Abstract Title: Concrete compositions containing glass powder with a particle size between 1mm and less than 35 microns

A concrete composition comprises a Portland cement mix, coarse and fine aggregate, water and glass powder having a particle size distribution between 1mm and less than 35 microns, with more than 30% being less than 45 microns and 10% less than 35 microns. The Portland cement mix may comprise one, one or more of: pulverised fly ash, ground granulated blast furnace slag, metakaolin, silica fume and rice husk ash. The coarse and or fine aggregates may include glass aggregates. The concrete may also include a super-plasticiser.
Concrete Composition

This invention relates to concrete compositions made with crushed and ground glass as coarse and fine aggregate. When exposed, using techniques known in the art, such concrete can have an attractive appearance and can make use of relatively inexpensive sources of glass such as recycled glass.

However, the application of the present invention is not limited to compositions where glass forms a visible and aesthetic feature of the concrete. The present invention is concerned with rendering concrete flowable without the need for additional compactive effort such as heavy vibration.

BACKGROUND

Concrete is usually poured into spaces in which it is employed. Sometimes this is to form floors where the "mould" comprises nothing more than simple shuttering. Sometimes it is concrete structural components, such as columns, where the shuttering is more precisely defined. Sometimes the components are not cast in-situ but pre-cast into moulds in factories, to form finished articles such as a kerb stones, tiles, or similar products. In all cases, it is usual to pour the concrete into the mould (whatever the structure is of the "mould"), and then to vibrate the concrete so that it is agitation into all parts of the mould and fully-compacted. However, this thixotropic nature of concrete is increasingly being exploited to render the compositions liquid and flowable without the need for vibration.

Concrete compositions (prior to pouring into moulds etc) contain at least water, cement and aggregates. Ideally the concrete should homogeneously flow under the action of vibration and gravity to fill the space into which it is poured without including air spaces or being of uneven composition. In the case of self-compacting concrete, in which no vibration is necessary to effect consolidation, it is not simply a matter of increasing the wetness of concrete compositions to effect this change in rheology as this methodology encourages segregation to occur which prevents the components of the mix from flowing in a homogenous manner.

It is known that adding superplasticizers (such as carboxylic acid-based water-reducers and others known to the art) modifies the rheology of concrete and increase its
flowability. However these do not, on their own, guarantee that the stability of components will be sufficient to impart cohesive, non-segregating flow.

It is also known to add glass, particularly recycled glass, to concrete to improve the appearance of concrete. However, the addition of glass usually exacerbates the already-known problem of the alkali silica reaction (ASR) where the alkali components of the cement react with the silica components of the aggregate to produce a gel-like substance that imbibes water, expands, undermines the strength of the concrete and frequently results in cracking and surface spalling. There are a number of techniques that have been investigated to reduce the ASR and these include the addition of E-glass particles and/or pozzolans and/or lithium salts. US-B-6699321 (Pelot) discloses such compositions and includes E-glass particles finer than 45 microns in size and up to 30% by weight of the cementitious component.

Normally the addition of high levels of fine ground material, such as Portland cements or other fine material, to concrete or mortar initially assists the cohesion of the paste to the aggregate, but at a certain point the surface area of the fine material becomes such that there is simply not enough water to lubricate the surfaces of the particles and workability (ability to flow with agitation) of the material drops dramatically, even with use of superplasticizers.

It is an object of the invention to provide a concrete composition that does not require agitation or vibration to flow, and whereby moulds can be filled merely by filling them with concrete and relying on the quasi-Newtonian flow properties of concrete in the self-compacting state to complete the consolidation, unaided by agitation. In this invention, concrete should be understood to include mortar, although it is not normally a requirement or even desirable feature of mortar that it is able to flow.

BRIEF SUMMARY OF THE DISCLOSURE

In accordance with the present invention, there is provided a concrete composition comprising the following components:

- Portland cement mix;
- Coarse aggregate;
- Fine aggregate;
- Glass powder; and
water,
wherein:

a) said Portland cement mix comprises Portland cement and none, one or more of the following elements:
   - pulverised fly ash (PFA);
   - ground granulated blast furnace slag (GGBS);
   - metakaolin (MK);
   - silica fume (SF); and
   - rice-husk ash (RHA);

b) said coarse aggregate comprises any aggregate suitable for concrete having particle sizes in excess of 5mm;

b) said fine aggregate comprises any aggregate suitable for concrete having particle sizes less than 5mm; and

d) said glass powder is present in the composition in an amount of between 50-400 kg/m³, having a particle size distribution between 1mm and less than 35 microns, with more than 30% being less than 45 microns and more than 10% less than 35 microns.

