

Claims

1. A method of providing a particulate slag suitable for use to replace sand or fine aggregates in a concrete, the method comprising the steps of:
 - (a) feeding a municipal solid waste and one or more of a wastewater sludge, a freshwater sludge and a sludge incineration ash through a top portion of a gasifier; and
 - (b) collecting a molten slag formed from the municipal solid waste and one or more of the wastewater sludge, the freshwater sludge and the sludge incineration ash from a slag collection outlet of the gasifier, quenching the molten slag to form granules and removing at least some diamagnetic metal particles from the slag to provide a slag suitable for using to replace sand or fine aggregates in a concrete, wherein:
 - the weight to weight ratio of the municipal solid waste to one or more of the wastewater sludge, the freshwater sludge and the sludge incineration ash is from 10:1 to 1:2; and
 - a bottom section of the gasifier is operated at a temperature of from 1,200 to 2,500 °C.
2. The method according to Claim 1, wherein the temperature of the bottom section of the gasifier is from 1,300 to 2,200 °C, such as from 1,500 to 2,000 °C, such as about 1,600 °C.
3. The method according to Claim 1 or Claim 2, wherein the weight to weight ratio of the municipal solid waste to one or more of the wastewater sludge, the freshwater sludge and the sludge incineration ash is from 9:1 to 1:1, such as 3.17:1 to 2:1.
4. The method according to any one of the preceding claims, wherein the wastewater sludge, the freshwater sludge and the sludge incineration ash is selected from one or more of the group consisting of a dewatered alum sludge, a dried sludge from a wastewater treatment facility, bottom ash particles formed from incineration of a sludge, and sludge incineration fine ash particles.
5. The method according to any one of the preceding claims, wherein the loading rate for the municipal solid waste is from 200 to 500±110 kg/h, such as from 222 to 428±108 kg/h and the loading rate of the one or more of the wastewater sludge, freshwater sludge and the sludge incineration ash may be commensurate with the weight:weight ratios described in Claim 1 or Claim 3.
6. The method according to any one of the preceding claims, wherein the total loading rate for one or more of the wastewater sludge, the freshwater sludge and the sludge

incineration ash is from 40 to 250 ± 60 kg/h, such as from 42 to 217 ± 60 kg/h and the loading rate of the municipal solid waste is commensurate with the weight:weight ratios described in Claim 1 or Claim 3.

7. The method according to any one of the preceding claims, wherein the apparatus used in the method further comprises a combustion chamber, a boiler, a cyclone, a gas cooling tower and a bag filter, which are fluidly linked in series in order to process a syngas produced by feeding both of the municipal solid waste and one or both of the wastewater sludge and a sludge incineration ash into the gasifier.

8. A particulate slag suitable for use to replace sand or fine aggregates in a concrete, the slag's elemental composition comprising each of Ca, Si, Al, Na, Fe, Mg, P, K, Ti, and Mn in an amount greater than 1g/kg.

9. The particulate slag according to Claim 8, wherein the slag has one or more properties selected from:

- (i) a mean particle size diameter that is less than 40 mm, optionally wherein the mean particle size diameter is from 1 to 5 mm, such as from 2.0 to 3.1 mm;
- (ii) the water absorption of the slag is from 0.5 to 0.7%, such as about 0.64%;
- (iii) the specific gravity of the slag is from 2.6 to 2.9, such as from 2.72 to 2.8;
- (iv) the bulk density of the slag is from 1.2 to 1.6 g/cm³, such as from 1.31 to 1.51 g/cm³;
- (v) the particle density of the slag on an oven-dried basis is from 2.5 to 3.0 g/cm³, such as from 2.74 to 2.80 g/cm³.

10. The particulate slag according to Claim 9, wherein the slag has all of the properties listed in (i) to (v) of Claim 9.

11. The particulate slag according to any one of Claims 8 to 10, wherein the particulate slag has angular to sub-angular morphology.

12. The particulate slag according to any one of Claims 8 to 11, wherein the particulate slag is in an amorphous solid form.

13. A mortar comprising:

- a particulate slag according to any one of Claims 8 to 12, or a particulate slag obtainable from a method according to any one of Claims 1 to 7; and
- a cement.

14. A concrete comprising:
- a particulate slag according to any one of Claims 8 to 12, or a particulate slag obtainable from a method according to any one of Claims 1 to 7;
 - a cement;
 - an admixture; and
 - coarse aggregates.
15. The concrete according to Claim 14, wherein the concrete has one or more of the following properties:
- (ia) a water absorption of from 1.85 to 2.00%;
 - (ib) a resistance to chloride ingress, once cured, of from 1379 to 1877 coulombs;
 - (ic) a compressive strength comparable to a concrete of Claim 14 made using sand instead of the particulate slag.