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REVIEW

Performance and sustainability overview of alkali-activated self-compacting concrete

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Abstract

Self-compacting concrete (SCC) has gained huge attention recently due to its high workability which eliminates the need for vibration and makes its placement easier compared to conventional concrete. However, the production of Portland cement (PC) which is the main binder in SCC is energy-intensive and one of the major contributors to the world's carbon dioxide emission. On the other hand, the use of alkali-activated binders (AABs) in concrete has been reported to reduce the energy consumption and carbon emission of concrete by more than 50%. Therefore, the use of AAB as a binder in SCC can help to achieve an eco-friendlier concrete. This paper gives a short overview of the performance of SCC made with AABs. The effect of various factors on the performance of alkali-activated self-compacting concrete (AASCC) was discussed and a simplified sustainability assessment of AASCC was carried out. Discussions from this paper showed that AASCC with acceptable fresh and hardened properties can be achieved with the proper selection of materials. In addition, the evaluation of the embodied energy and carbon of different types of concrete showed that AASCC is more sustainable. However, more research in this field is required to encourage its universal acceptance and large-scale application.

Keywords Concrete · Self-compacting concrete · Alkali-activated concrete · Sustainability · Clean technology

Abbreviations

AAB	Alkali activated binders
AAC	Alkali activated concrete
AASCC	Alkali activated self-compacting concrete
CP	Ceramic powder
FA	Fly ash
HRWRA	High-range water-reducing admixture
MK	Metakaolin
NH	Sodium hydroxide
NS	Sodium silicate
PC	Portland cement
PCC	Portland cement concrete
RHA	Rice husk ash
SL	Slag
QP	Quartz powder

Introduction

The last decade has seen increasing research and use of alkali-activated binders (AAB) as a sustainable alternative to the conventional Portland cement. AABs are sustainable compared to PC as the high-energy consumption and carbon dioxide emission from the production of the PC is eliminated [1, 2]. AABs are made up of aluminosilicate precursors, mostly waste materials, and activated with an alkali media to produce alkali-activated concrete (AAC) [3–5]. In general, AAC has been found to have excellent mechanical and durability performance compared to Portland cement concrete (PCC) [6–8]. The advancement in concrete technology has also led to the development of a special type of concrete called self-compacting concrete (SCC). As the name implies, SCCs are very flowable and able to consolidate under their weight [9]. In addition, to their self-compacting ability, they possess high passing and filling ability coupled with outstanding segregation resistance which makes them suitable for various applications. However, the presence of PC as a binder in SCC is still a major concern due to the high embodied energy and carbon of PC [10, 11]. Despite the extensive use of AAB

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to produce AAC, its use as a binder is very limited. To create more awareness about this clean material and technology, this study was undertaken as part of an extensive study to improve the sustainability of SCC. This paper presents a short overview of the performance of AASCC in terms of its fresh and hardened properties. A simplified sustainability comparison of different types was concrete was also carried out. It is anticipated that this paper will create more awareness about ways to improve the sustainability of building materials and technologies. It is also anticipated that this review will be a useful resource to researchers and scientists working on ways to incorporate clean technologies into building materials.

Self-compacting concrete (SCC)

As mentioned earlier, SCC is a special type of concrete that can be placed and compacted under its weight in contrast to the conventional SCC where vibration or compaction is needed. The compaction of conventional concrete is energy-intensive, expensive, takes time, and emits carbon dioxide into the environment. In addition to the self-compacting ability of these types of concrete, they are capable of free-flowing around reinforcement and do not exhibit any segregation. Therefore, compared to the use of PCC for construction applications, SCCs are more sustainable and cheaper. The use of SCC has also been found to result in time-saving and results in a reduction in noise pollution due to the elimination of the vibration process. The use of AABs as a binder has also been explored recently to improve the sustainability of SCC. SCCs made with AAB are further referred herein as alkali-activated self-compacting concrete (AASCC).