Preferably, one component of the concrete composition is a super-plasticiser.

Said coarse aggregate may include glass aggregates. Likewise, said fine aggregate may include glass aggregates, and ideally waste glass processor extraction material. Indeed, preferably, said fine aggregate comprising glass and said glass powder are sourced from a single blend of glass processor extraction dust.

Preferably, said components are in the following quantities:
   - 200-600 kg/m³ Portland cement mix;
   - 550-1200 kg/m³ coarse aggregate;
   - 100-700 kg/m³ fine aggregate;

0.5-25 kg/m³ super-plasticiser; and/or
150-250 kg/m³ of water.

Preferably, said elements are in the following proportions, based on the weight of the Portland cement mix:

0-30% pulverised fly ash;
0-70% ground granulated blast furnace slag;
0-20% metakaolin;
0-15% silica fume; and/or
0-30% rice-husk ash.

Preferably, said elements, when present, are in the proportions, based on the weight of the Portland cement mix:

10-30% pulverised fly ash;
30-70% ground granulated blast furnace slag;
5-20% metakaolin;

5-15% silica fume; and/or
10-30% rice-husk ash.

If the aggregate comprises reactive silica, or the cement is particularly alkaline, then further components may be included to further reduce or inhibit the ASR. For example, lithium salts inhibit ASR, particularly lithium carbonate or lithium nitrate.

Moreover, no component known to a person skilled in the art as generally useful or beneficial in concrete compositions in certain circumstances is necessarily excluded from the ambit of the present invention, unless it renders the composition unflowable.

Thus, pigments may also be included, for example.

Despite such small particle sizes, the compaction problems hitherto experienced do not materialise in the composition according to the invention. Self-compacting concrete and mortar has a number of advantages in the pre-cast and ready-mixed concrete sectors, including health and safety (improving the work environment by removing the need for noisy vibration equipment and reducing the impact of “white finger” syndrome) and economics (reduction of capital costs and manpower to consolidate the concrete). Although not exclusively determined by this method, BS 8500 provides one definition of “self-compacting”. Variations in the proportions of the different components may be necessary or desirable in different circumstances to compensate for the effects of the coarse and fine aggregate grading. While superplasticiser may aid flow of the concrete, this does not necessarily achieve homogenous self-compaction without segregation of the components. Self compaction therefore means both adequate flow and non-segregation of the components. It is the fine glass particles included in the compositions of the invention that ensure the homogeneity.
Another advantage of using waste glass powder as a sand (as opposed to a cement replacement) in Portland cement concrete and mortars is that it reduces the likelihood of alkali-silica reaction taking place between the alkalis in Portland cement and reactive silica in some aggregates. This is unexpected because it is known that the silica in large glass particles reacts with the alkalis in cement systems and within the art it would be expected that such levels of fine glass, with their 14% sodium content may, on reaction, release this sodium alkali into the cementitious system thereby increasing the likelihood of alkali-silica reaction occurring with reactive aggregates. This does not happen. When the significant ASR-reduction of the present invention is combined with other ASR-reducing techniques already well-documented in the art, such as the use of pozzolans including PFA and/or MK and/or GGBS and/or SF and/or lithium salts, self-compacting concrete or mortar with a range of properties appropriate to different applications and with extremely high ASR resistance is produced. Such compositions are suitable for manufacturing self-compacting concrete that will suppress the ASR reaction of the most reactive aggregates, including glass aggregates.

The invention is further described hereinafter, by way of example, with reference to the following examples.
EXAMPLES

Compositions may be prepared using the data in the following table as a guide:

<table>
<thead>
<tr>
<th>Mix Proportions, kg/m³</th>
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</table>

**Note 1:** Minimum cementitious (PC + PFA + GGBS + MK + SF) = 200 kg/m³ and maximum 600 kg/m³.

**Note 2:** PFA, GGBS, MK and SF percentages refer to percentages of the total of the PC plus PFA plus GGBS plus MK plus SF content.

**Note 3:** Any PFA, GGBS, MK and SF combination substitutions may be made, within the guidelines given above, to meet the requirements of specific end applications.

