(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 November 2022 (24.11.2022)

WIPO | PCT

(10) International Publication Number
WO 2022/245201 A1

(51) International Patent Classification:
C04B 7/153 (2006.01) *C04B 28/00* (2006.01)
C04B 12/00 (2006.01) *C04B 28/08* (2006.01)

(21) International Application Number:
PCT/NL2022/050199

(22) International Filing Date:
11 April 2022 (11.04.2022)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2028226 17 May 2021 (17.05.2021) NL

(71) Applicant: **TECHNISCHE UNIVERSITEIT DELFT** [NL/NL]; Stevinweg 1, 2628 CN Delft (NL).

(72) Inventors: **YE, Guang**; P/a TU Delft, Innovation & Impact Centre, Postbus 5, 2600 AA Delft (NL). **ZHANG, Shizhe**; P/a TU Delft, Innovation & Impact Centre, Postbus 5, 2600 AA Delft (NL). **DONG, Hua**; P/a TU Delft, Innovation & Impact Centre, Postbus 5, 2600 AA Delft (NL).

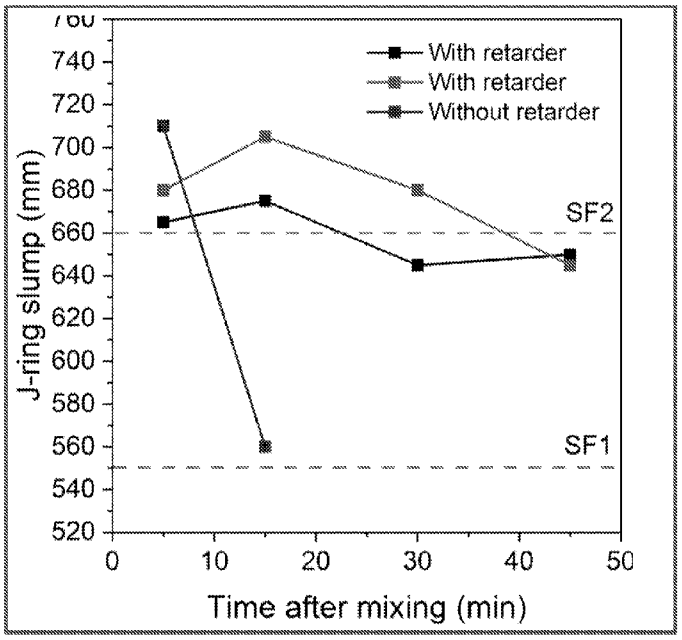
(74) Agent: **VOGELS, Leonard Johan Paul**; Patent Business B.V., p/a Agro Business Park 50, 6708 PW Wageningen (NL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) Title: SELF-COMPACTING ALKALI-ACTIVATED CONCRETE FOR PREFABRICATED PRODUCTION

Fig. 9



(57) Abstract: The present invention is in the field of self-compacting alkali-activated concrete for prefabricated production, a method of forming said concrete, and a prefabricate, such as pre-stressed elements, pre-cast elements, structural building elements, such as floors, walls, ceilings, supports, and frames. The prefabricate has improved characteristics and for production less carbon dioxide is required.

[Continued on next page]

WO 2022/245201 A1

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*
— *with amended claims (Art. 19(1))*

Self-compacting alkali-activated concrete for prefabricated production

FIELD OF THE INVENTION

The present invention is in the field of self-compacting alkali-activated concrete for prefabricated production, a method of forming said concrete, and a prefabricate, such as pre-stressed elements, pre-cast elements, structural building elements, such as floors, walls, ceilings, supports, and frames. The prefabricate has improved characteristics and for production less carbon dioxide is required.

BACKGROUND OF THE INVENTION

Concrete is a composite construction material composed primarily of aggregate, cement and water, with mortar being similar thereto, however using finer aggregates. There are many formulations that have varied properties. The aggregate is generally a coarse gravel or crushed rocks such as limestone, or granite, along with a fine aggregate such as sand. The cement, commonly Portland cement, and other cementing materials such as fly ash, blast furnace slag, ground calcium carbonate, etc. serve as a part of binder for the concrete. Typically further additives are present.

Various chemical admixtures can be added to achieve varied properties. Water is typically thereafter mixed with this dry or moist composite which enables it to be shaped (typically poured) and then solidified and hardened into rock-hard strength through a mineralogical transformation known as hydration and/or pozzolanic reaction. Also particle size and polarity of materials play a role in the performance of concrete. Concrete may be reinforced with materials that are strong in tension (often steel, such as steel bars).

Admixtures are ingredients other than water, fine aggregates, (hydraulic) cement, and fibres that are added to the concrete batch immediately before or during mixing, in order to change certain characteristics of the concrete, when set. The present invention is specifically related to adding further ingredients.

For concrete production the various ingredients mentioned above are mixed. It is noted that concrete production is time-sensitive. Once the ingredients are mixed, the concrete must be put in place before it hardens, such as by casting. Then, quite critical as well, care must be taken to properly cure concrete, e.g. to achieve a required strength and hardness. It is noted that cement requires a moist, controlled environment to gain strength and harden fully. Such a controlled environment is often difficult to provide and to maintain. The cement paste hardens over a relatively long period of time, initially setting and becoming rigid though very weak and gaining in strength in the weeks following. It is noted that hydration and hardening of concrete initially, i.e. during the first three days, is considered critical. Abnormally fast drying and/or shrinkage are unwanted. It is considered of importance that concrete is kept sealed during the initial process. Such may be achieved by spraying or ponding the concrete surface with water, thereby protecting the concrete mass from harmful effects of ambient conditions. Additional common curing methods include wet burlap and/or plastic or

paper sheeting covering the fresh concrete, or by spraying on a water-impermeable temporary curing membrane. In a prior art example a minimum thickness of e.g. 0.01 mm is required to ensure adequate strength in the (membrane) sheet (see e.g. ASTM C 171). Concrete should therein be covered with a membrane, either of plastic or of a chemical compound that will likely seal off the pores and retard the evaporation of water from concrete. After use such a sheet is typically removed.

The mixed cement-based composition comprising further ingredients, or the composition itself, may have unfavourable characteristics, such as sub-optimal rheology, ductility, mixing properties, etc., whereas a cured cement-based composition may suffer from sub-optimal elasticity, compressive strength, autogenous shrinkage, internal water availability, ductility, and morphology.

Some additives are added to cement-based materials. A prior art alternative to affect the autogenous shrinkage are Super Absorbent Polymers (SAPs), and water-saturated clay particles (Litag). Despite high expectations these materials have important drawbacks, and are therefore typically not put into practice.

Some prior art may be noted. For instance Patel et al. (doi:10.1016/j.serj.2018.08.004) investigate the effect of temperature curing and ambient curing on mechanical properties of Self Compacting Geopolymer Concrete (SCGC) blended using Ground Granulated Blast Furnace Slag (GGBFS) and Rice Husk Ash (RHA). The research also studied the effect of percentage (0, 5, 15 and 25%) replacement of RHA on the properties of SCGC. The compressive strength, split tensile strength and flexure strength were tested at 3, 7 and 28 days. Scanning Electron Microscopy (SEM) imaging was performed to understand the microstructure of SCGC specimens. The optimum percentage replacement of RHA with GGBFS is 5% at ambient curing and 15% at 70 °C temperature curing. The higher strength is obtained at 70 °C temperature curing than at ambient curing. The SEM imaging reveals that 5% RHA at ambient temperature and 15% RHA at 70 °C temperature have a dense microstructure and hence higher strength. Gülşan et al. (doi:10.1016/J.CONBUILDMAT.2019.03.228) investigate the simultaneous effect of nano-silica and steel fiber on the fresh and hardened state performance of self-compacting geopolymer concretes (SCGC). For this purpose, self-compacting geopolymer concretes without and with nano-silica (0, 1% and 2%), and without and with steel fiber (0, 0.5% and 1%) were produced. Hooked-end steel fibers were used with a length of 30 mm and an aspect ratio of 40. Self-compacting geopolymer mixes were produced using 50% fly ash (FA) and 50% ground granulated blast furnace slag (GGBFS) with a constant alkaline activator to binder ratio of 0.5. For the alkaline activator, sodium silicate solution (Na2SiO3) and sodium hydroxide solution (NaOH) were utilized with a ratio (Na2SiO3/NaOH) of 2.5. Fresh state experiments were carried out via slump flow, L-Box, and V-funnel tests, while hardened state experiments were conducted using compressive strength, flexural strength, and bonding strength tests to estimate the effects of nano-silica and steel fiber together on the resulting performances of SCGC specimens. Test results

were also evaluated statistically in order to clarify the contributions of the important parameters on the resulting performance. Moreover, correlations between the experimental data were studied to investigate the relationships between the fresh and hardened state performances. The results demonstrated that incorporation of nano-silica and steel fiber affected the fresh state properties adversely; however, a combined utilization of them improved bond strength and flexural performance of the SCGC specimens significantly. In addition, the effect of nano-silica was found to be dominant on fresh state properties and compressive strength, while the effect of steel fiber was found to be superior on flexural performance and bonding strength.

