



Effect of binding materials on carbide slag based high utilization solid-wastes autoclaved aerated concrete (HUS-AAC): Slurry, physic-mechanical property and hydration products

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HIGHLIGHTS

- Introducing sulphate aluminium cement (SAC) to adjust slurry performance of carbide slag based HUS-AAC.
- Time-depending rheological properties were investigated to evaluate the thickening property of rough slurry.
- Facilitating effect of SAC in promoting hydrothermal synthesis reaction between $\text{Ca}(\text{OH})_2$ and white mica has been proved.

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ABSTRACT

With the objective of adjusting rough-body foaming and thickening stability of carbide slag based high utilization solid-wastes autoclaved aerated concrete (HUS-AAC) during pre-curing process, the effect of binding material composition and admixture on slurry, physic-mechanical property and hydration products were investigated to put forward an appropriate slurry performance adjustment scheme. Slurry properties include slump flow, time-dependent rheological, and gas foaming properties. Slump flow was conducted to estimate the initial fluidity of primary slurry with different ordinary portland cement 42.5 (OPC42.5) content and sulphate aluminium cement (SAC) substitution ratio. The slurry time-dependent shear stress, apparent viscosity and gas foaming property were measured to evaluate the rough-body stability during the coupling of foaming and thickening process. Physic-mechanical properties were carried out to evaluating the influence of binding materials on applicability. The mineral composition (XRD), thermal characteristics (TG-DSC) and crystal characteristics (^{29}Si -NMR) of carbide slag based HUS-AAC hydration products were analyzed to making a thorough inquiry in the influence mechanism of binding materials on the mechanical properties. The results indicated that increasing OPC42.5 content can modify slurry properties in a small range, which was unable to meet the slurry adjustment target. Introducing of SAC can improve rough-body stability and shorten pre-curing time of HUS-AAC effectively. On the other hand, increasing proportion of OPC42.5 and SAC both has indistinctive effect on bulk density and positive effect on compressive strength of HUS-AAC. Furthermore, increment of OPC42.5 content resulted in increscent crystallinity and quantity of tobermorite, however, addition of SAC led to the opposite effect. The enhancement effect of SAC on HUS-AAC may attribute to the strengthen of pore partition material caused by substituting microcellular structure filling particles from soft white to tough quartz, which is equivalent to increase the strength of aggregate in pore partition material. In conclusion, from the angle of rough-body pre-curing stability and efficiency, and mechanical properties, the conventional OPC42.5 can be substituted by SAC completely.

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1. Introduction

Autoclaved aerated concrete (AAC) is a cellular material with excellent thermal insulation performance which can achieve self-heat insulation with sole material, beyond that, it was also widely

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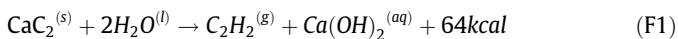
utilized as structure wall materials [1,2,3]. With the ever-increasing demand for building energy conservation, AAC products were increasingly popular both in newly-built constructions and existing building modification.

The raw materials of conventional commercialized AAC usually consisted of quicklime as calcareous material, silicon sand or fly ash as siliceous material, portland cement as binding material and aluminum pastes as gas forming agent [4,5]. Nevertheless, attribute to the motivating effect of hydrothermal synthesis reaction under saturated vapor pressure environment, the high activity and valued calcareous and siliceous materials can be replaced by low grade materials, especially industry solid wastes. In recent years, autoclaved aerated concrete utilizing multiple solid-wastes as substitution of calcareous and siliceous materials gradually received attention due to its low cost and solid waste consumption, such as air-cooled slag [6], coal bottom ash [7], blast furnace slag [8], carbide slag [9], efflorescence sand [10], copper tailings [8], coal gangue [11] and iron tailing [12], etc.

Quicklime is the most energy-extensive consumption component in conventional AAC raw materials with 20–30% weight proportion [13], the substitution of quick-lime can both save energy of lime calcination and reduce the emission of CO₂ [9]. Fan Junjie and Changlong Wang have taken a research of carbide slag AAC products and appropriate preparation conditions was proposed by investigating the influence of ingredients and process parameters on the physic-mechanical property and hydration products [9,12].

In this research, iron tailing and quartz tailing was introduced as siliceous material substitution, meanwhile, employing carbide slag to replace quicklime as calcareous material completely. Iron tailing is a primary emission during iron ore exploiting with nearly 1:2.5–3.0 production ratio to iron ore, which almost totally piled up into the tailings dam. In 2007–2015, more than 6 billion tons iron tailings emitted in China, and increasing year by year [14]. Quartz tailing is the accessory product of quartz mining and processing, which is an irreplaceable material in many important industrial areas. Millions tons of quartz tailing discharged in China every year with serious ground embezzlement and environmental contamination [15].