**Note 4:** RHA may be used as a substitute for PFA.

5 In the Table:

PC = Portland Cement;
PFA = pulverised fly ash;
GGBS = ground granulated blast furnace slag;
MK = metakaolin; and

10 SF = silica fume.
RHA = rice husk ash
EXAMPLE 1

To produce a self-compacting concrete with ASR resistance that can be used with 100% coarse glass aggregates exposed for architectural concrete:

Mix, using any efficient concrete mixer acceptable to the art, 350 kg/m³ Portland cement (preferably but not necessarily white Portland cement with optional pigment for colouration), a low-lime PFA (150 kg/m³), 200 kg/m³ water, 1000 kg/m³ coarse aggregate (any coarse aggregate used in the normal concreting art but also including decorative glass aggregates that may be exposed after the concrete sets to produce decorative effects using any method known in the art), 300 kg/m³ fine aggregate (which may be any natural or crushed sand with maximum size of 5mm, or crushed waste glass) and 400 kg/m³ of glass powder with grading from 1 mm to <35 micron, where 30% is <45micron and 10%<35 micron). Slight variations in these proportions may be necessary or desirable to compensate for the effects of the coarse and fine aggregate grading in order to achieve acceptable self-compaction. A carboxylic acid superplasticizer at around 1% by weight of cement and PFA may also be desirable to assist with the mobilisation.

The liquid, self-compacting concrete mix can then be poured into a mould (which is stiff enough to support the hydraulic forces induced by the liquid concrete and of the correct shape and size to produce the desired product). No vibration or other compactive effort is required to consolidate the concrete, which any entrapped air being allowed to rise to the surface and produce a smooth surface finish with few blemishes. This smooth-finished and self-compacted concrete is then be allowed to set for a period as appropriate within the art for the cementitious materials used. It may thereafter be cured at different temperatures and/or humidities to increase or decrease the rate of the gain of strength. Surface finishes may be applied as appropriate within the art to expose the aggregate.

EXAMPLES 2 to 6

Mix Proportion Example 2: Flowing Concrete Made with normal Portland Cement, Natural Aggregates and Glass Powder

A normal Portland Cement (PC) complying with British or European Standards: 400kg; Tap Water: 180kg;
A natural coarse natural aggregate (gravel), evenly graded from 5-20mm: 1000kg;
A natural fine aggregate (sand), with all particles less than 5mm and evenly graded to less than 35 micron: 600kg;
Glass powder with all particles being less than 1mm, >30% less than 45 micron and >10% less than 35 micron: 220kg; and
5 A carboxylic acid-based superplasticizer at dosage level between 0.1 and 1.5% by weight of Portland cement.

**Mix Proportion Example 3: Flowing Concrete made with White Portland Cement, Natural Aggregates and Glass Powder**

10 A white Portland Cement (PC) complying with British or European Standards: 400kg;
Tap Water: 180kg;
A natural coarse natural aggregate (gravel), evenly graded from 5-20mm: 1000kg;
A natural fine aggregate (sand), with all particles less than 5mm and evenly graded to less than 35 micron: 600kg;
15 Glass powder with all particles being less than 1mm, >30% less than 45 micron and >10% less than 35 micron: 220kg; and
A carboxylic acid-based superplasticizer at dosage level between 0.1 and 1.5% by weight of Portland cement.

20 **Mix Proportion Example 4: Flowing Concrete made with White Portland Cement, PFA, Glass Aggregates and Glass Powder**

A white Portland Cement (PC) complying with British or European Standards: 300kg;
A pulverized-fuel ash complying with British or European Standards: 100kg;
Tap Water: 160kg;
25 Crushed and evenly-graded glass aggregates from 3-12mm: 1100kg;
Crushed and evenly graded glass aggregates, from 1-3mm: 600kg;
Glass powder with all particles being less than 1mm, >30% less than 45 micron and >10% less than 35 micron: 140kg; and
A carboxylic acid-based superplasticizer at dosage level between 0.1 and 1.5% by weight of Portland cement.

30 **Mix Proportion Example 5: Flowing Concrete made with White Portland Cement, Ground-Granulated Blastfurnace Slag, Glass Aggregates and Glass Powder**

A white Portland Cement (PC) complying with British or European Standards: 320kg;
35 A ground-granulated blast furnace slag complying with British or European Standards: 80kg;
Tap Water: 180kg;
Crushed and evenly-graded glass aggregates from 3-12mm: 1000kg;
Crushed and evenly graded glass aggregates, from 1-3mm: 600kg;
40 Glass powder with all particles being less than 1mm, >30% less than 45 micron and >10% less than 35 micron: 220kg; and
A carboxylic acid-based superplasticizer at dosage level between 0.1 and 1.5% by weight of Portland cement.

**Mix Proportion Example 6: Flowing Concrete made with White Portland Cement, Metakaolin, Glass Aggregates and Glass Powder**

A white Portland Cement (PC) complying with British or European Standards: 380kg;
A fine metakaolin powder: 35kg;
Tap Water: 180kg;
Crushed and evenly-graded glass aggregates from 3-12mm: 1100kg;
Crushed and evenly graded glass aggregates, from 1-3mm: 600kg;
Glass powder with all particles being less than 1mm, >30% less than 45 micron and >10% less than 35 micron: 145kg; and
A carboxylic acid-based superplasticizer at dosage level between 0.1 and 1.5% by weight of Portland cement.

