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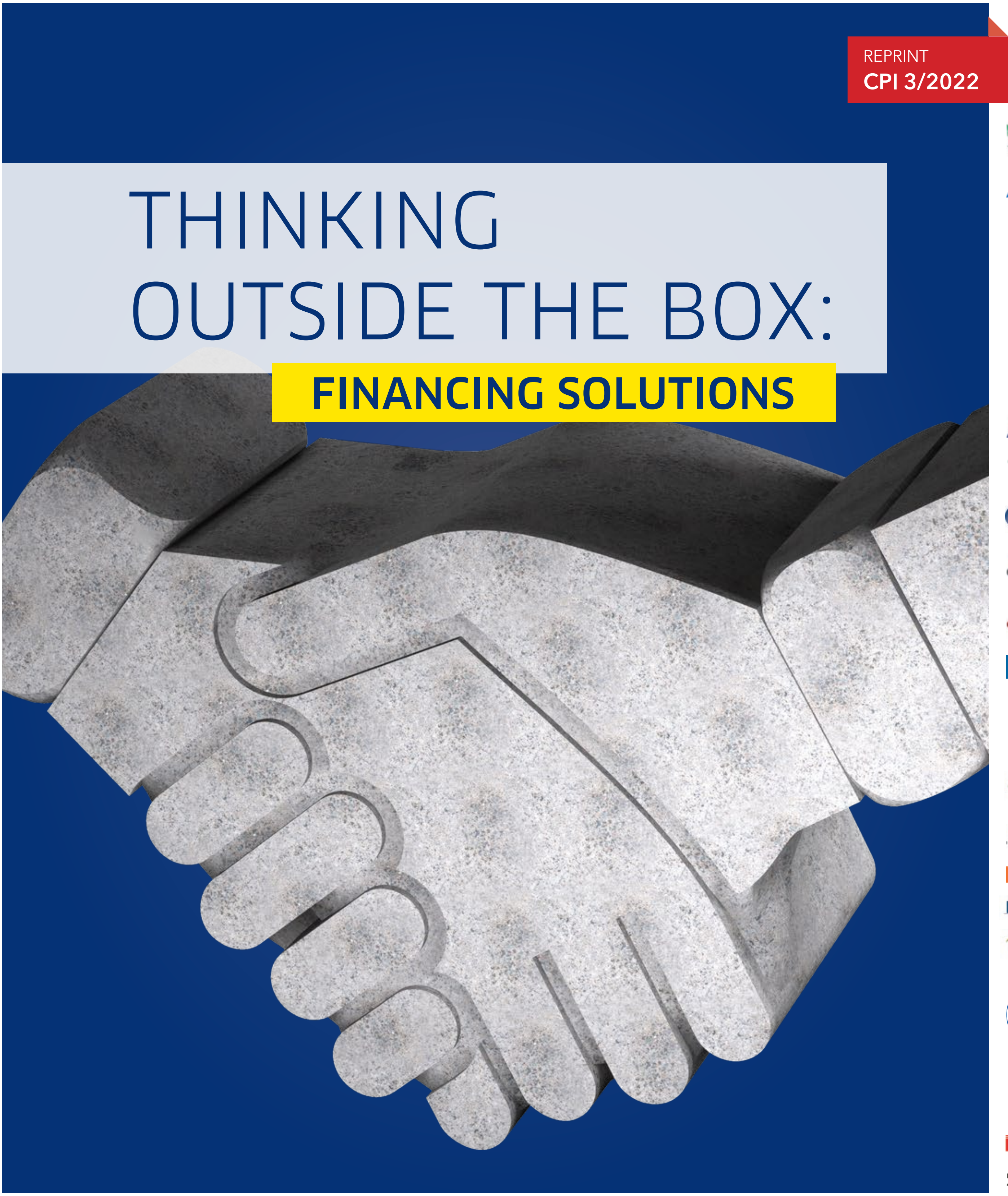

Combining SCMs with PRAs to produce more sustainable construction

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The unique properties of concrete make it one of the most common building materials, which nowadays, plays a significant role in construction worldwide with increasing demand. Despite all its remarkable benefits, concrete has its own limitations with sustainability. However, that can be remedied with the right construction methods.

