrete during the mixing process.

b) What is the benefit of the new solution compared to conventional concrete?
The carbon footprint of the concrete is reduced because:

- The injection of carbon dioxide to be permanently embedded in the concrete, resulting in a reduction of the carbon footprint of the concrete.
- Improvement in compressive strength, allowing a reduction in cement content through mix optimisation.

c) How does it change the concrete production process as compared to the conventional process?
Carbon dioxide is added as a new material into the concrete during the mixing process. There are no changes to the other raw materials used for concrete production.

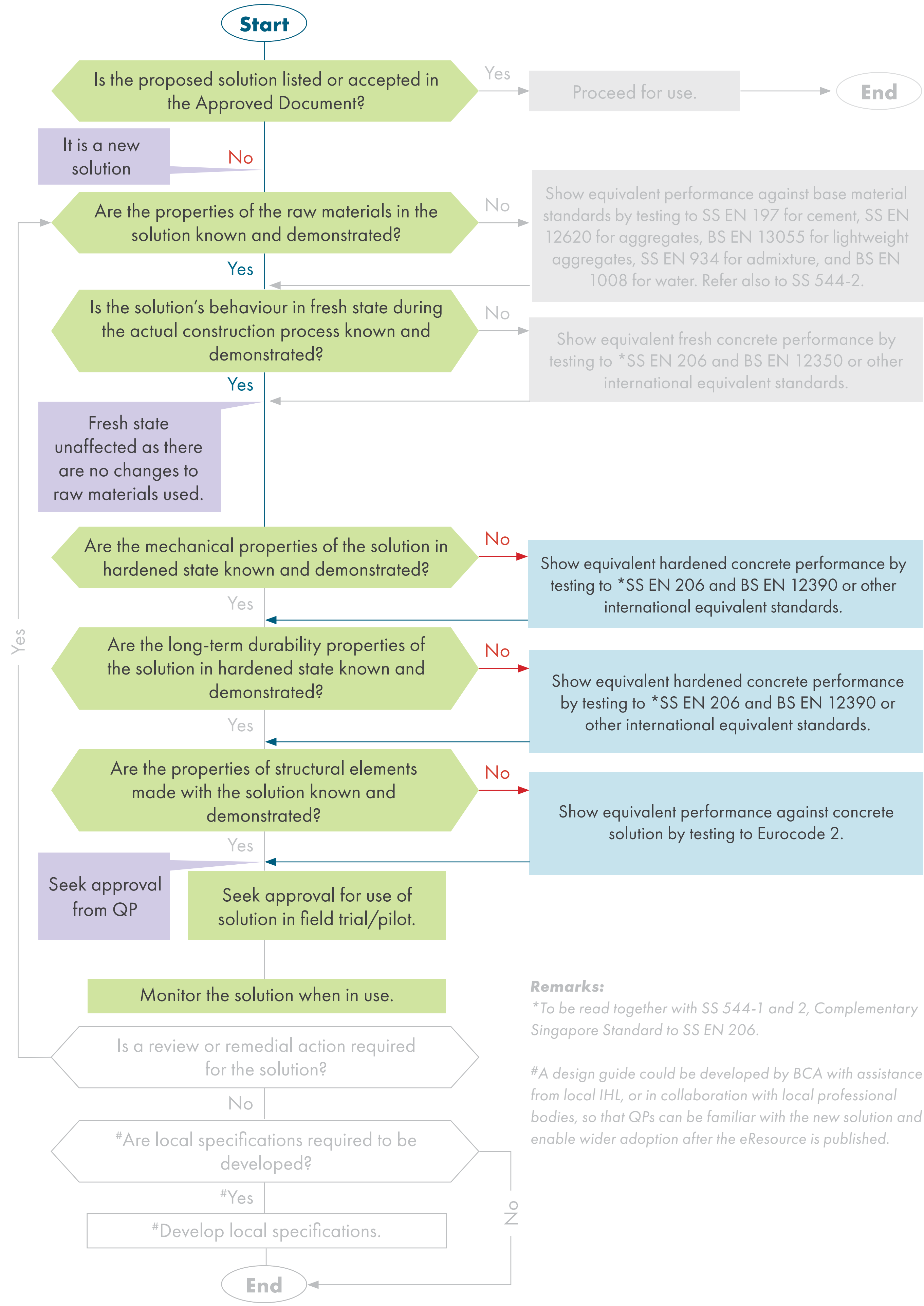
2. Identifying the necessary tests to conduct, based on the guiding questions in Figure 4.1.

S/n	Guiding question	Response	Decision
1	Is the proposed solution listed or accepted in the Approved Document?	No, because it is a new solution.	There is a need to conduct tests to demonstrate the performance of the new solution.
2	Are the properties of the raw materials in the solution known and demonstrated?	Yes, because there are no changes to the other raw materials used for concrete production.	There is no need to redo any raw material tests against base material standards. More concrete tests can be conducted for verification, if required and in case of doubt.
3	Is the solution's behaviour in fresh state during actual construction process known and demonstrated?	Yes, because there are no changes to the raw materials used for concrete production that affects the solution's behaviour in a fresh state.	There is no need to conduct any tests related to the solution's behaviour in a fresh state.
4	Are the mechanical properties of the solution in hardened state known and demonstrated?	No, there is insufficient knowledge of how CO_2 impacts the mechanical properties and behavior of hardened concrete.	There is a need to conduct tests to show equivalent performance in the mechanical properties against concrete solution by testing to *SS EN 206 and BS EN 12390.
5	Are the long-term durability properties of the solution in hardened state known and demonstrated?	No, there is insufficient knowledge of the durability performance, especially carbonation and rebar corrosion.	There is a need to conduct tests to show equivalent performance in the durability properties against concrete solution by testing to *SS EN 206 and BS EN 12390.

Summary: There is a need to conduct tests to show equivalent performance in the mechanical and durability properties of the new solution against concrete solution by testing to *SS EN 206 and BS EN 12390.

Referencing Annex B2, mechanical-related properties tests include compressive strength, flexural strength, splitting tensile strength, static modulus of elasticity, drying shrinkage, creep, etc.