For architectural purposes, all of Examples 2 to 6 above may be coloured with fine iron oxide or other pigments which affect the rheology and hence the superplasticizer level.

Throughout the description and claims of this specification, the words “comprise” and “contain” and variations of the words, for example “comprising” and “comprises”, means “including but not limited to”, and is not intended to (and does not) exclude other moieties, additives, components, integers or steps.

Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

Features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith.

The reader’s attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.
All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.
CLAIMS

1. A concrete composition comprising the following components:
   Portland cement mix;
   Coarse aggregate;
   Fine aggregate;
   Glass powder; and
   water,
   wherein:
   a) said Portland cement mix comprises Portland cement and none, one or more of
      the following elements:
      pulverised fly ash;
      ground granulated blast furnace slag;
      metakaolin;
      silica fume; and
      rice husk ash;
   b) said coarse aggregate comprises any aggregate suitable for concrete having
      particle sizes in excess of 5mm;
   c) said fine aggregate comprises any aggregate suitable for concrete having
      particle sizes less than 5mm; and
   d) said glass powder is present in the composition in an amount of between 50-400
      kg/m³, having a particle size distribution between 1mm and less than 35 microns,
      with more than 30% being less than 45 microns and more than 10% less than 35
      microns.

2. A composition as claimed in claim 1, in which said coarse aggregate includes
   glass aggregates.

3. A composition as claimed in claim 1 or 2, in which said fine aggregate includes
   glass aggregates.

4. A composition as claimed in claim 3, in which said fine glass aggregate
   comprises waste glass processor extraction material.

5. A composition as claimed in claim 4, in which said fine glass aggregate and
   said glass powder are sourced from a single blend of glass processor extraction dust.
6. A composition as claimed in any preceding claim, in which another component of the concrete composition is a super-plasticiser.

7. A composition as claimed in any preceding claim, in which, said components are in the following quantities:
   200-600 kg/m³ Portland cement mix;
   550-1200 kg/m³ coarse aggregate;
   100-700 kg/m³ fine aggregate;
   0-25 kg/m³ super-plasticiser; and/or
   150-250 kg/m³ of water.

8. A composition as claimed in claim 7, in which there is at least 0.5 kg/m³ super-plasticiser.

9. A composition as claimed in claim 6, 7 or 8, in which said super-plasticiser is a carboxylic acid super-plasticiser.

10. A composition as claimed in any preceding claim, in which said elements are in the following proportions, based on the weight of the Portland cement mix:
    0-30% pulverised fly ash;
    0-70% ground granulated blast furnace slag;
    0-20% metakaolin;
    0-15% silica fume; and/or
    0-30% rice husk ash.

11. A composition as claimed in claim 10, in which, said elements, when present, are in the following proportions, based on the weight of the Portland cement mix:
    10-30% pulverised fly ash;
    30-70% ground granulated blast furnace slag;
    5-20% metakaolin;
    5-15% silica fume; and/or
    10-30% rice husk ash.
12. A composition as claimed in any preceding claim, further comprising lithium salts to inhibit ASR, wherein said lithium salts are in approximately the same amount as the alkali content of the cement.

13. A composition as claimed in claim 12, in which said lithium salts are one or both of lithium carbonate and lithium nitrate.

**Application No:** GB0608284.6  
**Examiner:** Hayley Yates  
**Claims searched:** 1-14  
**Date of search:** 16 June 2006

**Patents Act 1977: Search Report under Section 17**

### Documents considered to be relevant:

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| A        | -                  | JP 2005350333 A  
          |                    | Cra KK; see abstract translation  |
| A        | -                  | US 2003/0037707 A  
          |                    | Sunde  |
| A        | -                  | GB 1592788 A  
          |                    | Institut für Privatwirtschaft, Gschwend & Stadler  |
| A        | -                  | WO 93/08135 A  
          |                    | Delcon AB Concrete Development  |
| A        | -                  | RU 2179160 A  
          |                    | Penzen G Arkhitekturno Striote  |
| A        | -                  | WO 03/082768 A  
          |                    | Mo G Str Uni MGSU  |
| A        | -                  | US 6699321 A  
          |                    | Pelot et al  |

**Categories:**

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Search of GB, EP, WO & US patent documents classified in the following areas of the UKC:

- **C1H**

Worldwide search of patent documents classified in the following areas of the IPC:

- **C04B**

The following online and other databases have been used in the preparation of this search report.