The concrete industry significantly affects the environment by extracting massive quantities of raw materials, consuming considerable amounts of energy and creating extensive pollution and waste. Furthermore, even though concrete is recognized as a long-lasting and durable material, there is enough evidence that global concrete construction has been failing to fulfill its specified service life due to how rapidly many concrete structures have been deteriorating.

Given these stated limitations and the vast volume of concrete consumed globally, any advancement that leads to an increase in the life of concrete structures or optimizes the usage of and savings in raw materials and energy consumption, no matter how little, substantially influences the economy and the environment.

Considering the importance of this matter, several more sustainable approaches have consequently been studied in recent years in regard to concrete, waterproofing design, and elsewhere. One of the most efficient approaches is the use of cement replacements, such as supplementary cementitious materials (SCMs), as well as the use of permeability-reducing admixtures (PRAs).

SCM Benefits

These materials, such as fly ash, slag, and silica fume, are by-products of other industries [1]. They can thus provide a sustainable replacement for cement as they minimize the consumption of raw materials and energy.

These SCMs are not limited to just this one particular positive fact either. These materials can also lower the permeability of concrete, increasing the concrete's longevity. At the same time, they can conserve natural resources by helping to construct more durable concrete structures that do not need to be repaired or replaced so frequently.

SCMs are currently seen as one of the integral components of today's concrete because of those beneficial qualities. However, they cannot fulfill all of the requirements for different projects on their own, which necessitates the inclusion of other concrete admixtures in many situations.

PRA Benefits

To meet the diverse demands of today's concrete, many additives have been developed. These include PRAs, which are defined in Chapter 15 of ACI 212.3R-16 as a class of materials that regulate water and moisture flow and limit chloride ion penetration to enhance concrete durability [2].

Given the direct correlation between concrete permeability and durability, PRAs are the most effective admixtures for building more durable and thus sustainable structures. That is especially beneficial for structures exposed to water and water-borne chemicals.

Combining SCMs and PRAs

Based on the reasons stated and the benefits of SCMs and PRAs, it appears at first glance that combining them is the perfect combination. In fact, concrete additives can have synergic effects in certain situations. As a result, adding them to a concrete mix can be helpful, but it should be emphasized that this is not always the case.

This is because not all PRAs have the same chemical composition. As a consequence of this divergence, while using SCMs and PRAs together can be useful for certain situations, combining SCMs with certain PRAs can diminish their benefits. Hence, the simultaneous use of some PRAs and SCMs in a mix should be given closer attention. It is critical to know their chemistry and possible interactions and to choose them accordingly.

Chemical Similarities

In recent decades, several different types of PRAs have been developed to reduce the permeability of concrete based on diverse chemistry and various mechanisms of action. Therefore, they offer varied effectiveness.

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One of the common types of PRA is one that reacts with calcium hydroxide (CH) [3]. These admixtures include but are not limited to active silicates that react with the CH released by the hydration of Portland cement in concrete mixes to create insoluble crystals in concrete capillaries, voids, and cracks, which results in increased resistance to water ingress.

Meanwhile, SCMs, are defined as materials that when combined with Portland cement, they enhance concrete characteristics via hydraulic or pozzolanic reaction (PR), or both. However, it is crucial to remember that PR is essentially a chemical reaction of SCM and CH to form cementitious products like calcium silicate hydrates.

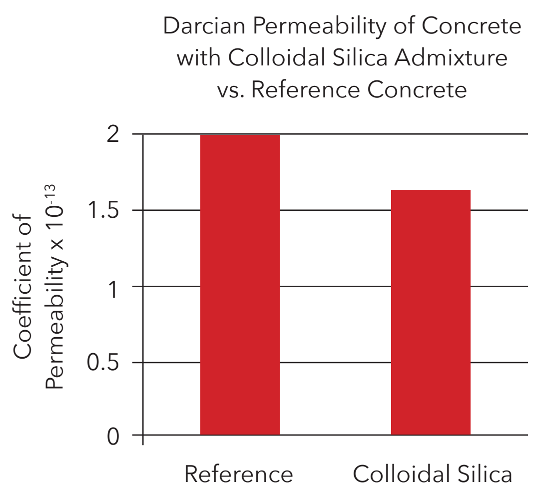

Fig. 1: Minimal reduction in permeability of concrete with silicate-based waterproofing

Chemical Limitations

By comparing the chemical reactions of SCMs and silicate-based PRAs, it can be inferred that they both require CH for their chemical activities, implying that they are reliant on CH availability. However, the amount of CH in concrete is not unlimited, and hydrated Portland cement contains around 15% to 25% CH.