Alkali activated self-compacting concrete (AASCC)

As the name implies, alkali-activated self-compacting concrete is SCCs made with AABs. As AASCC differs from the conventional AAC due to its high workability and self-compacting properties, it is essential to have a good understanding of how its components affect its performance. Table 1 presents the precursor, activator, and composition of various SCCs from the literature. It can be seen from Table 1 that the most used precursor for AASCC is SL in various forms. The preferred choice of SL compared to other precursors can be associated with its higher hydraulic reactivity and calcium content which makes it possible to cure in ambient conditions compared to those made with FA which requires elevated temperature curing. In terms of the alkali activators used, it can be seen from Table 1 that the most used activator is sodium hydroxide (NH) and sodium silicate (NS). These activators are preferred due to their outstanding performance as exhibited in AAC [12–15]. However, the use of these conventional activators (i.e. NH and NS) results in various issues that can be resolved with the use of alternative activators [3, 16, 17]. It is worth to mention that the types of products formed in these composites differ from the type of precursor and activator used. The product from the alkali activation of slag is hydrated calcium silicate but less crystalline when compared to the calcium silicate hydrate (CSH) formed during PC hydration. Also, in contrast to the CSH gel formed when PC is used, the calcium-to-silicate ratio is lower but possesses higher aluminate content [18]. The alkali activation of fly ash is different compared to that of slag and the temperature is very critical to the activation process. Typically, the rate of activation of fly ash particles is very low at ambient conditions. Therefore, an elevated temperature is always required to increase the alkali activation process when FAs are used as precursors. The alkali activation of FA produces amorphous 3D structures composed of aluminosilicate hydrates [19–21]. The negative charges in these hydrates are balanced by the alkaline ions. The ambient curing conditions stated in Table 1 imply temperature of 23 °C ± 3 °C and relative humidity 55% ± 10%.

Performance of AASCC

Slump

The slump of SCC is one of the major properties that determine its classification and application. Following the requirements of EFNARC [39], SCC must possess a slump in the range of 650–800 mm to be used for various applications. Similar to the conventional AAC, the increase in the concentration of the alkali activators used in AASCC is expected to result in a decrease in the workability of the AASCC mixtures. This decrease in the slump with a higher concentration of the alkali can be associated with the higher dissolution of the aluminate and silicate monomers with higher concentration. Saini and Vattipalli [23] reported a decrease in the workability of AASCC mixtures when the concentration of the NH increased from 10 to 16 M. The decrease in the workability of the mixtures with a higher concentration of NH was attributed to the quicker polymeric reaction rate coupled with the quick setting of the SL. Nonetheless, the higher dosage of HRWRA (i.e. 1.2% the SL content) used in the study resulted in all the mixtures satisfying the workability requirements of SCC (i.e. 650–800 mm). These observations are similar to that of Nagaraj and Babu [26] where the concentration of NH was increased from 2 to 12 M as shown in Fig. 1.

Table 1 Binder composition and curing methods of AASCC

Precursor	Activator	Curing regime	References
SL, FA	NH, NS	In water curing	[22]
SL	NH, NS	60 °C for 24 h followed by ambient temperature curing	[23]
SL	NH, NS	Ambient temperature curing	[24]
SL	NH, NS	Ambient temperature curing	[25]
SL, QP	NH, NS	Ambient temperature curing	[26]
SL, FA	NH, NS	23 °C for 24 h followed by 48 h at 70 °C and water cure	[27]
FA, SF	NH, NS	60–90 °C for 24–96 h, ambient temperature curing	[28]
FA	NH, NS	Ambient temperature curing	[29]
FA, SF	NH, NS	Ambient temperature curing	[30]
SL, FA	NH, NS	60–70 °C for 24 h followed by ambient temperature curing	[31]
SL, FA, RHA	NH, NS	Ambient temperature curing	[32]
MK, SF	NH, NS	Ambient temperature curing	[33]
SL, CP	NH, NS	Elevated heat for 48 h, followed by ambient temperature curing	[34]
FA	NH, NS	70 °C for 48 h followed by ambient temperature curing	[35]
SL, CP	NH, NS	Ambient temperature curing	[36]
FA	NH, NS	60–80 °C for 24–72 h, ambient temperature curing	[37]
MK	NH, NS	Ambient temperature curing	[38]
FA, SL, MK	NH, NS	Ambient temperature curing	[12]

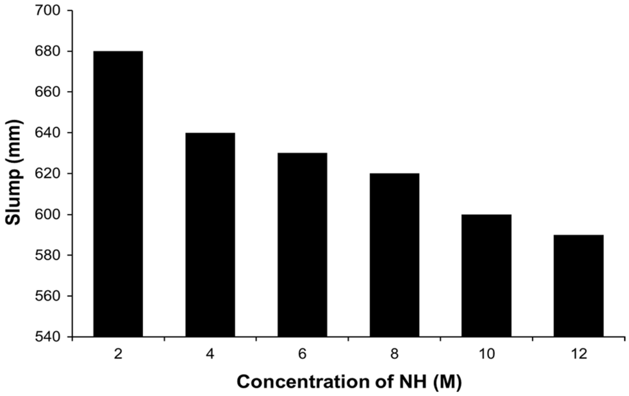

Fig. 1 Effect of NH concentration on slump (adapted from [26])