Prefabrication relates typically to assembling components of a structure in a factory or the like, and thereafter transporting complete assemblies or sub-assemblies to a construction site where the structure is to be assembled. The term is used to distinguish this process from the more conventional construction practice of transporting the basic materials to the construction site where all assembly is carried out. An example thereof is house-building. In a conventional method of building a house components thereof, such as bricks, timber, cement, sand, steel, and construction aggregate, etc. are transported to the site of construction, and thereafter constructed into the house on site. In prefabricated construction, typically only the foundations are constructed in this way, while sections of walls, floors and roof are prefabricated (assembled) in a factory (possibly with window and door frames included), transported to the site, lifted into place by a crane and bolted together.

Despite a long history there still is a need for improved concrete composition, or at least improvement from one or more characteristics thereof. In particular at least one of the 1-day strength, elastic modulus, strength class, slump flow class, viscosity class, passing ability class, segregation resistance class, and slump retention, may be of interest.

The present invention relates in particular to an improved concrete for a prefabricate and various aspects thereof which overcomes one or more of the above disadvantages, without jeopardizing functionality and advantages.

SUMMARY OF THE INVENTION

The present invention relates in a first aspect to a self-compacting alkali-activated concrete for prefabricated production, with limited environmental impact, increased durability, and increased service life. Typically the 1-day strength is >30 MPa, the elastic modulus is > 30 GPa at 28 days, the strength class is C45/55, the slump flow class is SF2 according to EN206-1, the viscosity class is VS1 according to the European Guidelines for self-compacting concrete (EFNARC), the passing ability class is J-ring blocking step ≤ 10 mm,, the segregation resistance class is SR2<15% according to EFNARC, and the slump retention after 45 min is >580 mm (SF1). The self-compacting alkali-activated concrete for prefabricated production comprises as main components 400-600 kg blast furnace slag, in particular 500-560 kg slag, 250-350 kg of at least one alkaline activator (AA), the AA comprising an alkali alkaline component, such as OH^-, and CO_3^{2-}, or a combination

thereof, combined with an alkali metal cation, such as Na^+, K^+, and combinations thereof, a silicate, and as a remainder water, in particular 280-320 kg AA, 1200-1800 kg of a concrete aggregate, in particular 1300-1600 kg aggregate, and 1.30-1.50 kg of a retarder, in particular 1.35-1.40 kg retarder, more in particular 1.37-1.38 kg retarder, wherein the retarder comprises a divalent cation, wherein amounts are based on 1 m^3 concrete. The present alkaline activator typically comprises 5-15 wt.% solids, in particular 7-12 wt.% solids, more in particular 8-10 wt.% solids, such as 8.5-9.5 wt.% solids, in particular wherein the solids are Na_2O and SiO_2, or a suitable form thereof, based on the total weight, of the binder mass of the slag. The alkaline activator to binder (slag) ratio of the present invention is typically 0.35-0.6, in particular 0.4-0.5, more in particular 0.43-0.48, such as 0.46. These main components are typically intimately mixed and thereafter cured. Typically thereto the present method is applied. The present self-compacting alkali-activated concrete is particularly suited for prefabricated production, such as pre-stressed elements, pre-cast elements, and structural building elements, in particular for bridge girders, sections of walls, sections of floors, and sections of roof, possibly with window and door frames included. Depending on a size the term "section" may relate to a "full" wall or the like. Typically the size of the prefabricated product is limited by transport limitations, such as a height of bridges, a width of the road, etc. Structures of up to 10 meters in length, and 3-5 meters in height are feasible, a thickness being as required, such as from 10-40 cm. The prefabricated product is typically lifted on a transportation vehicle, and likewise lifted to its intended place on the construction site.

In a second aspect the present invention relates to a method of producing a self-compacting alkali-activated concrete for prefabricated production according to the invention, comprising providing 400-600 kg slag, such as blast furnace slag, in particular ground granulated blast-furnace slag (GGBFS), 500-560 kg slag, in particular 250-350 kg of at least one alkaline activator (AA), the AA comprising an alkali alkaline component, a silicate, and as a remainder water, in particular 280-320 kg AA, 1200-1800 kg of a concrete aggregate, in particular 1300-1600 kg aggregate, and 1.30-1.50 kg of a retarder, in particular 1.35-1.40 kg retarder, more in particular 1.37-1.38 kg retarder, wherein amounts are based on 1 m^3 concrete, thoroughly dry-mixing slag, sand, and pebbles forming a dry-mix, adding an aqueous alkaline activator solution to the dry-mix and mixing said aqueous alkaline activator solution through the aggregate forming a fresh-mix, and adding an aqueous retarder solution to the fresh-mix forming flowable concrete. The aqueous alkaline activator solution is preferably prepared by mixing the alkali compound, such as a hydroxide, such as sodium hydroxide, the silicate, such as sodium silicate, in water. Typically the hydroxide is added first, and then the silicate. Mixing typically takes at least five minutes. After mixing the solution is preferably homogenized, such as for 30-120 minutes, such as for 60 minutes. Preferably relatively fresh aqueous alkaline activator solution is used, such as less than one day old solution. Likewise the retarder is prepared by dissolving into water, typically wherein the retarder comprises a divalent cation, in particular selected from Mg, Ca, and Ba, and an anion, such as Cl^-, more

in particular $BaCl_2$. Mixing thereof typically takes more than 20 minutes, such as more than 35 minutes. The obtained concrete reaches an optimum flowability, whereafter it is typically cast into a mould or the like, typically after 10-15 minutes.

In a further aspect the present invention relates to a method of curing the self- compacting alkali-activated concrete for prefabricated production according to the invention, comprising obtaining the flowable concrete, applying the flowable concrete in a mould, increasing the temperature to at least 5 K above an ambient temperature during a period of at least 60 minutes, thereby curing the mixed components. The self-compacting alkali-activated concrete mixture is preferably sealed from the environment, such as with a plastic film. It is preferably heat-cured under an increased temperature, such as of 25 °C, in particular for at least 24 hours, such as 36 hours. Thereafter it is preferably moisture-cured, such as in a climate chamber, at an ambient temperature, such as at 20 °C, under a relative humidity (RH) >95%, for a period of typically at least 3 days. For curing it is preferred to use wet burlaps to cover the surface of the prefabricated product, and thereafter seal it, such as with a plastic film. Early age water loss is best prevented from happening thereby.

In a further aspect the present invention relates to a prefabricated product obtained by the present method, or obtainable by a similar method, in particular wherein the prefabricated product is selected from pre-stressed elements, pre-cast elements, structural building elements, such as bridge girders, floors, walls, ceilings, supports, and frames.

Thereby the present invention provides a solution to one or more of the above-mentioned problems.

Advantages of the present description are detailed throughout the description. References to the figures are not limiting, and are only intended to guide the person skilled in the art through details of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In an exemplary embodiment the present self -compacting alkali-activated concrete for prefabricated production may comprise as further component water.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the slag may be selected from blast furnace slag, preferably granulated blast furnace slag, and combinations thereof.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the retarder may comprise a divalent cation, in particular selected from Mg, Ca, and Ba, and an anion, such as Cl^-, more in particular $BaCl_2$.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the AA may be in solid or in fluid form.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the silicate may have a modulus of <1.2, preferably < 1.0, in particular from 0.8-0.98, more in particular from 0.86-0.97, such as 0.90-0.92, wherein the modulus is defined as the ratio SiO_2/X_2O, wherein X is selected from monovalent cations,