On the other hand, with the increasing use of SCMs in today's concrete, the amount of cement and consequently, CH reduces. And as the SCM content rises, the demand for CH to fulfill PR increases.

In practice, increasing the SCM content in today's mix substantially decreases the overall quantity of CH, especially over time. Therefore, when both SCMs and silicate-based PRAs are employed in a mix, their performances, particularly their long-term performance, will be compromised due to the restricted amount of CH.

Although the CH deficit and lack of performance of these combinations may not be seen as expected under laboratory and short-term conditions due to time limitations, in practice and given the serviceable life expectancy of today's structures, the simultaneous use of SCMs with silicate-based PRAs cannot be a reliable option.

Overall, it can be stated that the reactivity of SCMs with CH is limited due to the presence of the silicate-based admixture, and vice versa. Hence, considering the limitations of silicate-based PRAs, mainly on mixes that include SCMs, we should use PRAs that are not dependent on CH availability.

Conclusions

Because concrete is prone to cracking and chemical attack during its service life, an ideal PRA must be capable of sealing the cracks and protecting the structure for the entire length of the structure's life. However, silicate-based PRAs, which are used during the chemical process, would not be available, particularly at later stages, so they cannot satisfy this requirement.

This criterion can be met only by materials that act as a catalyst. That means working with reliable PRAs, like Krystol Internal Membrane™ (KIM®), which enhance the concrete properties in the short- and long-term but are not consumed, stay in the concrete for their entire life, and can be reactivated at any moment.

When added to concrete, KIM does not need CH to chemically enact its protection. Instead, its Krystol® technology chemically reacts with water and unhydrated cement particles to form insoluble, needle-shaped crystals. These fill capillary pores and micro-cracks in the concrete, blocking the pathways for water and waterborne contaminants.

That allows KIM to reduce the concrete's permeability significantly, which can be seen in the Annacis Island wastewater treatment plant report produced by AGRA Earth and Environmental. There, KIM was able to produce as high as a 75% reduction in permeability [4].

In short, with a PRA like KIM, concrete structures with any SCMs will always have waterproofing protection as any moisture introduced to the structures will trigger a protective chemical reaction without impacting the structure's SCM content.

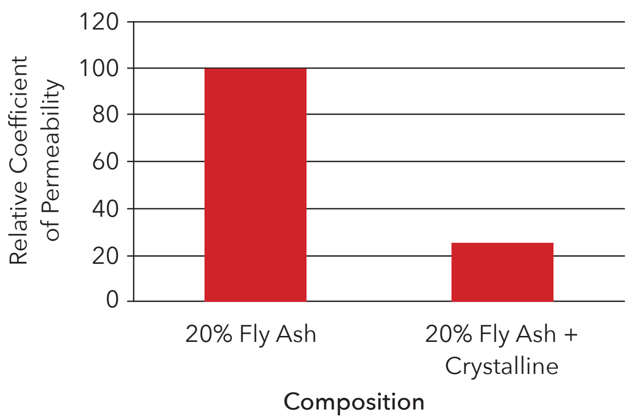

Fig. 2: Significant permeability reduction in fly ash mixture with the addition of crystalline admixture KIM

References

[1] ScienceDirect. Supplementary Cementitious Material, https://www.sciencedirect.com/topics/engineering/supplementary-cementitious-material, 2018.
[2] ACI Committee 212. Report on Chemical Admixtures for Concrete. Chapter 15. American Concrete Institute, USA, p. 43, 2016.
[3] ACI Committee 212. Report on Chemical Admixtures for Concrete. Chapter 15. American Concrete Institute, USA, p. 44, 2016.
[4] Steward, M., and Morgan, D. R. "Annacis Island Waste Water Treatment Plant – Concrete Submittals," Technical Report: Project VA-03222, AGRA Earth and Environmental, Burnaby, BC, 1994.

FURTHER INFORMATION

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