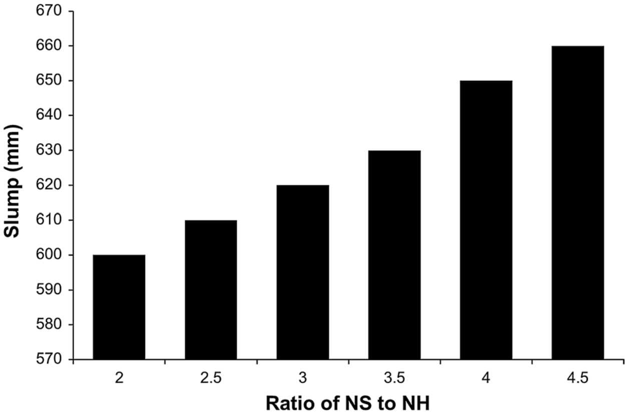

Fig. 2 Effect of NS to NH on slump (adapted from [26])

Most studies on AASCC used a binary combination of NH and NS as an activator in the range of 0.5–2.5. The study by Nagaraj and Babu [26] showed that despite the reduction in the workability of the mixtures with a higher concentration of NH, the workability of the mixtures improved when the content of NS was increased. The effect of NS-to-NH ratio on the slump of AASCC mixtures activated with 8 M of NH alongside NS is presented in Fig. 2. The improved workability with the introduction of the higher content of NS was attributed to its higher water content in comparison to that of NS.

A study by Huseien and Shah [40] where SL and FA were used as a precursor and activated with NH and NS indicates the slump of the AASCC increased with the higher replacement of SL with FA in the mixtures. The replacement of the SL with FA up to 70% resulted in an approximately 70 mm increase in the slump. This study indicated that only SL cannot be used as a precursor when activated with NS and NH in AASCC due to the lower slump obtained (i.e. 560 mm). To satisfy the EFNARC slump requirement, the SL content needs to be replaced with FA in the range of 20–60% as shown in Fig. 3. A similar increase in workability was observed when other methods, such as v-funnel, L-box, and J-ring, were used for the workability evaluation. The lower workability of mixtures incorporating higher content of SL can be attributed to its faster setting time which inhibits the ease at which the mixture flows. While the increase in the workability with the incorporation of FA can be associated with the ability of the FA to reduce the rate of water absorption of the mixture. These observations corresponded to other studies where the incorporation of FA into conventional SCC mixtures resulted in higher workability [9, 41, 42]. Patel and Shah [31] observed a significant decrease in the workability when RHA was incorporated as partial replacement of the FA up to 25% in AASCC mixtures. The reduction in the workability was

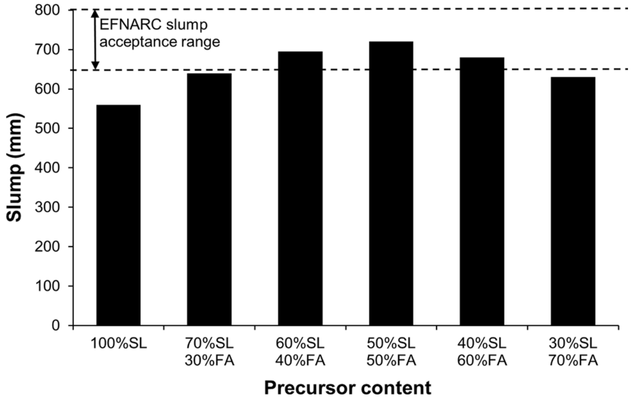

Fig. 3 Effect of precursor type and composition on slump (adapted from [40])

attributed to the higher specific area and water absorption of the RHA which result in a higher loss in workability due to the increase in the water requirement. Huseien et al. [33] reported an improvement in the workability of AASCC when ceramic tile powder (CP) was used to replace SL up to 80%. The slump of the AASCC incorporation CP as 80% replacement of SL is 43.6% higher than that with only SL as the precursor. The enhancement in the workability of the mixtures with the incorporation of CP was attributed to its lower water demand which results in more available water in the mixture. The larger particle size of CP can also responsible for the higher workability due to its lower specific surface area when compared to that of SL [33]. Similar to the effect of high-range water-reducing admixtures (HRWRA) in PCC, its incorporation into AASCC was found to increase the slump of the mixtures. The slump of AASCC was increased by 14% when the HRWRA content was increased from 12 to 28 kg/m^3 [35].