Referencing Annex B2, durability-related properties tests include, water absorption, depth of penetration of water, chloride diffusivity, carbonation, acid resistance, sulphate resistance, rebar corrosion, etc.



Remarks:

**To be read together with SS 544-1 and 2, Complementary Singapore Standard to SS EN 206.*

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Case Study 2 – Use of recycled concrete aggregates in concrete

1. Details of new solution

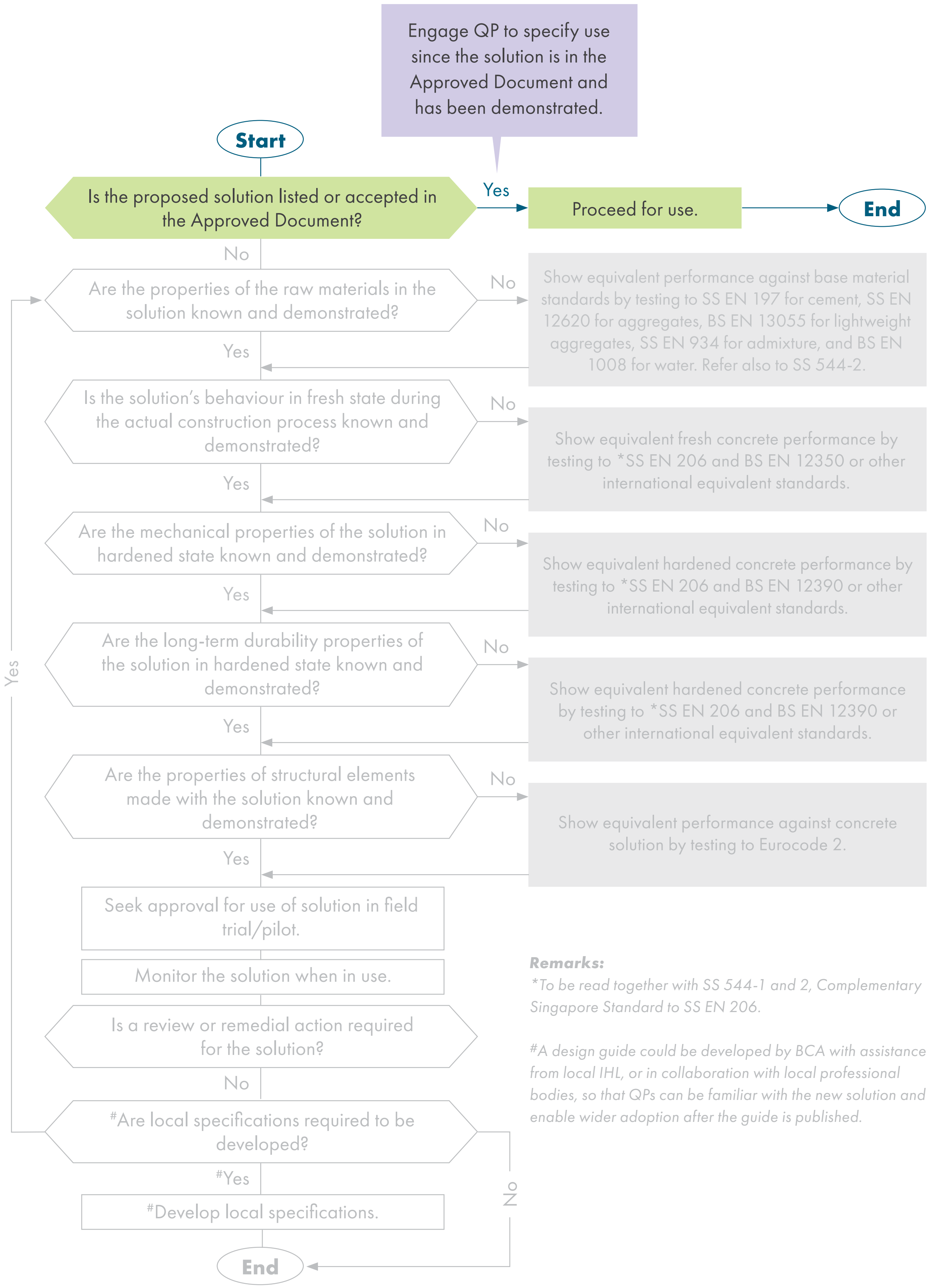
a. What is the innovation involved?
The use of recycled concrete aggregate (RCA), processed from construction and demolition waste to replace granite aggregates for structural concrete applications.

b. What are the benefits of the new solution compared to conventional concrete?
This innovation offers four benefits:
- Diverts demolished waste materials to landfill.
- Provides an alternative to imported coarse aggregates.
- Preserves the integrity of building structures with comparable performance as conventional concrete.
- Lowers the carbon footprint of concrete.

c. How does it change the concrete production process as compared to the conventional process?
RCA is added as a replacement of granite in concrete production. Depending on the quality of RCA and its replacement level, adjustments to the mix design of RCA concrete might be required to minimise the effect of RCA's high water absorption rate on concrete properties.

2. Identifying the necessary tests to conduct, based on the guiding questions in Figure 4.1.

S/n	Guiding question	Response	Decision
1	Is the proposed solution listed or accepted in the Approved Document?	Yes, SS EN 12620 allows the use of RCA as coarse aggregates for concrete.	The user can engage a QP to specify the use for their building project. The user may also choose to verify the concrete performance by testing to SS EN 206, BS EN 12350 and 12390.
2	Are the properties of the raw materials in the solution known and demonstrated?	NA	Not applicable as the solution is listed in the Approved Document.
3	Is the solution's behaviour in fresh state during actual construction process known and demonstrated?	NA	Not applicable as the solution is listed in the Approved Document.
4	Are the mechanical properties of the solution in hardened state known and demonstrated?	NA	Not applicable as the solution is listed in the Approved Document.
5	Are the long-term durability properties of the solution in hardened state known and demonstrated?	NA	Not applicable as the solution is listed in the Approved Document.
Summary: Concrete performance tests are done only for project-specific verification and in case of doubt as the solution is listed in the Approved Document			



Remarks:

**To be read together with SS 544-1 and 2, Complementary Singapore Standard to SS EN 206.*

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Case Study 3 – Use of biochar in concrete

1. Details of new solution

a. What is the innovation involved?
Biochar is a by-product derived from the pyrolysis of local biomass such as wood waste which would typically be incinerated and disposed. Biochar can be used as a partial replacement for cement in concrete.

b. What are the benefits of the new solution compared to conventional concrete?
This use of biochar in concrete product provides two benefits:
- Alleviates the disposal of ash generated from the incineration of the wood waste to landfill.
- Acts as an alternative to imported cement in concrete production. The lower CO_2 emission of biochar also helps reduce the carbon footprint of concrete.

c. How does it change the concrete production process as compared to the conventional process?
Biochar is added as a new material into concrete during the mixing process. There are no changes to the other raw materials used for concrete production.