Carbide slag is the main byproduct in C₂H₂ production and mainly contains calcium hydroxide (Ca(OH)₂) and water (F1), which has been used in cement production [16,17], xonotlite synthesis [18], CO₂ and SO₂ capture [19,20], etc.



Carbide slag was identified as an ideal substitution to quicklime due to its high Ca(OH)₂ content [9]. Nevertheless, some severe problems generated when quicklime was totally replaced by carbide slag. With substitution of carbide slag, the quicklime hydrated heat vanished, which not only slow down the reaction rate of aluminum (Al) paste and gas foaming rate, but also reduce the thickening speed of rough-body. Finally, it resulted in a mismatch of slurry gas foaming and thickening rate, which lead to instability of rough-body and extension of pre-curing time.

However, few researches have been conducted by substituting quicklime (calcareous material) with carbide slag [9]. The regulation and influence of the rough-body property which is an inevitable course between raw materials and final products and coupling gas foaming and thickening process were often ignored by scholars [23]. In order to ensure the stable and efficient production of HUS-AAC, the slurry foaming rate and thickening speed must be adjusted. One of the technical routes is improving the hydration heat and condensation rate of binding materials to accelerate the gas foaming and thickening rate of slurry. Increasing amount of binding material and introducing binding material with high

hydration heat and strength in early stage were two direct approaches.

Sulphate aluminium cement (SAC) is a prototypically early-strength binding material with high early stage hydration heat and strength which is commonly used in special property concrete batching [21]. Employing SAC in HUS-AAC is an efficiency way to shorten the pre-curing time and solve the stabilization problem of rough-body. Nevertheless, few people adopt SAC as binding material in AAC productions which mainly ascribing to the economical consideration. Therefore, study was hardly concentrate on the influence of SAC on the slurry property, physic-mechanical property and hydration products.

For the objective of improving the stability of HUS-AAC rough-body by adjusting slurry gas foaming and thickening properties, the influence of conventional ordinary portland cement 42.5 (OPC42.5) and SAC on slurry properties and physic-mechanical properties were discussed to determine the appropriate binding material constitution. Additionally, to expounding fundamental influence mechanism of binding materials on mechanical properties, the mineral composition (XRD), thermal characteristics (DSC-TG) and crystal feature (²⁹Si NMR) were analyzed.

2. Raw materials and methods

2.1. Raw materials

The raw materials contained carbide slag as calcareous material, iron tailing and quartz tailing as siliceous material and phosphor-gypsum as auxiliary material. The OPC42.5 and SAC were employed as binding materials to modify the gas foaming and thickening property of slurry. Carbide slag was provided by Hubei Yichang chemical industry Co., Ltd. As Fig. 1 presented, carbide slag mainly contains Ca(OH)₂ and CaCO₃. The calcite was generated by carbonation of Ca(OH)₂. Iron tailing from ore-dressing machinery was provided by Wuhan Iron and Steel (Group) Company in China. Quartz tailing was discharged during quartz sand exploit in Suizhou, Hubei. The commercial OPC42.5 was provided by Hubei Yadong cement Co., Ltd. SAC was produced by Sichuan Jiahua special cement Co., Ltd which initial and final coagulation time was 18 min and 25 min, respectively. The mineral analysis of SAC in Fig. 2 indicated that SAC mainly consist of ye'elimite (Ca₄(AlO₂)₆SO₄), belite (Ca₂SiO₄), anhydrite (CaSO₄) and calcite (CaCO₃). The early stage strength and heat effect of SAC are predominately from the hydration of ye'elimite and belite [22]. Al paste was employed as gas generating agent for slurry foaming, which had 80%solid content, 86% active Al content, and its coating

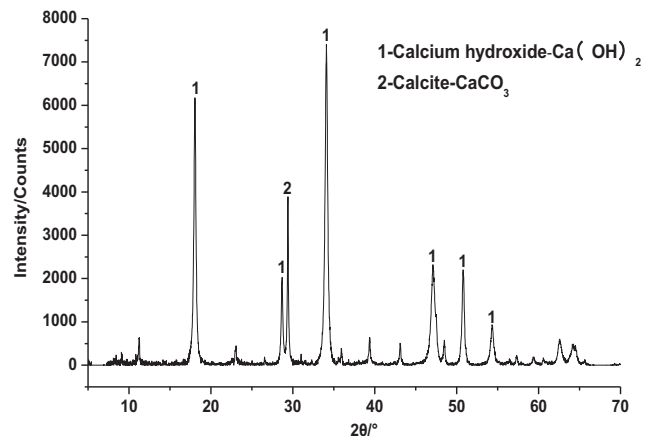


Fig. 1. XRD pattern of carbide slag.

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