such as from Li, Na, K, and combinations thereof.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production in the silicate $X_ySi_zO_q$ the ratio z:y may be <1.2, preferably < 1.0, in particular from 0.8-0.98, more in particular from 0.86-0.97, such as 0.90-0.92.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the silicate may be selected from crystalline and amorphous cyclic and single chain silicate (SiO_{2+n}^{2n-}), a pyrosilicate ($Si_2O_7^{6-}$), a branched silicate, and a component that forms a silicate, and combinations thereof, such as from nesosilicates $[SiO_4]^{4-}$, such as olivine, from sorosilicates $[Si_2O_7]^{6-}$, such as epidote, from cyclosilicates $[Si_nO_{3n}]^{2n-}$, such as tourmaline, from inosilicates with single chains $[Si_nO_{3n}]^{2n-}$, such as pyroxene, from inosilicates with double chains $[Si_{4n}O_{11n}]^{6n-}$, such as amphibole, from phyllosilicates $[Si_{2n}O_{5n}]^{2n-}$, such as mica and clay minerals; and from tectosilicates, preferably wherein the silicate comprises a monovalent cation, such as Na^+ and K^+.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the concrete aggregate may comprise as major components 40-60 wt.% sand, in particular <4mm sand, more in particular dry sand, 40-60 wt.% pebbles, such as pebble aggregate, in particular mixed pebbles selected from 20-30 wt.% 4-8 mm pebbles and 20-30 wt.% 8-16 mm pebbles, wherein all wt.% are based on the total weight of the concrete aggregate.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production an average particle size of the slag is 16± 2μm, and wherein three times the standard deviation ranges from 1-60 μm.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production an average particle size of the sand is 580± 20μm, and wherein three times the standard deviation ranges from 100 μm -7 mm.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production an average particle size of the 4-8 mm pebbles is 6.8± 1mm, and wherein three times the standard deviation ranges from 1-12 mm.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production an average particle size of the 8-18 mm pebbles is 10.2± 1mm, and wherein three times the standard deviation ranges from 1-20 mm.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production an average particle size of dry-mix is 1.5± 0.2mm, and wherein three times the standard deviation ranges from 2 μm -15 mm.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the average particle size of 8-16 mm pebbles is 15-30 times the average particle size of the sand, in particular 18-22 times the average particle size of the sand.

In an exemplary embodiment of the present self -compacting alkali-activated con-

crete for prefabricated production the average particle size of 4-8 mm pebbles is 8-12 times the average particle size of the sand, in particular 9-11 times the average particle size of the sand.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the average particle size of sand is 20-30 times the average particle size of the slag, in particular 24-26 times the average particle size of the sand,

The average particle size and standard deviation are based on a cumulative volume, and wherein particle sizes are measured using laser diffraction, such as by using a Malvern Mastersizer 3000.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the retarder/slag ratio may be from 0.0015-0.0030:1, in particular from 0.002-0.0025:1, wherein the water/solids ratio is from 0.40-0.45:1, in particular from 0.42-0.43:1.

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the 1-day strength may be >10 MPa, in particular >30 MPa (1 day curing @ 25°C, measured according to EN12390-3).

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the strength class may be C45/55 (@ ambient temperature curing after 1 day curing in mould at 25°C, measured according to EN12390-3).

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the elastic modulus may be >20 GPa, in particular >30 GPa (after 28 days, measured according to EN12390-3).

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the slump flow class may be SF2 (initial slump-flow 660-750 mm, measured according to EN12350-2).

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the slump after 45 min may be >580 mm, in particular >600 mm (SF1, measured according to EN12350-2).

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the viscosity flow class may be VS1 (T500≤2s, measured according to EN12350-2).

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production the passing ability class J-ring may be blocking step ≤10mm, measured according to EN12350-12 at 10-15 min after mixing).

In an exemplary embodiment of the present self -compacting alkali-activated concrete for prefabricated production a mass of a sample passing a sieve according to segregation resistance class SR2 may be < 15% (sieve segregation, measured according to EN 12350-11).

In an exemplary embodiment of the present self -compacting alkali-activated con-

crete for prefabricated production the slag comprises 30-35 wt.% SiO_2, in particular 31.5-33 wt.% SiO_2, 10-13 wt.% Al_2O_3, in particular 11-12 wt.% Al_2O_3, 0-2 wt.% Fe_2O_3, in particular 0.3-1.2 wt.% Fe_2O_3, 35-45 wt.% CaO, in particular 38-42 wt.% CaO, 8-12 wt.% MgO, in particular 9-10 wt.% MgO, 0.1-2.5 wt.% SO_3, in particular 1-2 wt.% SO_3, 0-1.2 wt.% Na_2O, in particular 0.1-0.4 wt.% Na_2O,and 0.1-1.2 wt.% K_2O, in particular 0.2-0.9 wt.% K_2O, wherein all weight percentages are based on the total weight of the slag.

The invention is further detailed by the accompanying figures and examples, which are exemplary and explanatory of nature and are not limiting the scope of the invention. To the person skilled in the art it may be clear that many variants, being obvious or not, may be conceivable falling within the scope of protection, defined by the present claims.

SUMMARY OF FIGURES

Figures 1, 2a-b, 3, 4a-b, 5-9 show experimental results.

DETAILED DESCRIPTION OF FIGURES

Figure 1 shows the cumulative volume versus particle diameter of individual compounds and mixture. The particle size packing of all materials is to fit the best packing according to modified Andreassen and Anderson model.

Figs. 2a shows J-ring slump performance over time. Figs. 2b shows the J-ring passing ability (blocking step) over time

Fig. 3 shows compressive strength as a function of curing temperature at early age.

Figs. 4a-b show compressive strength and splitting tensile strength as a function of time.

Fig. 5 shows the development of the elastic modulus and Poisson ratio over time, respectively.

Fig. 6 shows drying shrinkage and weight change over time.

Fig. 7 shows the compressive strength development over time for different silicate modulus of alkaline activator (Ms).

Figures 8 and 9 show the difference between a composition with and without (left lines) retarder, in terms of J-ring passing ability (mm) (Fig. 8) and J-ring slump (mm)(Fig. 9).

The figures are further detailed in the description.

The invention although described in detailed explanatory context may be best understood in conjunction with the accompanying figures.

Experimental results

1. Requirements for self-compacting geopolymer concrete (SCGC)

Self-compacting geopolymer concrete (SCGC)

1-day compressive strength (N/mm^2):

• 7-meter span: demoulding strength C25/30

28-day compressive strength:

I. • 7-meter span: C45/55 tested according to EN12390-3
II. Strength Class C45/55 tested according to EN12390-3
III. 1-day strength: >30 MPa tested according to EN12350-2
IV. Slump flow class: SF2 (initial slump-flow 660-750 mm) tested according to EN12350-2
V. Viscosity class: VS1 (T500 ≤ 2 s) tested according to EN12350-12
VI. Passing ability classes J-ring (Blocking step ≤10 mm) EN 12350-12
VII. Segregation resistance class (sieve segregation): SR2 <15% tested according to EN12350-11
VIII. Slump retention: 45 min > 580 (580-640) mm SF1 tested according to EN12350-2

2. Development of SCGC (C45/55)

• Raw materials characterization (Chemical and physical properties)
• Mixture packing optimization
• Fresh properties: (J-ring) slump flow, J-ring passing-ability, setting time, segregation resistance
• Curing regime definition

Self-compacting Geopolymer Concrete C45/55

Composition		Supplier	Amount kg/m^3
Binder	GGBFS	Ecocem	550.0
Alkaline activator	NaOH Sol. (50.0 wt.%)	Brentag	36.85
	Sodium silicate Sol. (48 wt.%, MS=2.0)	PQ	80.44
	Water	-	184
Admixture	BaCl2 retarder	Sigma-Aldrich	1.375
	Water	-	7.5
Aggregate	Sand 0-4 mm	Dekker	762.2
	Coarse pebble aggregate 4-8 mm	Sibelco	315.9
	Coarse pebble aggregate 8-16 mm	Sibelco	359.1

• Mechanical properties: compressive strength, elastic modulus/poison ratio, and tensile splitting strength
• Volume stability: drying shrinkage

3. Performance evaluation of SCGC

- Strength Class C45/55 → 59.3 MPa at 28d ✓
- 1-day strength: <30 Mpa → 33 MPa ✓
- Slump flow class: SF2 → SF2 until 30 min ✓
- Viscosity class: VS1 (T500 <= 2 s) ✓

- Passing ability classes J-ring (Blocking step ≤10 mm) ✓
- 6. Segregation resistance class (sieve segregation): SR2 <15% ✓
- 7. Slump retention: 45 min > 580 (580-640) mm ✓

Exemplary mixing procedure

Prepare alkaline activator solution

The alkaline activator solution is prepared using sodium hydroxide solution, sodium silicate solution and water. The mixing procedure is first adding water, then adding NaOH solution (50%),and in the end the water-glass solution(48%). The solution is further mixed for at least 5 min and is left for homogenization at least for 1 hour. Afterwards, the alkaline activator solution could be used for geopolymer concrete casting. The prepared alkaline activator solution is best used for casting on the same day.

Preparation of Ba-retarder

The Ba retarder is prepared by dissolving $BaCl_2$ salt in water. The mixing process takes 3 to 5 min.

Sequence of adding materials and mixing time

A free fall concrete mixer with capacity of 40 L is used. The binder material (GGBFS) is dry mixed with the fine sand 0-4 mm and coarse aggregates (both 4-8 mm and 8-16 mm) for 3 to 5 min. The alkaline activator solution is then gradually added in the mixer within 30s. The mixture is mixed further for 1-2 min before the Ba retarder solution is added. The mixing then continues until the concrete reached optimum flowability, which is normally achieved around 10-15 min.