2. Identifying the necessary tests to conduct, based on the guiding questions in Figure 4.1.

S/n	Guiding question	Response	Decision
1	Is the proposed solution listed or accepted in the Approved Document?	No, because it is a new solution.	There is a need to conduct tests to demonstrate the performance of the new solution.
2	Are the properties of the raw materials in the solution known and demonstrated?	No, the use of biochar as cement for concrete is not well-studied.	There is a need to conduct raw material tests against base material standards.
3	Is the solution's behaviour in fresh state during actual construction process known and demonstrated?	No, the impact of biochar on the fresh concrete properties is not known.	There is a need to conduct tests to show equivalent performance in the mechanical properties against concrete solution by testing to SS EN 206 and BS EN 12350.
4	Are the mechanical properties of the solution in hardened state known and demonstrated?	No, the impact of biochar on the mechanical properties is not known.	There is a need to conduct tests to show equivalent performance in the mechanical properties against concrete solution by testing to SS EN 206 and BS EN 12390.
5	Are the long-term durability properties of the solution in hardened state known and demonstrated?	No, the impact of biochar on the durability performance of concrete is not known.	There is a need to conduct tests to show equivalent performance in the mechanical properties against concrete solution by testing to SS EN 206 and BS EN 12390.

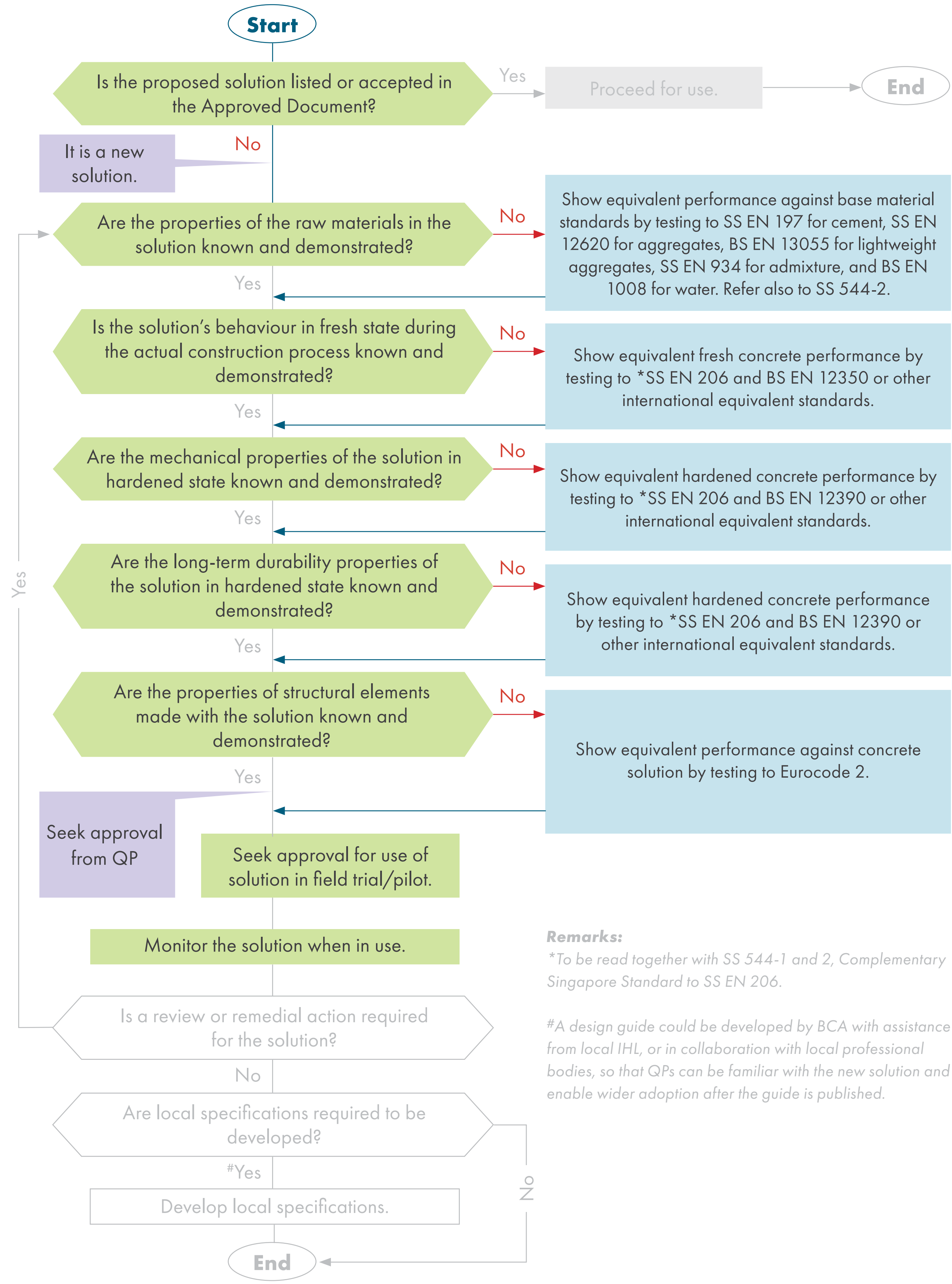
Summary: There is a need to conduct raw material property tests to demonstrate acceptable performance as a cementitious material or aggregate (depending on the intended application) based on the standards listed in Table 2.1.