Setting time

Setting time is one of the critical properties required for the practical application of concrete. The use of alkali-activated slag as a binder has been plagued with the quicker setting time of the binder due to the high reactivity of the SL [43]. However, this issue can be eliminated or reduced with the incorporation of FA as a replacement due to its spherical shape and lower reactivity [44]. Huesein and Shah [40] were able to increase the initial and final setting times of AASCC by approximately 680% and 625%, respectively, when 70% of SL was replaced with FA as shown in Fig. 4. These results indicate that depending on the designated application and required setting times, the content of FA and SL can be varied to achieve the desired setting times when sodium silicate and sodium hydroxide are used as an activator. Similar to the effect of CP on the workability of AASCC, its incorporation was also found to increase the initial and final setting times [33]. The higher setting time of AASCC incorporating CP was attributed to the lower reactivity of the CP in comparison to the SL which results in lower product formation and a consequential delay in the setting times. Therefore, in applications where extended setting times are desired, CP can be incorporated as a partial replacement of SL to delay the setting of the composite.

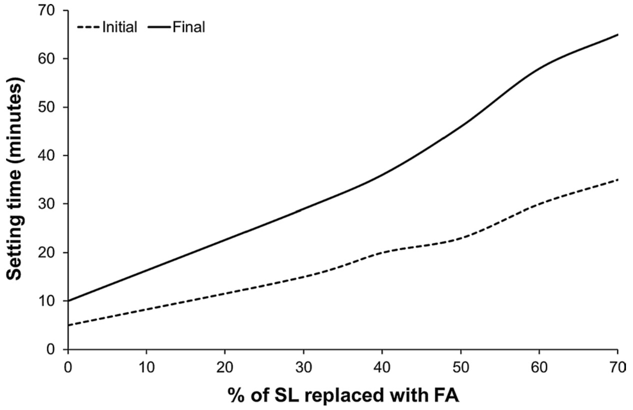

Fig. 4 Effect of precursor type and composition on slump (adapted from [40])

Compressive strength

Generally, the compressive strength of alkali-activated composites has been strongly associated with the ratio of the calcium to the aluminate which is dependent on the type of aluminosilicate precursor used [45–47]. The higher this ratio, the higher the resulting compressive strength of the composite. In contrast to the negative effect of higher concentration of alkali activator on the workability properties, there is a positive influence on the compressive strength. The higher strength of AAC made with a higher concentration of the alkali activator can be attributed to higher dissolution of silicate and aluminate monomers which results in more gel formation and a corresponding increase in strength. An increase in the compressive strength of AASCC mixtures made with NS and NH activated SL was observed when the concentration of NH was increased from 10 to 16 M [23]. This observation corresponds to that of Nagaraj and Babu [26] where the concentration of NH was used in the range between 2 M and 12 M as shown in Fig. 5. However, for mixtures in which the concentration of NH was 4 M and less, the compressive was less than 20 MPa at 90 days. Nagaraj and Babu [26] also reported that the increase in the NS-to-NH resulted in lower compressive strength of AASCC mixtures as shown in Fig. 6. The decrease in the compressive strength with the higher ratio of NS-to-NH was attributed to the introduction of surplus silicate monomers into the matrix coupled with an increase in the water content which results in more polymerization product formation [48].

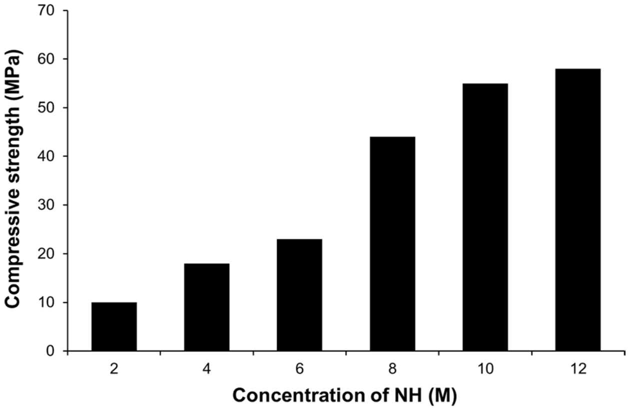

Fig. 5 Effect of NH concentration on compressive strength (adapted from [26])