Curing condition

The obtained concrete mixture is sealed with plastic film and is heat-cured under 25 °C for 1 day and afterward moisture-cured in the climate chamber at 20 °C with relative humidity (RH) >95% until testing ages. It is recommended for curing to use wet burlaps to cover the surface of the specimen and then seal it with a plastic film. This is very important to prevent early age water loss.

Exemplary slag composition (calculated on oxide basis)

Oxide (wt.%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	LOI
Slag	32.91	11.84	0.46	40.96	9.23	1.60	–	0.33	1.15

Comparative example

The mixture of Patel et al. (see above) of Self Compacting Geopolymer Concrete (SCGC) blended using Ground Granulated Blast Furnace Slag (GGBFS) and Rice Husk Ash (RHA) was reworked. Thereto inventors closely followed the method and materials disclosed in Section 2.1 thereof to prepare the raw materials. The sand and gravel are similar as specified in the article. The slag used has a similar chemical compositions on oxide basis as the one disclosed in table 1, GGBFS. The average particle size of slag is 17 μm in the reworked case, compared to 14 μm used in the article.

The slag used is locally produced in the Netherlands. The activator is made by the NaOH solutions and Na-silicate solution as suggested in the article. The 12M NaOH is prepared by dissolving NaOH solution (50%) with water. The Na-Silicate solution used has similar Na_2O, SiO_2, and water composition as of the article. The final AA composition in the form of Na_2O, SiO_2, and water is in the end exactly the same as indicated in the article. It is noted that in the article the alkaline activator (AA) concentration with respect to binder (slag) content is Na2O =8.30%, SiO2=9.71%, and water to binder ratio 0.325. The total solid content in AA is 18.09%. In the article superplasticizer master Glenium sky8784 is used. Inventors used superplasticizer master Glenium 51, which is considered to provide the same characteristics to the flowability of concrete. The solid content in these two superplasticizers is similar (30%) and they are both PCE-based superplasticizers. In the end, the reworked mixture does not show self-compacting behavior, as provided by the present invention. In fact, it is not able to be cast into molds. A major improvement over the disclosure of the article is therefore provided, as exemplified throughout the description.

It should be appreciated that for commercial application it may be preferable to use one or more variations of the present system, which would be similar to the ones disclosed in the present application and are within the spirit of the invention.

CLAIMS

1. A self-compacting alkali-activated concrete for prefabricated production comprising as main components

400-600 kg slag, wherein the slag is grounded blast furnace slag, in particular 500-560 kg slag,

250-350 kg of at least one alkaline activator (AA), the AA comprising an alkali alkaline component, a silicate, and as a remainder water, in particular 280-320 kg AA,

1200-1800 kg of a concrete aggregate, in particular 1300-1600 kg aggregate, and

1.300-1.500 kg of a retarder, in particular 1.350-1.400 kg retarder, more in particular 1.370-1.380 kg retarder, wherein the retarder comprises a divalent cation,

wherein amounts are based on 1 m^3 concrete.

2. The self-compacting alkali-activated concrete for prefabricated production according to claim 1, comprising as further component water.

3. The self -compacting alkali-activated concrete for prefabricated production according to claim 1 or 2, wherein the slag is granulated blast furnace slag, and/or

wherein the retarder comprises a divalent cation selected from Mg, Ca, and Ba, and an anion, such as Cl^-, more in particular $BaCl_2$.

4. The self -compacting alkali-activated concrete for prefabricated production according to claim 3, wherein the AA is in solid or in fluid form, and/or

wherein the alkaline activator typically comprises 5-15 wt.% solids, in particular 7-12 wt.% solids, more in particular 8-10 wt.% solids, such as 8.5-9.5 wt.% solids, in particular wherein the solids are Na_2O and SiO_2, or a suitable form thereof, based on the total weight of the slag, and/or

wherein the silicate has a modulus of <1.2, preferably < 1.0, in particular from 0.8-0.98, more in particular from 0.86-0.97, such as 0.90-0.92, wherein the modulus is defined as the ratio SiO_2/X_2O, wherein X is selected from monovalent cations, such as from Li, Na, K, and combinations thereof, and/or

wherein in the silicate $X_ySi_zO_q$ the ratio z:y is <1.2, preferably < 1.0, in particular from 0.8-0.98, more in particular from 0.86-0.97, such as 0.90-0.92, and/or

wherein the silicate is selected from crystalline and amorphous cyclic and single chain silicate (SiO_{2+n}^{2n-}), a pyrosilicate ($Si_2O_7^{6-}$), a branched silicate, and a component that forms a silicate, and combinations thereof, such as from nesosilicates $[SiO_4]^{4-}$, such as olivine, from sorosilicates $[Si_2O_7]^{6-}$, such as epidote, from cyclosilicates $[Si_nO_{3n}]^{2n-}$, such as tourmaline, from inosilicates with single chains $[Si_nO_{3n}]^{2n-}$, such as pyroxene, from inosilicates with double chains $[Si_{4n}O_{11n}]^{6n-}$, such as amphibole, from phyllosilicates $[Si_{2n}O_{5n}]^{2n-}$, such as mica and clay minerals; and from tectosilicates.

5. Self-compacting alkali-activated concrete for prefabricated production according to any of claims 3-4, wherein the concrete aggregate comprises as major components 40-60 wt.% sand, in particular <4mm sand, more in particular dry sand, 40-60 wt.% pebbles, such as

pebble aggregate, in particular mixed pebbles selected from 20-30 wt.% 4-8 mm pebbles and 20-30 wt.% 8-16 mm pebbles, wherein all wt.% are based on the total weight of the concrete aggregate, and/or

wherein an average particle size of the slag is 16± 2μm, and wherein three times the standard deviation ranges from 1-60 μm, and/or

wherein an average particle size of the sand is 580± 20μm, and wherein three times the standard deviation ranges from 100 μm -7 mm, and/or

wherein an average particle size of the 4-8 mm pebbles is 6.8± 1mm, and wherein three times the standard deviation ranges from 1-12 mm, and/or

wherein an average particle size of the 8-16 mm pebbles is 10.2± 1mm, and wherein three times the standard deviation ranges from 1-20 mm, and/or

wherein an average particle size of dry-mix is 1.5± 0.2mm, and wherein three times the standard deviation ranges from 2 μm -15 mm, and/or

wherein the average particle size of 8-16 mm pebbles is 15-30 times the average particle size of the sand, in particular 18-22 times the average particle size of the sand, and/or

wherein the average particle size of 4-8 mm pebbles is 8-12 times the average particle size of the sand, in particular 9-11 times the average particle size of the sand, and/or

wherein the average particle size of sand is 20-30 times the average particle size of the slag, in particular 24-26 times the average particle size of the sand,

wherein the average particle size and standard deviation are based on a cumulative volume, and wherein particle sizes are measured using laser diffraction, such as by using a Malvern Mastersizer 3000.

6. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-5, wherein the retarder/slag ratio is from 0.0015-0.0030:1, in particular from 0.002-0.0025:1, and/or

wherein the water/solids ratio is from 0.40-0.45:1, in particular from 0.42-0.43:1.

7. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-6, wherein the 1-day strength is >10 MPa, in particular >30 MPa (1 day curing @ 25°C, measured according to EN12390-3).

8. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-7, wherein the strength class is C45/55 (@ ambient temperature curing after 1 day curing in mould at 25°C, measured according to EN12390-3).

9. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-8, wherein the elastic modulus is >20 GPa, in particular >30 GPa (after 28 days, measured according to EN12390-3).

10. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-9, wherein the slump flow class is SF2 (initial slump-flow 660-750 mm, measured according to EN12350-2).

11. Self-compacting alkali-activated concrete for prefabricated production according to any

of claims 1-10, wherein the slump after 45 min is >580 mm, in particular >600 mm (SF1, measured according to EN12350-2).

12. Self-compacting alkali-activated concrete for prefabricated production according to any of claims 1-11, wherein the viscosity flow class is VS1 (T500≤2s, measured according to EN12350-2).

13. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-12, wherein the passing ability class J-ring is blocking step ≤10mm, measured at 10-15 min after mixing according to EN12350-12).

14. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-13, wherein a segregation resistance class SR2 is < 15% (sieve segregation, measured according to EN 12350-11).

15. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-14, wherein slag comprises

30-35 wt.% SiO_2, 10-13 wt.% Al_2O_3, 0-2 wt.% Fe_2O_3, 35-45 wt.% CaO, 8-12 wt.% MgO, 0.1-2.5 wt.% SO_3, 0-1.2 wt.% Na_2O, and 0.1-1.2 wt.% K_2O, wherein all weight percentages are based on the total weight of the slag.