There is a need to conduct tests to show equivalent performance of the new solution against concrete solution by testing to SS EN 206, BS EN 12350 and BS EN 12390.

Referencing Annex B1, fresh concrete properties include workability, setting time, bleeding, etc.

Referencing Annex B2, mechanical-related properties tests include compressive strength, flexural strength, splitting tensile strength, static modulus of elasticity, shrinkage, creep, etc.

Referencing Annex B2, durability-related properties tests include water absorption, depth of penetration of water, chloride diffusivity, carbonation, acid resistance, sulphate resistance, rebar corrosion, etc.



Remarks:

**To be read together with SS 544-1 and 2, Complementary Singapore Standard to SS EN 206.*

#A design guide could be developed by BCA with assistance from local IHL, or in collaboration with local professional bodies, so that QPs can be familiar with the new solution and enable wider adoption after the guide is published.

Annex A

Common material property tests for constituents of concrete

Annexes A.1 and A.2 detail the significance of the typical raw materials properties tested for cementitious materials and aggregates used in concrete.

A.1: Common material property tests for cementitious materials

Cementitious materials are key ingredients in concrete. These are typically powdery substances that, when mixed with water, form a glue-like paste that hardens as the concrete sets.

There are two main types of cementitious materials: hydraulic cement and supplementary cementitious materials (SCMs). The most common type of hydraulic cement is Ordinary Portland Cement (OPC). SCMs, such as fly ash, ground granulated blast-furnace slag, and silica fume, are often used as substitutes for OPC to enhance the performance and properties of concrete.

The following paragraphs describe the common properties tested and their importance.

a. Autogenous shrinkage

Autogenous shrinkage is the natural shrinkage of cement that occurs without any external influences, like changes in temperature or moisture. This happens because of the chemical reactions that occur as the cement hydrates, which leads to a reduction in volume.

b. Cement compressive strength

Cement compressive strength is directly linked to the compressive strength of hardened concrete. It indicates how much load concrete made with that cement can withstand before failing and helps determine the strength of the concrete for various uses. Typically, mortar cubes are used to test cement compressive strength instead of concrete cubes.

c. Cement consistency

Cement consistency helps determine the right water-to-cement ratio needed for achieving the desired workability of fresh concrete and its designed strength. If too much water is added to the mix, it can lead to problems like bleeding and segregation in fresh concrete, as well as lower strength in hardened concrete.

d. Chemical analysis

Chemical analysis of a cementitious material reveals the chemical compounds it contains and identifies any potential impurities, hazardous substances, or issues that could affect concrete production. By comparing the analysis results with the specified limits in relevant standards, we can ensure that the material meets the required chemical composition for its intended use.

e. Conformity

Cementitious materials used in concrete production must meet specific composition, requirements, and conformity criteria outlined in standards. In addition to meeting these requirements, various properties of the cementitious material can affect how fresh concrete behaves and influence the mechanical strength and durability of hardened concrete.

f. Drying shrinkage

Drying shrinkage is the reduction in size or volume that occurs as cement hardens and dries over time. When water is mixed with cement, it forms a paste that solidifies as it cures. During this process, water evaporates from the paste, leading to shrinkage. This shrinkage can worsen if the material is not properly cured and is exposed to dry or hot weather. Excessive shrinkage can cause cracking and structural problems in concrete structures. By measuring and understanding the amount of shrinkage, engineers and builders can design and construct stronger concrete structures.

g. Fineness

The fineness of cementitious materials is usually measured by the total surface area available for hydration. Hydration starts on the surface of the cement particles, which is essential for developing their strength. Finer cementitious materials have a larger total surface area for hydration, resulting in faster and more complete hydration and quicker strength development.

h. Heat of hydration

When water reacts with cementitious material, it releases heat during a process called hydration. This is when the water-cement paste hardens and binds the aggregate particles together. The heat of hydration refers to the amount of heat produced during this process.

The temperature at which hydration occurs affects how quickly heat is generated and how fast the concrete gains strength. Excessive heat can create temperature differences within the concrete, leading to potential cracking, especially in large concrete placements.

Therefore, it’s important to understand the heat-producing properties of cementitious materials and choose the right material for a specific application. Proper measures can also be taken to manage the heat of hydration, considering the properties of the cementitious material, the surrounding environment, and the intended use.

i. Setting time

Setting time refers to how long it takes for the cementitious paste to change from a fluid state to a hardened state. The initial setting time marks the moment when hardening begins, while the final setting time indicates when the paste has reached a certain level of hardness.

Factors like temperature and humidity in the surrounding environment can affect the setting time. Understanding the setting time is important because it helps determine whether the cementitious paste meets the required working conditions during casting and curing for its intended use.

j. Soundness

Cement soundness is the ability of cement to maintain its volume after it hardens, without expanding or shrinking too much. If cement doesn’t remain stable, it can cause cracks in the concrete, which affects its performance and durability. Measuring cement soundness helps prevent problems like cracking, spalling, and other structural issues in concrete construction.

A.2: Common material property tests for aggregates

Aggregates make up at least three-quarters of the volume of concrete. Their properties significantly influence the strength, durability, and overall performance of the concrete. If aggregates have undesirable qualities, they are unlikely to produce satisfactory concrete.

Aggregates used in concrete are classified into two types: fine aggregates and coarse aggregates. The main difference between them is their size. Fine aggregates, such as sand, have a maximum particle size of 4mm or less. Coarse aggregates, like granite commonly used in Singapore, have larger particle sizes, ranging from over 4mm up to a maximum of 20mm.