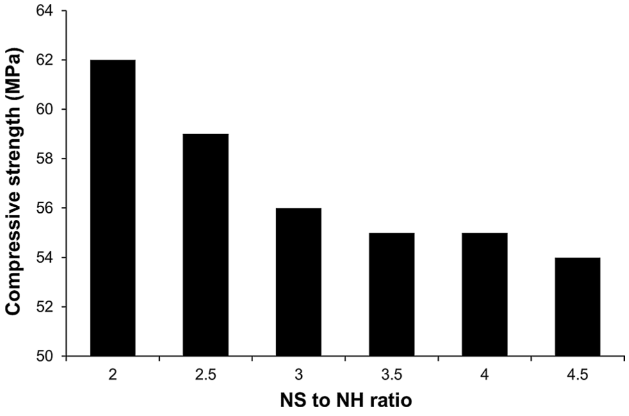

Fig. 6 Effect of NS to NH ratio on compressive strength (adapted from [26])

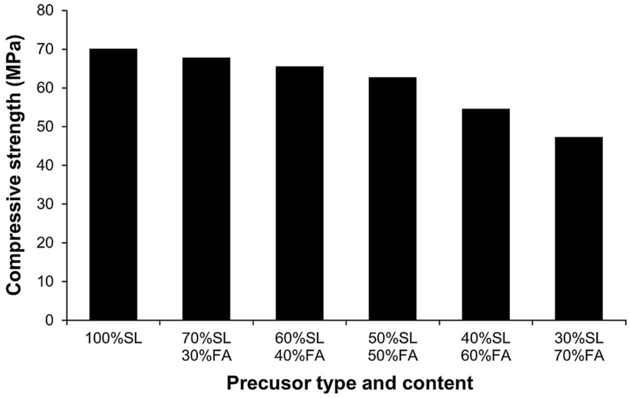

Fig. 7 Effect of precursor type and composition on the 28 days compressive strength

The replacement of SL with FA in AASCC using NS and NH was found to result in a decrease in the compressive strength as shown in Fig. 7 [40]. This observation was also reported to be consistent at all ages when the compressive strengths of the AASCC were evaluated at 1, 3, 7, 28, 56, and 90 days. The reduction in the compressive strength can be attributed to the lower reactivity of the FA as a result of its low calcium-to-silicate and aluminate. Patel and Shah [31] reported a decrease in the compressive strength when RHA was used as FA replacement in AASCC cured at ambient conditions. The reduction in the compressive strength was associated with the increase in the amount of unreacted silica in the system which results in a corresponding increase in the silicate-to-aluminate ratio. However, when heat curing was employed in the first 24 h of casting, there is a significant increase in the compressive strength of the AASCC with increasing content of RHA up to 15%. This increase in the compressive strength of AASCC cured at elevated temperatures can be associated with an increase in the reactivity and activation of the RHA at higher temperatures. Despite the beneficial benefit of CP on the workability of AASCC, it has a consequential effect on the compressive strength [33]. The compressive strength of AASCC was found to reduce with a higher content of CP as partial replacement of SL. Nonetheless, AASCC mixtures incorporating CP as replacement of up to 80% replacement of SL still exhibited a compressive strength higher than 25 MPa at 28 days showing the viability of using the mixture for structural applications. The reduction in the compressive strength with the incorporation of CP can be attributed to the lower calcium oxide in the CP which results in lower strength gain. The lower reactivity of the CP in comparison to that of the SL could also be responsible for the reduction in strength of the AASCC. Saini and Vattipalli [23] explored the effect of nano-silica on the performance of AASCC. Their study showed that the incorporation of 2% nano-silica resulted in a significant increase in the compressive strength. The increase in the strength of the AASCC mixtures with the incorporation of nano-silica was attributed to the nano-silica densifying the tetrahedral aluminosilicate matrix structure [49]. The incorporation of nanomaterials has been found to enhance the performance of cementitious composites [50, 51].

Tensile strength

Similar to the trend observed for compressive strength, an increase in the split tensile strength of AASCC mixtures was found to increase with the concentration of the alkali activator [23]. Also, the use of RHA as a replacement of FA in AASCC cured at ambient temperature was found to result in lower tensile strength [31]. However, samples cured at elevated temperatures exhibited higher tensile strength. The higher tensile strength at elevated temperatures can be associated with the increase in the dissolution of the silicate and aluminate monomers at higher temperatures. In contrast, the incorporation of CP as partial replacement of SL was found to result in a reduction in the split tensile strength of the AASCC [33]. The tensile strength of AASCC mixtures incorporating CP as 80% replacement of SL is 53.1% lower than that with only SL as a precursor. The decrease in the split tensile strength with the incorporation of the CP was attributed to its lower reactivity and low calcium content.