16. Method of producing a self- compacting alkali-activated concrete for prefabricated production according to any of claims 1-15, comprising

providing 400-600 kg slag, wherein the slag is grounded blast furnace slag, in particular 500-560 kg slag, 250-350 kg of at least one alkaline activator (AA), the AA comprising an alkali alkaline component, a silicate, and as a remainder water, in particular 280-320 kg AA, 1200-1800 kg of a concrete aggregate, in particular 1.300-1.600 kg aggregate, and 1.300-1.500 kg of a retarder, in particular 1.350-1.400 kg retarder, more in particular 1.370-1.380 kg retarder, wherein the retarder comprises a divalent cation, wherein amounts are based on 1 m^3 concrete,

thoroughly dry-mixing slag, sand, and pebbles forming a dry-mix,

adding an aqueous alkaline activator solution to the dry-mix and mixing said aqueous alkaline activator solution through the dry-mix forming a fresh-mix, and

adding an aqueous retarder solution to the fresh-mix forming flowable concrete.

17. Method of curing a self- compacting alkali-activated concrete for prefabricated production according to claim 16, comprising

obtaining the flowable concrete,

applying the flowable concrete in a mould,

increasing the temperature to at least 5 K above an ambient temperature during a period of at least 60 minutes, thereby curing the mixed components.

18. Prefabricate obtained by the method according to claim 16 or 17, in particular wherein the prefabricated product is selected from pre-stressed elements, pre-cast elements, structural building elements, such as bridge girders, floors, walls, ceilings, supports, and frames.

AMENDED CLAIMS
received by the International Bureau on 30 August 2022 (30.08.2022)

1. A self-compacting alkali-activated concrete for prefabricated production comprising as main components

400-600 kg slag, wherein the slag is grounded blast furnace slag, in particular 500-560 kg slag,

250-350 kg of at least one alkaline activator (AA), the AA comprising an alkali alkaline component, a silicate, and as a remainder water, in particular 280-320 kg AA,

1200-1800 kg of a concrete aggregate, in particular 1300-1600 kg aggregate, and

1.300-1.500 kg of a retarder, in particular 1.350-1.400 kg retarder, more in particular 1.370-1.380 kg retarder, wherein the retarder comprises a divalent cation selected from Mg, Ca, and Ba, and as anion Cl^-,,

wherein amounts are based on 1 m^3 concrete.

2. The self-compacting alkali-activated concrete for prefabricated production according to claim 1, comprising as further component water.

3. The self -compacting alkali-activated concrete for prefabricated production according to claim 1 or 2, wherein the slag is granulated blast furnace slag only

4. The self -compacting alkali-activated concrete for prefabricated production according to claim 3, wherein the AA is in solid or in fluid form, and/or

wherein the alkaline activator typically comprises 5-15 wt.% solids, in particular 7-12 wt.% solids, more in particular 8-10 wt.% solids, such as 8.5-9.5 wt.% solids, in particular wherein the solids are Na_2O and SiO_2, or a suitable form thereof, based on the total weight of the slag, and/or

wherein the silicate has a modulus of <1.2, preferably < 1.0, in particular from 0.8-0.98, more in particular from 0.86-0.97, such as 0.90-0.92, wherein the modulus is defined as the molar ratio SiO_2/X_2O, wherein X is selected from monovalent cations, such as from Li, Na, K, and combinations thereof, and/or

wherein in the silicate $X_ySi_zO_q$ the molar ratio z:y is <1.2, preferably < 1.0, in particular from 0.8-0.98, more in particular from 0.86-0.97, such as 0.90-0.92, and/or

wherein the silicate is selected from crystalline and amorphous cyclic and single chain silicate (SiO_{2+n}^{2n-}), a pyrosilicate ($Si_2O_7^{6-}$), a branched silicate, and a component that forms a silicate, and combinations thereof, such as from nesosilicates $[SiO_4]^{4-}$, such as olivine, from sorosilicates $[Si_2O_7]^{6-}$, such as epidote, from cyclosilicates $[Si_nO_{3n}]^{2n-}$, such as tourmaline, from inosilicates with single chains $[Si_nO_{3n}]^{2n-}$, such as pyroxene, from inosilicates with double chains $[Si_{4n}O_{11n}]^{6n-}$, such as amphibole, from phyllosilicates $[Si_{2n}O_{5n}]^{2n-}$, such as mica and clay minerals; and from tectosilicates.

5. Self-compacting alkali-activated concrete for prefabricated production according to any of claims 3-4, wherein the concrete aggregate comprises as major components 40-60 wt.% sand, in particular <4mm sand, more in particular dry sand, 40-60 wt.% pebbles, such as

pebble aggregate, in particular mixed pebbles selected from 20-30 wt.% 4-8 mm pebbles and 20-30 wt.% 8-16 mm pebbles, wherein all wt.% are based on the total weight of the concrete aggregate, and/or

wherein an average particle size of the slag is 16± 2µm, and wherein three times the standard deviation ranges from 1-60 µm, and/or

wherein an average particle size of the sand is 580± 20µm, and wherein three times the standard deviation ranges from 100 µm -7 mm, and/or

wherein an average particle size of the 4-8 mm pebbles is 6.8± 1mm, and wherein three times the standard deviation ranges from 1-12 mm, and/or

wherein an average particle size of the 8-16 mm pebbles is 10.2± 1mm, and wherein three times the standard deviation ranges from 1-20 mm, and/or

wherein an average particle size of dry-mix is 1.5± 0.2mm, and wherein three times the standard deviation ranges from 2 µm -15 mm, and/or

wherein the average particle size of 8-16 mm pebbles is 15-30 times the average particle size of the sand, in particular 18-22 times the average particle size of the sand, and/or

wherein the average particle size of 4-8 mm pebbles is 8-12 times the average particle size of the sand, in particular 9-11 times the average particle size of the sand, and/or

wherein the average particle size of sand is 20-30 times the average particle size of the slag, in particular 24-26 times the average particle size of the sand,

wherein the average particle size and standard deviation are based on a cumulative volume, and wherein particle sizes are measured using laser diffraction, such as by using a Malvern Mastersizer 3000.

6. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-5, wherein the retarder/slag weight ratio is from 0.0015-0.0030:1, in particular from 0.002-0.0025:1, and/or

wherein the water/solids weight ratio is from 0.40-0.45:1, in particular from 0.42-0.43:1.

7. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-6, wherein the 1-day strength is >10 MPa, in particular >30 MPa, with 1 day curing @ 25°C, measured according to EN12390-3.

8. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-7, wherein the strength class is C45/55 @ ambient temperature curing after 1 day curing in mould at 25°C, measured according to EN12390-3.

9. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-8, wherein the elastic modulus is >20 GPa, in particular >30 GPa(after 28 days, measured according to EN12390-3.

10. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-9, wherein the slump flow class is SF2 initial slump-flow 660-750 mm, measured according to EN12350-2.

11. Self-compacting alkali-activated concrete for prefabricated production according to any of claims 1-10, wherein the slump after 45 min is >580 mm, in particular >600 mm SF1, measured according to EN12350-2.

12. Self-compacting alkali-activated concrete for prefabricated production according to any of claims 1-11, wherein the viscosity flow class is VS1, according to T500≤2s, measured according to EN12350-2.

13. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-12, wherein the passing ability class J-ring is blocking step ≤10mm, measured at 10-15 min after mixing according to EN12350-12.

14. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-13, wherein a segregation resistance class SR2 is < 15%, according to sieve segregation, measured according to EN 12350-11.

15. The self -compacting alkali-activated concrete for prefabricated production according to any of claims 1-14, wherein slag comprises

30-35 wt.% SiO_2, 10-13 wt.% Al_2O_3, 0-2 wt.% Fe_2O_3, 35-45 wt.% CaO, 8-12 wt.% MgO, 0.1-2.5 wt.% SO_3, 0-1.2 wt.% Na_2O, and 0.1-1.2 wt.% K_2O, wherein all weight percentages are based on the total weight of the slag.

16. Method of producing a self- compacting alkali-activated concrete for prefabricated production according to any of claims 1-15, comprising

providing 400-600 kg slag, wherein the slag is grounded blast furnace slag, in particular 500-560 kg slag, 250-350 kg of at least one alkaline activator (AA), the AA comprising an alkali alkaline component, a silicate, and as a remainder water, in particular 280-320 kg AA, 1200-1800 kg of a concrete aggregate, in particular 1.300-1.600 kg aggregate, and 1.300-1.500 kg of a retarder, in particular 1.350-1.400 kg retarder, more in particular 1.370-1.380 kg retarder, wherein the retarder comprises a divalent cation, wherein amounts are based on 1 m^3 concrete,

thoroughly dry-mixing slag, sand, and pebbles forming a dry-mix,

adding an aqueous alkaline activator solution to the dry-mix and mixing said aqueous alkaline activator solution through the dry-mix forming a fresh-mix, and

adding an aqueous retarder solution to the fresh-mix forming flowable concrete.