Many properties of aggregates can be tested, and some of the common tests are discussed in the following paragraphs.

a. Aggregates crushing value (ACV), fragmentation/ impact resistance

These parameters evaluate how well aggregates resist crushing and breaking apart when a load or impact is applied gradually. A higher ACV or lower fragmentation/impact resistance means the aggregates are weaker, which could result in more concrete failures. By assessing these parameters, engineers can confirm that the aggregates meet the necessary requirements for concrete production.

b. Bulk density

Bulk density is the mass of aggregates that can fit into a container of a specific volume. It depends on the shape and size of the aggregate particles. When both large and small particles are used together, they can pack more closely because the smaller particles fill the gaps between the larger ones. This increases the bulk density of the material. A higher bulk density means there are fewer gaps to fill with fine aggregates and cementitious materials.

c. Chemical properties of aggregates

Chemicals found in aggregates can cause negative reactions with cement in the concrete mix. Testing the chemical properties of aggregates helps identify potential issues, such as sulphate attack, carbonation, chloride attack, and silica reaction. The silica reaction happens when alkalis in cement interact with specific minerals in the aggregates, forming a gel that can expand and crack the concrete over time. This can affect the strength, durability, and overall performance of the concrete. By testing for reactive minerals in aggregates, engineers can reduce the risk of alkali-aggregate reactions.

d. Drying shrinkage

Aggregates affect how much concrete shrinks, depending on their shape, size, texture, and moisture content. By carefully choosing and mixing the right aggregates, engineers and concrete producers can manage and reduce concrete shrinkage. For instance, using larger and angular aggregates can help decrease shrinkage, while smooth or fine aggregates might increase it. Well-graded aggregates, which have a mix of different sizes, can improve packing density and further help control shrinkage in concrete mixes.

e. Fineness modulus/sieve analysis

The fineness modulus is a number calculated from a sieve analysis[4] to measure how coarse the aggregates are. A higher fineness modulus means the aggregates are coarser. This number shows how much the aggregate sizes vary from the same source and gives an idea of how the fresh concrete will perform with that particular grading. If the aggregates have too many fine particles, more water or additives (admixtures) may be needed during mixing to ensure the concrete is workable.

[4] The aggregates sample is separated into different size fractions using a series of sieves with varying mesh sizes to determine the particle size distribution.

f. Particle density

The particle density of aggregates has a direct effect on the properties of the concrete mix. If the particle density is not sufficient, it can cause problems like reduced strength, increased permeability, and poor workability of the concrete. By understanding the particle density, construction professionals can optimise the mix of aggregates during the design process to achieve the desired performance for the concrete.

g. Particle shape and texture

Particle shape and texture refer to the outer physical characteristics of aggregates. The shape of crushed aggregates depends on the original material and the type of crusher used. The shape and texture of aggregates can affect the concrete mix's properties, including how much water is needed for workability and the strength of the bond between the aggregates and the cement paste.

There are several indexes to describe these properties of aggregates. Here are three common ones:

1. Angularity measures the percentage of voids when aggregates are packed together.
2. Flakiness Index shows the percentage of flaky particles in the aggregate mass.
3. Elongation Index indicates the percentage of elongated particles in the aggregate mass.

h. Potential alkali-aggregate reactivity (AAR)

The alkali-aggregate reactivity test checks how likely aggregates are to react with alkalis in cement. This test helps identify potential issues like alkali-silica reactions (ASR) or alkali-carbonate reactions (ACR), which can lead to concrete expansion, cracking, and long-term durability problems.

ASR and ACR tests are necessary if the new materials are likely to react with alkalis or if required by regulatory authorities. For guidelines on preventing ASR, solution providers can refer to the following standards:

- SS EN 206: Clause 5.2.8 (limits on chloride content) and Clause 5.2.3.5 (resistance to ASR)
- SS 544-1: Clause A.8.1 (alkali-aggregate reactions)
- SS 544-2: Clause 4.3 (limits on sulphate content) and Annex D (ways to minimise the risk of damaging ASR in concrete)

Additionally, calcium chloride should not be included in any concrete mixes.

i. Voids

Voids in aggregates can impact the strength and performance of concrete, as well as its resistance to freeze-thaw cycles. These voids allow water to enter, which can cause concrete to crack and chip over time. Generally, it is better to have a lower void content because this means the material is denser and more compact, with fewer weak points that could lead to problems.

j. Water absorption of aggregates

Water absorption of aggregates is measured by looking at how much their weight increases after being soaked in water for 24 hours. This increase in weight, compared to the original dry weight, is called absorption. The amount of water that aggregates absorb can affect how workable the fresh concrete is, so it is important to consider this when determining the total water needed for mixing the concrete.

Annex B

Common material property tests for fresh and hardened concrete

Annexes B.1 and B.2 describe the significance of typical fresh and hardened concrete properties tested.

B.1: Common material property tests for fresh concrete

Tests on fresh concrete give an early indication of whether it meets quality standards based on its workability, which is classified by a consistency class. The usual properties tested in fresh concrete and the related test standards help construction professionals decide whether to accept the concrete based on on-site tests. Detailed descriptions of each property will be provided in the following paragraphs.

a. Bleeding of concrete

The concrete bleeding test measures how much water rises to the surface of freshly mixed concrete as it settles and hardens. Controlling the amount of bleed water is important to ensure that the concrete will have the desired properties and performance once it hardens. If there is too much bleeding, it may indicate a high water-cement ratio, which can lead to lower strength, increased permeability, and poor durability. Excessive bleeding can also cause segregation, resulting in uneven distribution of aggregates and cement paste, which can weaken the structure.

b. Workability/consistence of fresh concrete [expressed by consistence class of concrete, as defined by SS 544-1]

The workability or consistence of concrete refers to how easily and uniformly it can be mixed, placed, compacted, and finished without the different components — like aggregates and cement paste — separating. It is important to determine how much effort is needed to compact the concrete to its maximum density. The required workability depends on factors like the intended use, accessibility, the amount of reinforcement, and the size of the concrete element.

For special types of concrete, such as self-compacting or self-consolidating concrete, which flow more easily, specific tests like the slump flow test, V-funnel test, J-ring test, and L-box test are used to assess workability. Additionally, slump retention tests are often performed to track changes in slump and evaluate how workability changes over time.