Water absorption and permeability

The water absorption of concrete is a good indication of its overall durability. Huseien and Shah [40] explored the effect of replacing slag with FA in AASCC activated with NH and NS. The study showed that the incorporation of FA as a replacement of the SL increased the water absorption of the composite. The increase in the absorption was attributed to the slower reactivity of the FA when compared to that of SL which results in less densified microstructure and a consequential higher absorption. Similar observations were made when CP was used to partially replace SL up to 80% in AASCC mixtures [33]. An approximately 100% increase in the water absorption of AASCC was observed when CP was used to replace 80% of SL. The increase in the water absorption of the mixtures with the incorporation of CP can be associated with the lower reactivity of the CP which results in less product formation and a consequential porous microstructure. A study by Nagaraj and Babu [26] on the evaluation of AASCC made with SL activated by NH and NS showed that increasing the concentration of the NH resulted in less water absorption of the composites. The reduction with a higher concentration of NH was attributed to the dissolution of more monomers at higher concentrations of NH which results in more product formation and the densification of the microstructure. However, an increase in the ratio of NS-to-NH was found to be detrimental to the water absorption properties due to the increase in the silicate and water content in the mixture. The effect of NH concentration and the ratio of NS-to-NH on the water absorption of the AASCC is presented in Fig. 8.

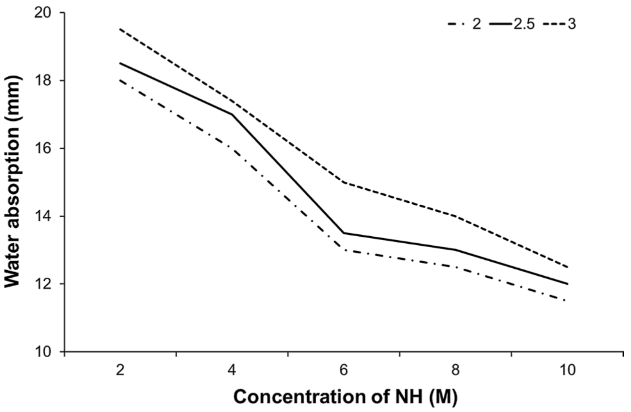

Fig. 8 Effect of NH concentration and ratio of NS to NH on water absorption (adapted from [26])

Sulphate resistance

Nagaraj and Babu [26] reported a higher resistance in AASCC activated with a higher concentration of NH when samples are immersed in a 5% magnesium sulfate solution for 90 days. Whereas, increasing the NS-to-NH ratio resulted in opposite effects. However, a study by Shaiq et al. [36] showed that AASCC has a higher resistance to sulfate attack compared to the conventional SCC. Despite the negative effect of CP on the water absorption of AASCC, its incorporation was found to increase the resistance of the AASCC to sulfate attack [33]. AASCC mixtures incorporating CP up to a dosage of 80% as replacement of SL exhibited a lower strength loss and weight loss compared to that with only SL as precursor when subjected to the sulfuric environment. The enhancement of the resistance of the AASCC mixtures with the incorporation of CP can be attributed to its lower calcium content.

Acid attack

Acid attack is one of the major durability threat concrete structures subjected to a constant supply of moisture and soil. Huseien and Shah [40] reported that there was an increase in the loss of strength due to acid attack in AASCC mixtures that incorporated FA as a replacement of the SL. Nonetheless, it was observed that mixtures incorporating only SL also exhibited a loss in mass when exposed to a sulphuric acid attack. However, the loss in mass was lower compared to those incorporating FA. This observation is similar to that of Nagaraj and Babu [26] where the binder component of the AASCC is made up of SL activated with NS and NH. The study showed that the loss in mass of samples subjected to acid attack reduces with the concentration of NH. When 12 M NH was used alongside NS as an alkali activator, there was no significant loss in mass nor deterioration observed on the samples. However, at a lower concentration of NH (i.e. less than 12 M), the loss in mass of the samples increases with higher NS-to-NH ratios as shown in Fig. 9. These observations are strongly correlated to the compressive strength results where the increase in the ratio of NS-to-NH was found to be detrimental to the performance of the AASCC.