17. Method according to claim 16, comprising

obtaining the flowable concrete,

applying the flowable concrete in a mould,

increasing the temperature to at least 5 K above an ambient temperature during a period of at least 60 minutes, thereby curing the mixed components.

18. Prefabricate obtained by the method according to claim 16 or 17, in particular wherein the prefabricated product is selected from pre-stressed elements, pre-cast elements, structural building elements, such as bridge girders, floors, walls, ceilings, supports, and frames, hav-

ing at least one of
a 1-day strength of >10 MPa, in particular >30 MPa, with 1 day curing @ 25°C, measured according to EN12390-3, and
a strength class of C45/55 @ ambient temperature curing after 1 day curing in mould at 25°C, measured according to EN12390-3, and
an elastic modulus of >20 GPa, in particular >30 GPa(after 28 days, measured according to EN12390-3, and
a slump flow class of SF2 initial slump-flow 660-750 mm, measured according to EN12350-2, and
a slump after 45 min of >580 mm, in particular >600 mm SF1, measured according to EN12350-2, and
a viscosity flow class of VS1, according to T500≤2s, measured according to EN12350-2, and
a passing ability class J-ring of blocking step ≤10mm, measured at 10-15 min after mixing according to EN12350-12, and
a segregation resistance class SR2 of < 15%, according to sieve segregation, measured according to EN 12350-11.

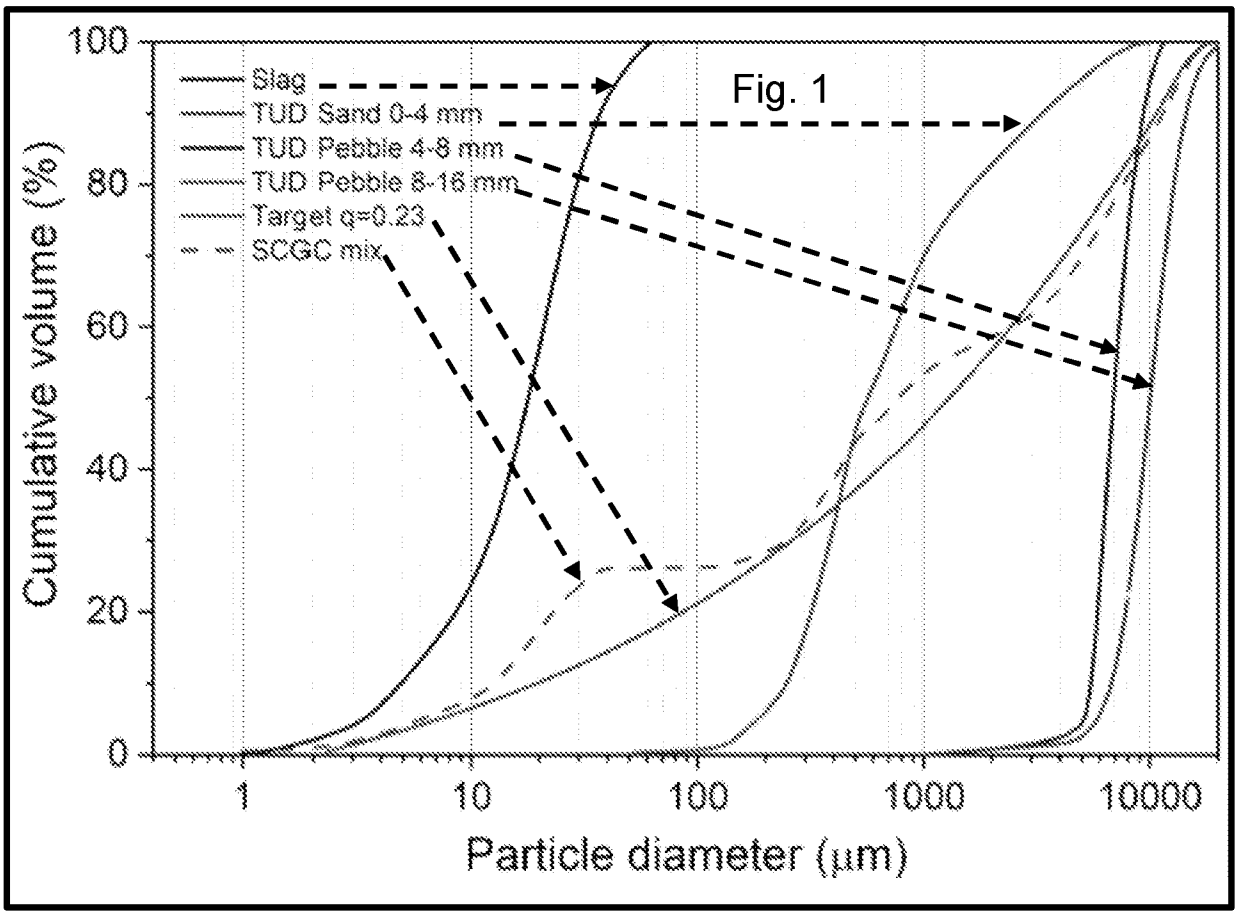
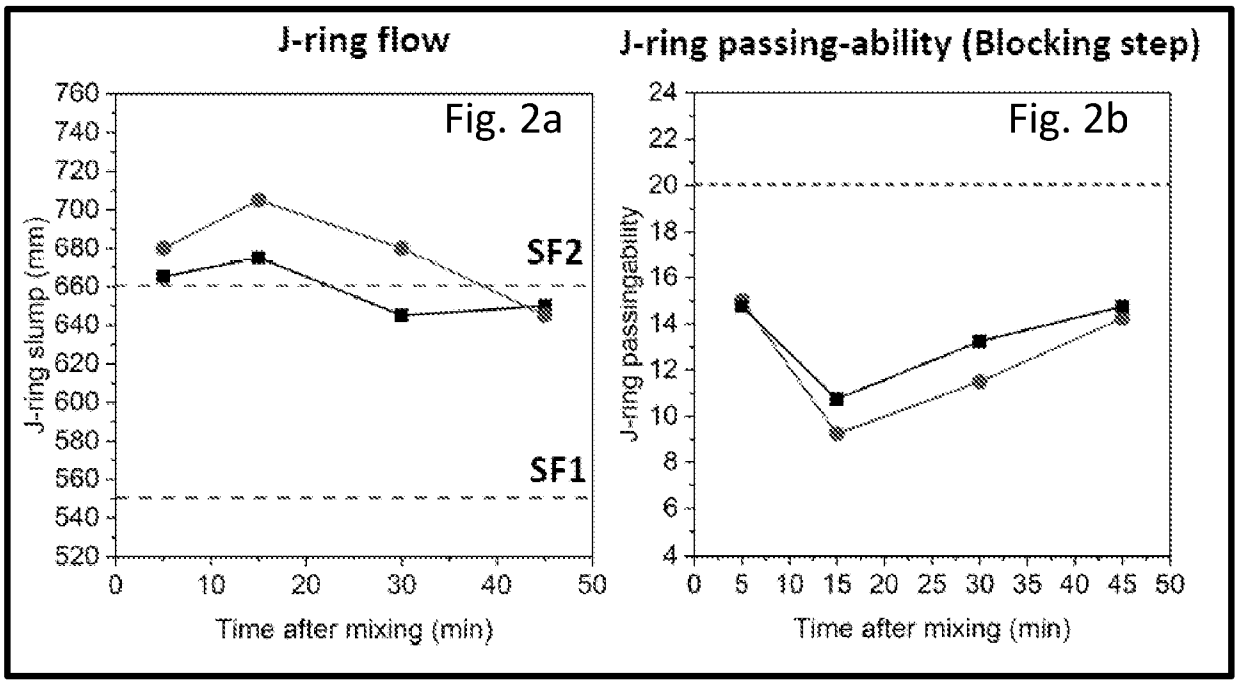


Fig. 1
Slag
TUD Sand 0-4 mm
TUD Pebble 4-8 mm
TUD Pebble 8-16 mm
Target q=0.23
SCGC mix
Cumulative volume (%)
Particle diameter (µm)
0
20
40
60
80
100
1
10
100
1000
10000


J-ring flow
Fig. 2a
SF2
SF1
J-ring slump (mm)
Time after mixing (min)
J-ring passing-ability (Blocking step)
Fig. 2b
J-ring passingability
Time after mixing (min)