B.2: Common material properties tests for hardened concrete

The type, quality, and amount of materials used to make concrete significantly affect how well the hardened concrete performs. There are two main types of tests for hardened concrete: mechanical performance tests and durability performance tests. These tests are important for construction professionals to consider when designing structures, as explained in the following sections.

a. Mechanical properties

Mechanical properties of concrete show how the material behaves when force is applied. This includes measurements like compressive strength, tensile strength, flexural strength, shrinkage, and creep. All of these properties are related to the strength of the concrete.

• Compressive strength

Compressive strength is one of the most important properties of concrete. It measures how well concrete can handle axial compressive loads. To find the compressive strength, one should divide the maximum load applied to the concrete sample by its cross-sectional area. Both cylindrical and cubic samples can be tested for compressive strength, and different standards specify the test conditions for each type.

• Concrete density

Concrete density is closely linked to its strength and durability. Concrete density indicates that the concrete mix has been correctly proportioned and compacted, ensuring it meets the necessary standards for strength, durability, and performance for its intended use.

• Creep

Creep in concrete refers to the gradual deformation of a concrete structure when it is under a constant load over time. This load can cause the concrete to change shape or size. While creep typically does not lead to the failure of the structure, it does affect the stresses and strains experienced by both the concrete and the reinforcement steel in reinforced concrete. Understanding creep is important for construction professionals, especially when designing pre-stressed concrete elements.

• Concrete shrinkage

Concrete shrinkage refers to the decrease in the size or volume of concrete as it cures, dries, and hardens. To assess this shrinkage, a test is conducted over a specific period. The results help determine how much the concrete may shrink and the likelihood of cracking or deformation. These shrinkage properties can affect the durability and long-term performance of the concrete structure.

• Permeable voids

Permeable voids are interconnected spaces within concrete that allow fluids, like water or chemicals, to pass through. If concrete has many permeable voids, it can more easily absorb these fluids, which may lead to corrosion of the reinforcement and damage to the concrete itself.

• Static modulus of elasticity

The static modulus of elasticity measures the stiffness of concrete. Stiffer concrete can handle more load without bending or changing shape. When concrete has a higher modulus of elasticity, it means it will deform less under pressure. Therefore, structures made from stiffer concrete will experience less bending when a load is applied.

• Tensile and flexural strength

Concrete is weak in tension, which is why it needs reinforcement, typically with steel, to handle these types of loads. Knowing how strong concrete is under tension helps predict when it might crack, which is important for designing structures. There are two common tests to measure concrete's tensile strength:

1. Flexural strength test: this test measures how well concrete can resist bending. A concrete beam is supported at both ends and a load is applied in the middle.
2. Splitting tensile strength test: this test measures the tensile strength of concrete by applying a load along the length of a cylindrical sample.

b. Durability properties

The durability of concrete refers to how well it can resist damage over time due to external or internal factors.

- External factors include long-term exposure to the environment.
- Internal factors involve reactions between different raw materials in the concrete and any contaminants.

To evaluate concrete's durability, tests are performed to see how well it withstands specific conditions and to predict its long-term performance and service life.

The results of these tests help construction professionals choose the right concrete solutions and protective measures, ensuring that the concrete meets the necessary requirements for its intended use.

• Carbonation

Carbonation in concrete lowers the pH of the pore water within hardened concrete. Normally, the high pH provides a protective layer that keeps reinforcing steel safe from rust caused by reactions with water and oxygen. When the pH decreases due to carbonation, this protective layer is compromised, making the steel vulnerable to corrosion.

To test for carbonation, concrete samples are placed in an environment with high levels of carbon dioxide. This speeds up the process of carbon dioxide entering the concrete. The results of this accelerated test help assess how durable the concrete is and how likely it is to suffer from corrosion caused by carbonation.

• Chloride diffusivity

Chloride diffusivity measures how well hardened concrete resists the ingress of chloride ions. In this test, concrete samples are exposed to a chloride solution, and pressure or electrical currents are used to speed up the movement of chloride ions into the concrete.

Chloride ions can lead to the corrosion of reinforcing steel in concrete structures, so understanding their diffusivity is important for assessing the durability of the concrete. This information helps construction professionals design adequate concrete covers, which can extend the lifespan of concrete, especially in environments where chloride is prevalent.

• Water absorption

Absorption is the process by which water enters hardened concrete through its pores. A water absorption test measures how much water the concrete can absorb, which helps indicate its porosity. High porosity means the concrete is more likely to face moisture-related problems over time.

• Water permeability

Permeability refers to how easily water can flow through concrete along its pore structure. It depends not only on the amount of pores (porosity) but also on the size and connectivity between those pores, as well as the pathways they create. If the pore structure is not continuous, it will slow down the movement of moisture, leading to lower permeability. The water penetration depth of hardened concrete can also help assess its permeability. While high permeability may indicate that concrete could face moisture-related problems over time, some concrete designed with higher permeability can be beneficial for specific uses.

• Other durability-related assessment

Common tests like water permeability, chloride diffusivity, and carbonation tests help determine how well concrete can resist water, chloride ions, and carbonation. In addition to these, other tests can evaluate the concrete's durability under specific conditions and suggest protective measures. For example, acid resistance tests check how concrete holds up in acidic environments, while sulphate resistance tests do the same for environments with sulphate ions. The half-cell potential test can assess the likelihood of rebar corrosion in reinforced concrete.

Internationally recognised accelerated tests and standards are often used to evaluate the durability and long-term performance of concrete. These tests simulate harsh environmental conditions and speed up the deterioration processes that would naturally occur over time. However, it is important to use professional judgment when interpreting the results of accelerated tests. Understanding their limitations in mimicking real-world conditions and considering the specific circumstances of the tests are crucial for making informed decisions about concrete durability and the service life of concrete structures.

Annex C

Testing facilities in Singapore

There are commercial and institutional testing facilities that businesses can use for various tests. Commercial testing facilities focus on conducting tests, developing results, certifying those results, and offering consultancy services for new solutions. These facilities are accredited by the Singapore Accreditation Council under the Singapore Laboratory Accreditation Scheme (SAC-SINGLAS).