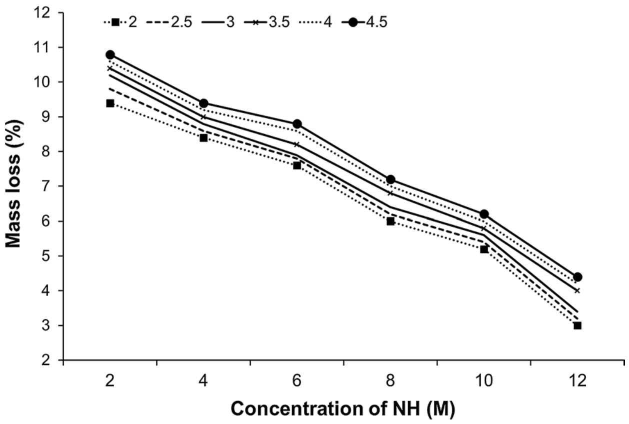

Fig. 9 Effect of NH concentration and ratio of NS to NH on acid attack (adapted from [26])

Drying shrinkage

One of the major issues associated with the use of SL in AAC is its high-drying shrinkage [3, 8, 17, 52, 53]. To reduce this detrimental impact, FA can be used to replace a proportion of SL [52]. A significant reduction in the drying shrinkage of AASCC was observed when FA was used to replace SL up to 70% [40]. The reduction in the drying shrinkage with the incorporation of FA was attributed to the lower calcium content in the FA which results in a slower rate of hydration. On the contrary, a study by Nagaraj and Babu [26] showed that increasing the concentration of NH will result in higher shrinkage in AASCC made with the only slag as a precursor. This is anticipated as the higher dissolution of monomers at higher concentrations of the NH will result in a quick setting and loss of moisture from the composites coupled with higher contraction. Nevertheless, it was found out increasing the NH concentration form 2 to 6 M does not result in any significant effect on the drying shrinkage of AASCC. As drying shrinkage is also dependent on the amount of water present in the fresh mixture, the increase in the drying shrinkage with a higher concentration of NH can be attributed to the lower water content due to the replacement of water with NH pellets to achieve higher concentration. Nonetheless, the increase in the ratio of NS-to-NH was found to reduce the drying shrinkage of the AASCC mixtures due to the introduction of more water into the mixtures [26].

Carbonation

Similar to the chloride ion penetration of AASCC, there is only one study on the carbonation properties of AASCC. Despite the benefit of the incorporation of FA as replacement of SL in AASCC activated by sodium silicate and sodium hydroxide, its incorporation resulted in a detrimental effect on the carbon depth [40]. This observation was attributed to the higher porosity of AASCC incorporating FA due to the slower reactivity of the FA which results in a less dense matrix. This observation can be correlated to the water absorption results where the incorporation of FA was found to increase the absorption of water into the composite [40, 44].

Abrasion resistance

For applications where AASCC is to be used in the construction or rehabilitation of structures, such as pavements and flooring, it is essential to ensure that this composite is capable of resisting the effects of moving loads on its surface. Generally, the study on the abrasion in SCC, AAC, and AASCC is very limited. Nonetheless, an extensive study carried out by Nagaraj and Babu [26] on the evaluation of AASCC indicated that the abrasion resistance increases with a higher concentration of NH. This increase in abrasion resistance with higher concentration can be associated with the enhanced strength and densified microstructure with increasing NH concentration which results in a corresponding resistance against the moving loads. However, in contrary to the other performance evaluated, there was no significant effect of the NS-to-NH ratio in the range of 2–3.5.

Sustainability of AASCC

A simplified sustainability analysis was used to assess the embodied carbon and energy of the PCC, SCC, AAC, and AASCC. The embodied energy and carbon of the materials used for the calculations were obtained from literature and presented in Table 2. Equations 1 and 2 were used to calculate the embodied carbon and energy, respectively, of the different types of concrete. Table 3 presents the composition of the concrete mixtures that were used for the sustainability assessment. Based on Eqs. 1 and 2, the corresponding embodied carbon and energy of the mixtures presented in

Table 2 Embodied carbon and energy of materials

Materials/process	Embodied Energy (MJ/kg)	Embodied Carbon (kgCO$_2$/kg)	References
PC	4.8	0.93	[57]
SL	1.6	0.083	[10]
FA	0.10	0.010	[10]
NH	18	0.86	[58]
NS	4.6	0.43	[59]
Superplasticizer	18.3	0.72	[60]
Water	0	0	[61]
Fine aggregate	0.17	0.025	[62]
Coarse aggregate	0.12	0.0062	[63]
Compaction process	0.009	0.001	[64]

Table 3 Composition of concrete mixtures (kg/m^3)