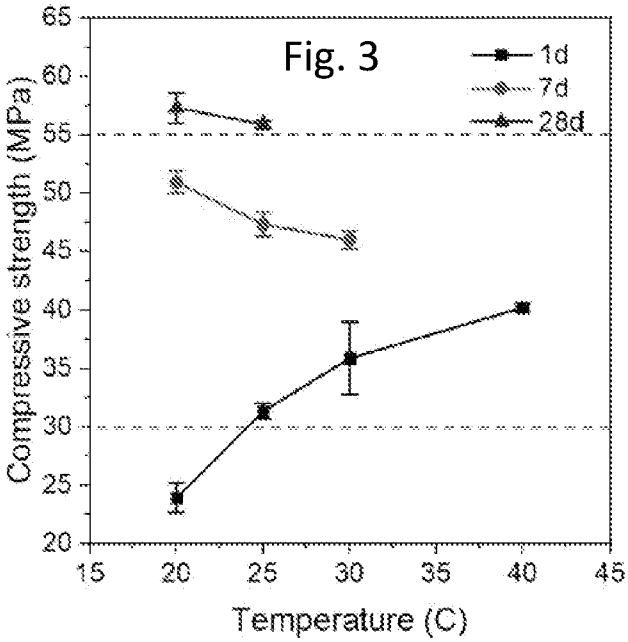


Fig. 3
1d
7d
28d
Compressive strength (MPa)
Temperature (C)

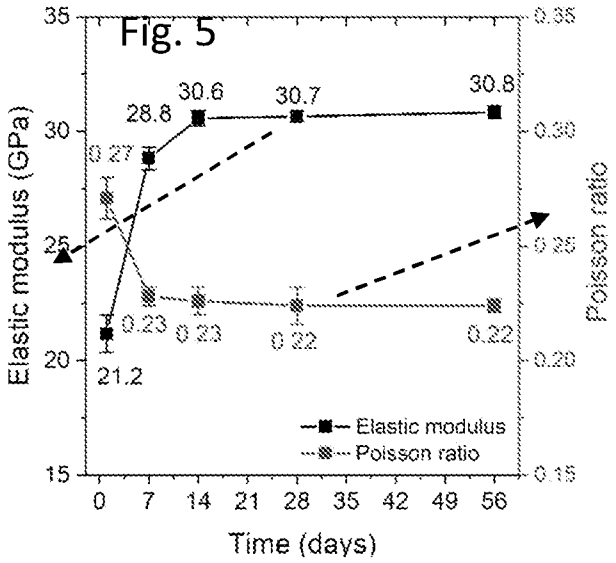


Fig. 5
Elastic modulus (GPa)
Poisson ratio
Time (days)
Elastic modulus
Poisson ratio
21.2
28.8
30.6
30.7
30.8
0.27
0.23
0.23
0.22
0.22

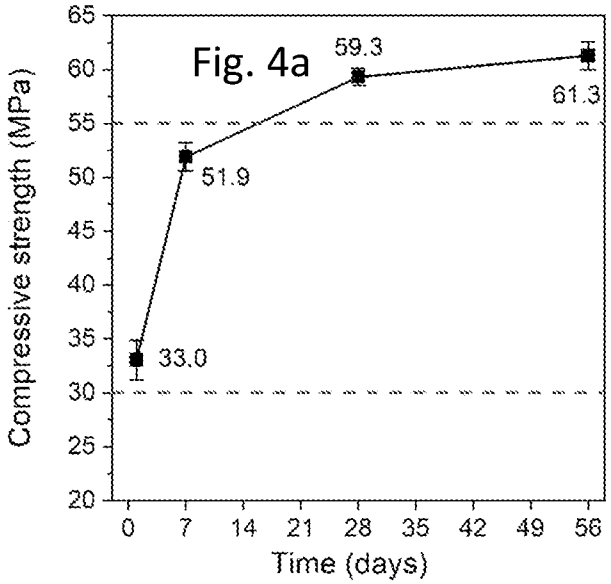


Fig. 4a
Compressive strength (MPa)
Time (days)
33.0
51.9
59.3
61.3

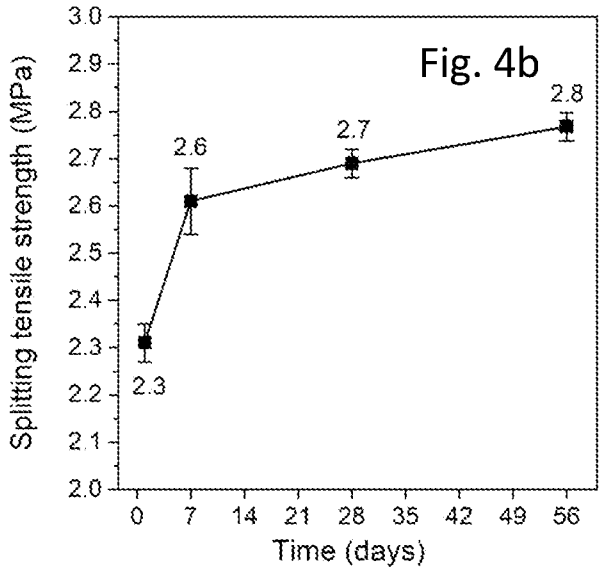


Fig. 4b
Splitting tensile strength (MPa)
Time (days)
2.3
2.6
2.7
2.8

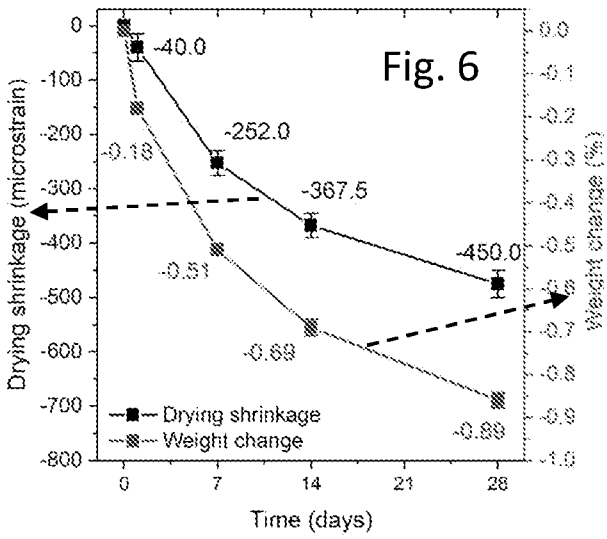


Fig. 6
Drying shrinkage (microstrain)
Weight change (%)
Time (days)
Drying shrinkage
Weight change
-40.0
-252.0
-367.5
-450.0
-0.18
-0.51
-0.69
-0.89