Institutional testing facilities specialise in providing detailed analysis and assessment of test results. They are equipped to perform more complex tests, including structural tests on reinforced concrete elements. Results from commercial testing facilities can be sent to institutional facilities for further analysis and professional evaluation.

Testing costs vary between commercial and institutional facilities because they have different focuses. Therefore, the choice of which facility to use depends on what the solution provider aims to achieve. Factors may include the complexity of the tests needed or the desire for a professional assessment of the results. Table C.1 lists various commercial and institutional testing facilities that solution providers can contact to discuss different types of tests.

Table C.1. List of testing facility operators and contact details

s/n	Test facility	Information and contact details
Commercial test facility		
1	CAST Laboratories Pte Ltd.	Information: https://www.castlab.com.sg Email: cast@castlab.com.sg Contact: +65 6801 6000
2	Element Construction Testing (S) Pte. Ltd.	Information: https://www.element.com/locations/asia/singapore-sungei-kadut-loop Contact: +65 6362 9066
3	R. A. K. Materials Consultants Pte Ltd.	Information: https://rakmat.com.sg/ Email: enquiry@rakmat.com.sg Contact: +65 6561 5366
4	Samwoh Innovation Centre Pte Ltd.	Information: https://www.samwoh.com.sg/what-we-do/innovative-solutions/#research-innovation Email: info@samwoh.com.sg Contact: +65 6368 9972
5	Setsco Services Pte. Ltd.	Information: https://www.setsco.com Email: marketing@setsco.com Contact: +65 6566 7777

6	TUV SUD PSB Pte. Ltd.	Information: https://www.tuvsud.com/en-sg Email: info.sg@tuvsud.com Contact: +65 6240 0200
Institutional test facility		
1	Advanced Materials Technology Centre, Singapore Polytechnic	Information: https://www.sp.edu.sg/industry/amtc Contact: +65 6772 1867
2	Centre for Advanced Materials and Structures, National University of Singapore	Information: https://cde.nus.edu.sg/cee/research/research-centres/centre-for-advanced-materials-and-structures/ Contact: +65 6516 6827
3	Centre of Urban Sustainability, Temasek Polytechnic	Information: https://www.tp.edu.sg/research-and-industry/centres-of-excellence/centres-under-school-of-applied-science/centre-for-urban-sustainability.html Contact: +65 6780 4163
4	Construction Technology Laboratory and Protective Engineering Laboratory, Nanyang Technological University	Information: https://www.ntu.edu.sg/cee/about-us/laboratories/construction-technology-and-protective-engineering-laboratory/about-the-lab Contact: +65 6790 6193
5	Environmental Technology Centre, Republic Polytechnic	Information: https://www.rp.edu.sg/sas/industry/environmental-technology-centre Contact: https://for.edu.sg/rpcontactus

Annex D

Summary of relevant reference test standards

Table D.1. Cement test standards

s/n	Standard	Title
1	ASTM C109/C109M	Standard test method for compressive strength of hydraulic cement mortars
2	ASTM C114	Standard test methods for chemical analysis of hydraulic cement
3	ASTM C157/C157M	Standard test method for length change of hardened hydraulic-cement mortar and concrete
4	ASTM C191	Standard test methods for time of setting of hydraulic cement by vicat needle
5	ASTM C204	Standard test methods for fineness of hydraulic cement by air-permeability apparatus
6	ASTM C1698	Standard test method for autogenous strain of cement paste and mortar
7	ASTM C1702	Standard test method for measurement of heat of hydration of hydraulic cementitious materials using isothermal conduction calorimetry
8	ASTM C1753/C1753M	Standard practice for evaluating early hydration of hydraulic cementitious mixtures using thermal measurements
9	BS EN 196-2	Methods of testing cement — Part 2: Chemical analysis of cement
10	BS EN 196-3	Methods of testing cement — Part 3: Determination of setting times and soundness
11	BS EN 196-6	Methods of testing cement — Part 6: Determination of fineness
12	BS EN 196-11	Methods of testing cement — Part 11: Heat of hydration - Isothermal conduction calorimetry method
13	BS EN 450-1	Fly ash for concrete. Definition, specifications and conformity criteria
14	BS EN 450-2	Fly ash for concrete. Conformity evaluation
15	BS EN 13263	Silica fume for concrete
16	SS EN 196-1	Methods of testing cement. Determination of strength
17	SS EN 197-1	Cement — Part 1: Composition, specifications, and conformity criteria for common cement
18	SS EN 197-2	Cement — Part 2: Conformity evaluation
19	SS EN 15167-1	Ground granulated blast furnace slag for use in concrete, mortar, and grout — Definitions, specifications, and conformity criteria
20	SS EN 15167-2	Ground granulated blast furnace slag for use in concrete, mortar, and grout — Conformity evaluation

Table D.2. Aggregates test standards

s/n	Standard	Title
1	ASTM C127	Standard test method for relative density (specific gravity) and absorption of coarse aggregate
2	ASTM C128	Standard test method for relative density (specific gravity) and absorption of fine aggregate
3	ASTM C131/131M	Standard test method for resistance to degradation of small-size coarse aggregate by abrasion and impact in the Los Angeles machine
4	ASTM C136/C136M-19	Standard test method for sieve analysis of fine and coarse aggregates
5	ASTM C295/C295M	Standard guide for petrographic examination of aggregatesfor concrete
6	ASTM C1260	Standard test method for potential alkali reactivity of aggregates (mortar-bar method)
7	ASTM D4791	Standard test method for flat particles, elongated particles, or flat and elongated particles in coarse aggregate
8	BS 812-1	Testing aggregates. Methods for determination of particle size and shape
9	BS 812-2	Testing aggregates. Methods for determination of density
10	BS 812-105.1	Testing aggregates. Methods for determination of particle shape flakiness index
11	BS 812-110	Testing aggregates. Methods for determination of aggregate crushing value (ACV)
12	BS EN 933-1	Tests for geometrical properties of aggregates – Determination of particle size distribution. Sieving method
13	BS EN 933-3	Tests for geometrical properties of aggregates – Determination of particle shape. Flakiness index
14	BS EN 933-4	Tests for geometrical properties of aggregates – Determination of particle shape. Shape index
15	BS EN 933-10	Tests for geometrical properties of aggregates assessment of fines. Grading of filler aggregates (air jet sieving)
16	BS EN 1097-2	Tests for mechanical and physical properties of aggregates – Part 2: Methods for the determination of resistance to fragmentation
17	BS EN 1097-3	Tests for mechanical and physical properties of aggregates – Determination of loose bulk density and voids
18	BS EN 1097-6	Tests for mechanical and physical properties of aggregates – Determination of particle density and water absorption
19	BS EN 1367-4	Tests for thermal and weathering properties of aggregates – Part 4: Determination of drying shrinkage
20	BS EN 1744-1	Tests for chemical properties of aggregates — Part 1: Chemical analysis
21	BS EN 1744-5	Tests for chemical properties of aggregates — Part 5: Determination of acid soluble chloride salts