Mixture	PCC	SCC	AAC	AASCC
PC	428	400	–	–
SL	–	–	360	194
FA	–	20	–	290
NH	–	–	–	16
NS	–	–	67	34
HRWRA	222	2.5	–	0
Water	1039	180	151	292
Coarse aggregate	784	876	1130	756
Fine aggregate	52	845	830	844
Comp. strength (MPa)		55	50	55
References	[65]	[66]	[67]	[40]

Table 4 Sustainability of concrete mixtures

Mixture	Embodied carbon (kgCO$_2$/m^3)	Embodied energy (MJ/m^3)
PCC	427	2335
SCC	401	2216
AAC	89	1184
AASCC	73	1018

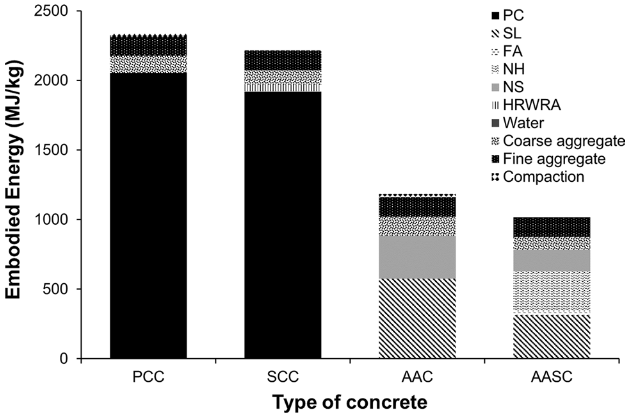

Fig. 10 Embodied energy of different types of concrete

Table 3 are presented in Table 4. It can be seen from Table 4 that the embodied carbon and energy of AASCC is lower compared to other types of concrete. The embodied energy and carbon of AASCC are 56% and 83% lower than that of PCC. These results further confirmed the sustainability advantage associated with the use of AASCC as a construction material. The lower carbon footprint and energy consumption of AASCC can be associated with the use of AABs as a binder and the elimination of the compaction process. The embodied energy and carbon of each material for each type of concrete are presented in Figs. 10 and 11, respectively. It can be seen from the figures that the elimination of PC as binder resulted in a significant reduction in the embodied energy and carbon of concrete. It is also evident that the elimination of compaction in AASCC also resulted in more reduction in the embodied and energy of carbon. However, as the aggregates contribute significantly to the embodied carbon and energy of different types of concrete, the possible use of recycled material as aggregates will result in more reduction in the energy carbon and energy of concrete [54–56].

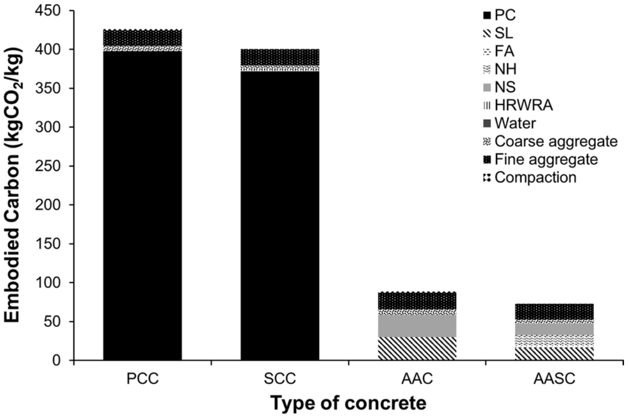

Fig. 11 Embodied carbon of different types of concrete

$$\mathrm{CO}_{2\mathrm{e}} = \sum_{i=1}^{n} \left(W_i \times \mathrm{CO}_{2i} \right), \tag{1}$$

$$E_{\mathrm{e}} = \sum_{i=1}^{n} \left(W_i \times E_i \right). \tag{2}$$

Conclusions

The paper presents a short overview of the performance of AASCC. The performances of the AASCC were explored in terms of its fresh and hardened properties. A sustainability comparison was also made to evaluate the sustainability advantage of AASCC. Results from this study shows that AASCC has a lower embodied energy and carbon due to the elimination of PC as a binder and being placed without compaction. The use of a higher concentration of sodium hydroxide was also found to improve the performance of AASCC. However, there is a more detrimental effect on the workability of the mixtures. The sustainability of AASCC can be improved with the use of alternative activators with lower embodied energy and carbon. Also, the use of alkali activators with lower concentrations is expected to improve the workability of the mixtures. In general, more studies on the durability performance of AASCC should be carried out as the limited studies available so far only focused on the mechanical properties. The influence of less corrosive activators on the performance of AASCC should also be explored.

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Compliance with ethical standards

Conflict of interests The author declares that there is no competing interest.

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