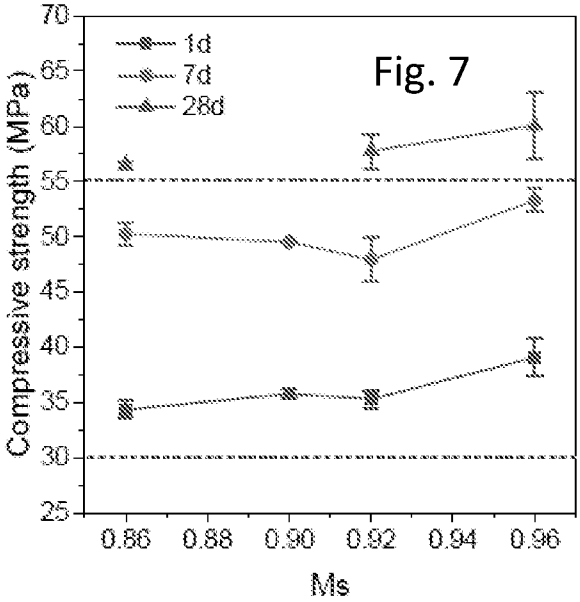


Fig. 7
1d
7d
28d
Compressive strength (MPa)
Ms

Fig. 8

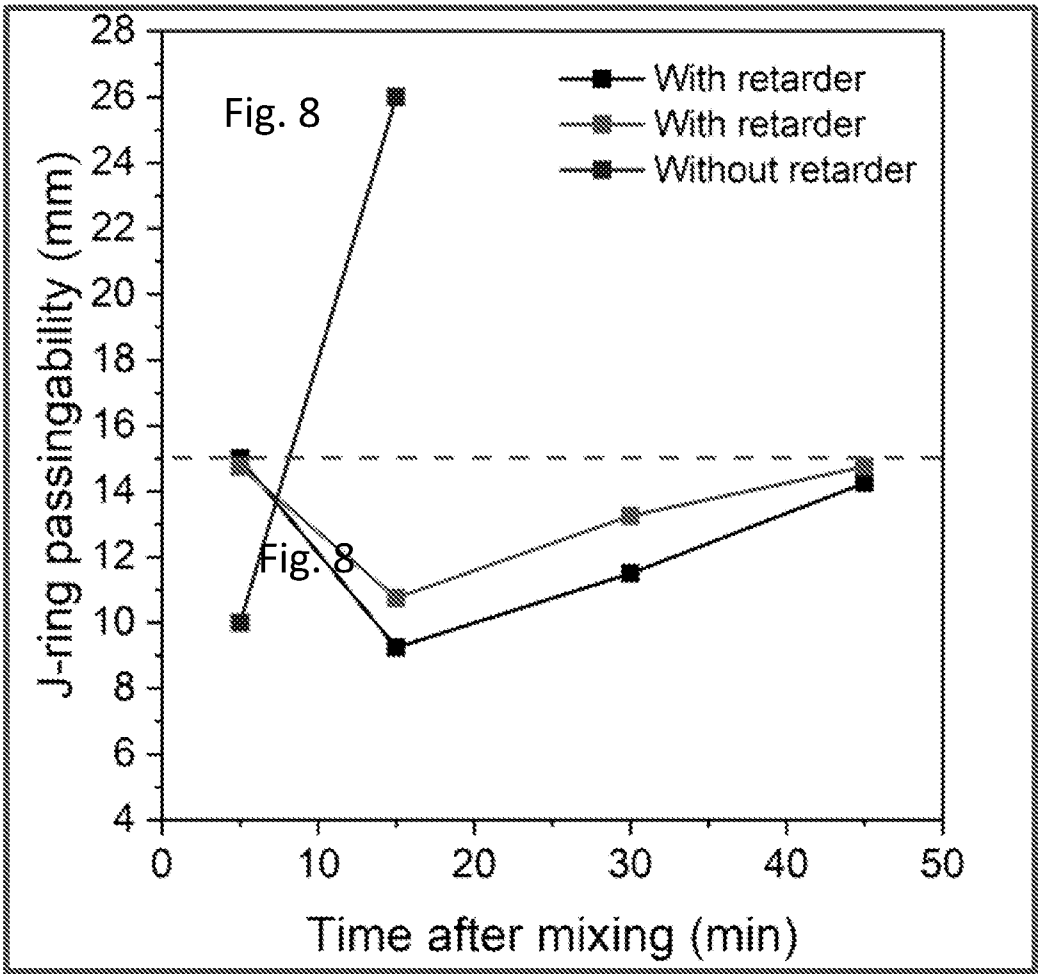
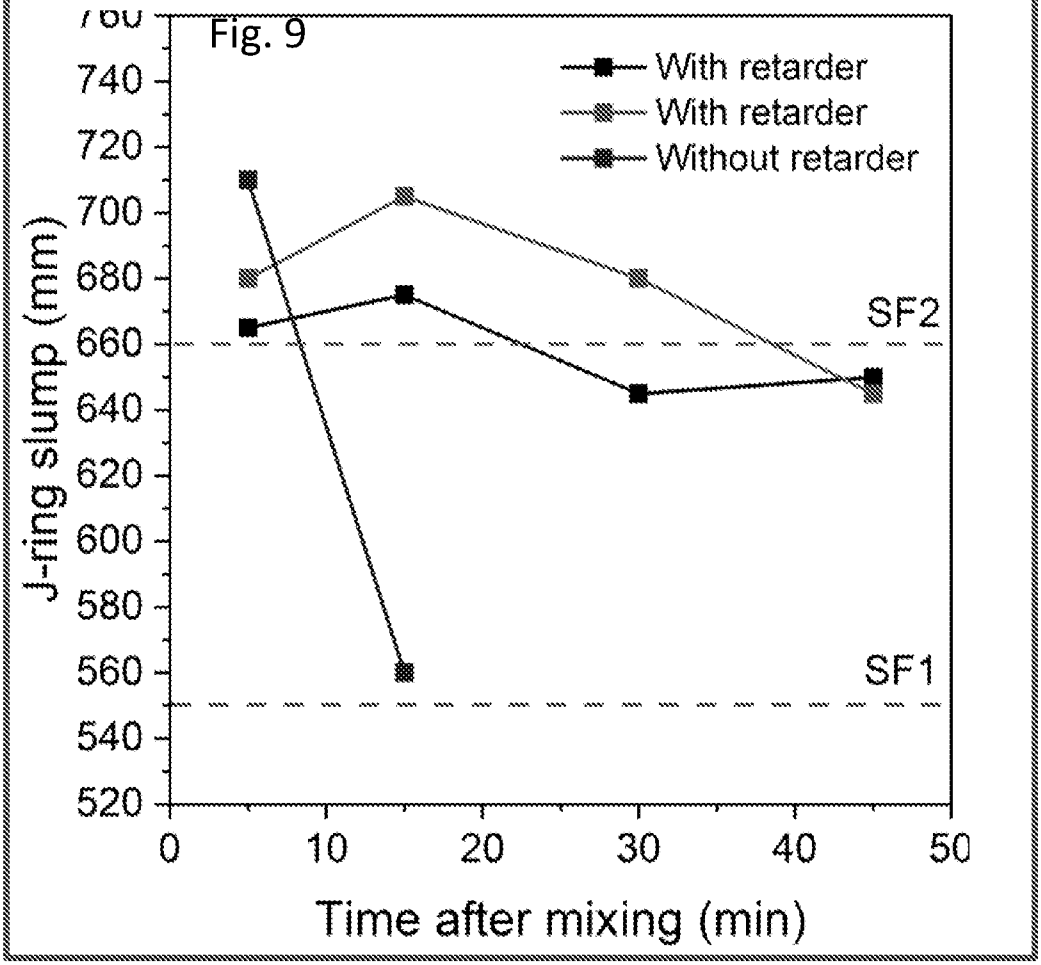


Fig. 8

Fig. 9



INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2022/050199

A. CLASSIFICATION OF SUBJECT MATTER
INV. C04B7/153 C04B12/00 C04B28/00 C04B28/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATEL YAMINI J. ET AL: "Development of self-compacting geopolymer concrete as a sustainable construction material", SUSTAINABLE ENVIRONMENT RESEARCH, vol. 28, no. 6, 1 November 2018 (2018-11-01), pages 412-421, XP055881201, TW ISSN: 2468-2039, DOI: 10.1016/j.serj.2018.08.004 example S2; table 2 chapters 2.1-2.4, 3.1-3.3 and 4; figures 1-5; tables 1,3,4 ----- -/--	1-18

[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 July 2022	11/07/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Büscher, Olaf

1

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GÜLSAN MEHMET EREN ET AL: "Development of fly ash/slag based self-compacting geopolymer concrete using nano-silica and steel fiber", CONSTRUCTION AND BUILDING MATERIALS, vol. 211, 25 March 2019 (2019-03-25), pages 271-283, XP085666815, ISSN: 0950-0618, DOI: 10.1016/J.CONBUILDMAT.2019.03.228 example SF0NS0; table 2 chapters 2.1-2.5, 3.1-3.4, 4; figures 1-16; tables 1-4	18
A	CN 110 642 582 A (UNIV NORTH CHINA WATER RESOURCES & ELECTRIC POWER) 3 January 2020 (2020-01-03) in particular examples 1-4; claims 1-10	1-17
A	WO 2019/116124 A1 (UNIV AMERICA CATHOLIC [US]) 20 June 2019 (2019-06-20) in particular claims 1 and 13-16; claims 1-27 examples 8-10; table 4 paragraphs [0003], [0004], [0027] - [0049], [0066] - [0078]	1-17
A	MANJUNATH R ET AL: "Studies on development of high performance, self-compacting alkali activated slag concrete mixes using industrial wastes", CONSTRUCTION AND BUILDING MATERIALS, vol. 198, 24 October 2018 (2018-10-24), pages 133-147, XP085582821, ISSN: 0950-0618, DOI: 10.1016/J.CONBUILDMAT.2018.11.242 examples HPAASC-1 - HPAASC-9; table 8 chapters 2.1, 2.2, 3.1-3.6, 4; figures 1-15; tables 1-14	1-17

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2022/050199

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 110642582 A	03-01-2020	NONE	
WO 2019116124 A1	20-06-2019	AU 2018383125 A1	18-06-2020
		BR 112020011832 A2	24-11-2020
		CA 3084903 A1	20-06-2019
		CN 111511699 A	07-08-2020
		EP 3724145 A1	21-10-2020
		JP 2021506708 A	22-02-2021
		KR 20200089335 A	24-07-2020
		RU 2020122769 A	17-01-2022
		WO 2019116124 A1	20-06-2019