22	BS EN 1744-6	Tests for chemical properties of aggregates — Part 6: Determination of the influence of recycled aggregate extract on the initial setting time of cement
23	BS EN 13055-1	Lightweight aggregates — Lightweight aggregates for concrete, mortar and grout
24	BS EN 13055-2	Lightweight aggregates — Lightweight aggregates for bituminous mixtures and surface treatments and for unbound and bound applications
25	SS EN 12620	Specification for aggregates for concrete

Table D.3. Mixing water test standard

s/n	Standard	Title
1	BS EN 1008	Mixing water for concrete. Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete

Table D.4. Admixtures test standards

s/n	Standard	Title
1	BS EN 480-4	Admixtures for concrete, mortar and grout — Test methods. Determination of bleeding of concrete
2	BS EN 480-14	Admixtures for concrete, mortar and grout — Test methods. Determination of the effect on corrosion susceptibility of reinforcing steel by potentiostatic electro-chemical test
3	SS EN 934-1	Admixtures for concrete, mortar and grout. Common requirements
4	SS EN 934-2	Admixtures for concrete, mortar and grout – Part 2: Concrete admixtures – Definitions, requirements, conformity, marking and labelling

Table D.5. Fresh concrete test standards

s/n	Standard	Title
1	ASTM C143/C143M	Standard test method for slump of hydraulic-cement concrete
2	ASTM C232/C232M	Standard test method for bleeding of concrete
3	ASTM C1611/C1611M	Standard test method for slump flow of self-consolidating concrete
4	BS EN 12350-2	Testing fresh concrete — slump test
5	BS EN 12350-3	Testing fresh concrete — Vebe test
6	BS EN 12350-8	Testing fresh concrete — self-compacting concrete. Slump-flow test

Table D.6. Hardened concrete test standards

s/n	Standard	Title
1	AASHTO T277	Standard method of test for electrical indication of concrete's ability to resist chloride ion penetration
2	ASTM C39/C39M	Standard test method for compressive strength of cylindrical concrete specimens
3	ASTM C157/C157M	Standard test method for length change of hardened hydraulic cement mortar and concrete
4	ASTM C267	Standard test method for chemical resistance of mortars, grouts, and monolithic surfacing and polymer concretes
5	ASTM C403/C403M	Standard test method for time of setting of concrete mixtures by penetration resistance
6	ASTM C349	Standard test method for compressive strength of hydraulic-cement mortars (using portions of prisms broken in flexure)
7	ASTM C512/C512M	Standard test method for creep of concrete in compression
8	ASTM C642	Standard test method for density, absorption, and voids in hardened concrete
9	ASTM C876	Standard test method for corrosion potentials of uncoated reinforcing steel in concrete
10	ASTM C1012/C1012M	Standard test method for length change of hydraulic-cement mortars exposed to a sulphate solution
11	ASTM C1202	Standard test method for electrical indication of concrete's ability to resist chloride ion penetration
12	BS 1881-121	Testing concrete. Method for determination of static modulus of elasticity in compression
13	BS 1881-122: 2011+A1	Testing concrete. Method for determination of water absorption
14	BS 1881-210	Testing hardened concrete. Determination of the potential carbonation resistance of concrete. Accelerated carbonation method
15	BS EN 480-14	Admixtures for concrete, mortar and grout – Test methods. Determination of the effect on corrosion susceptibility of reinforcing steel by potentiostatic electro-chemical test
16	BS EN 1352	Determination of static modulus of elasticity under compression of autoclaved aerated concrete or lightweight aggregate concrete with open structure
17	BS EN 12390-3	Testing hardened concrete – Compressive strength of test specimens
18	BS EN 12390-5	Testing hardened concrete – Flexural strength of test specimens
19	BS EN 12390-6	Testing hardened concrete – Tensile splitting strength of test specimens
20	BS EN 12390-7	Testing hardened concrete – Density of hardened concrete
21	BS EN 12390-8	Testing hardened concrete – Depth of penetration of water under pressure
22	BS EN 12390-13	Testing hardened concrete – Determination of secant modulus of elasticity in compression
23	BS EN 12390-16	Testing hardened concrete – Determination of the shrinkage of concrete
24	BS EN 12390-17	Testing hardened concrete – Determination of creep of concrete in compression

25	BS EN 14630	Products and systems for the protection and repair of concrete structures. Test methods. Determination of carbonation depth in hardened concrete by the phenolphthalein method
26	BS ISO 1920-8	Testing of concrete – Part 8: Determination of the drying shrinkage of concrete for samples prepared in the field or in the laboratory
27	DIN 1048-5	Testing Concrete – testing of hardened concrete
28	NT Build 492-99	Concrete, mortar and cement-based repair materials: chloride migration coefficient from non-steady-state migration experiments
29	SS 544-1	Concrete – Complementary Singapore Standard to SS EN 206: Method of specifying and guidance for the specifier
30	SS EN 206	Concrete – Specification, performance, production and conformity
31	SS EN 12390-7	Testing hardened concrete – Part 7: Density of hardened concrete

FEEDBACK

This eResource will be updated periodically. We welcome your comments to help us improve this. Please provide your inputs at https://go.gov.sg/eresourceconcretesolutions or scan the QR code.