



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.06.2017 Bulletin 2017/23

(51) Int Cl.:
G21F 9/16 ^(2006.01) **G21F 1/04** ^(2006.01)
G21F 9/30 ^(2006.01) **G21F 9/34** ^(2006.01)
G21F 9/36 ^(2006.01)

(21) Application number: **16196600.7**

(22) Date of filing: **31.10.2016**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(72) Inventors:
• **TAKIZAWA, Tsutomu**
Tokyo 163-1343 (JP)
• **SAKAMOTO, Yuichi**
Tokyo 190-0013 (JP)

(74) Representative: **Vossius & Partner**
Patentanwälte Rechtsanwälte mbB
Siebertstrasse 3
81675 München (DE)

(30) Priority: **13.11.2015 JP 2015222913**

(71) Applicant: **SE Corporation**
Tokyo 163-1343 (JP)

(54) **CONCRETE AND METHOD FOR MANUFACTURING THEREOF**

(57) Cement and water are put into a form. Cement paste is made of the cement and the water. Then aggregates are put into the form to distribute the aggregates

in the cement paste, to make fresh concrete in the form. Then the fresh concrete is solidified to make concrete in the form.

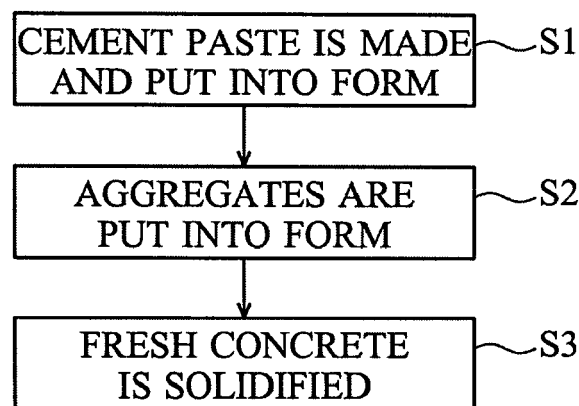


Fig. 1

Description

[0001] Priority is claimed on Japanese Patent Application No. 2015-222913, filed on November 13, 2015, the content of which is incorporated herein by reference.

Technical Field

[0002] The present invention is related to concrete.

Background Art

[0003] It is known that a concrete container for shielding radiation can be used for storing radioactive waste, such as soil contaminated by radioactive materials splattered by a nuclear accident, such as ^{131}I (Iodine 131), ^{134}Cs (Cesium 134) or ^{137}Cs (Cesium 137).

[0004] It is also known that increment of shield materials in weight can improve shielding performance against radiation. This can be achieved by increasing thickness of a container wall. For example, 23cm wall made of normal-weight concrete shields 85% of γ (gamma)-ray radiated from ^{137}Cs , which has a half-life of about 30 years.

[0005] Increasing density of the container wall can also achieve the increment of shield materials. This is a reason for replacing the normal-weight concrete, which has a density, or specific gravity, of about 2 to 2.5g/cm³, with heavyweight concrete, which has a density of 3.5g/cm³ or higher, which is achieved by using heavyweight aggregates with high density. This enables to reduce the thickness of the container wall. See, for example, Fujikura et al., "Development of high performance radiation shielding containers for contaminated soil in Fukushima", Fujuta Technology Research Report, Vol. 48, pp. 61-66, 2012.

Summary of Invention

Problem to be Solved

[0006] Making container having sufficient shielding performance by using normal-weight concrete requires sufficiently thick walls. This makes the container very large.

[0007] Using heavyweight concrete enables to make the wall thinner, and subsequently to make the container smaller. However, kneading fresh concrete containing the heavyweight aggregates may produce inhomogeneous distribution of the aggregates. This may reduce strength and/or shielding performance of the concrete.

[0008] This may be prevented by reducing a water/cement ratio of the fresh concrete, which is a weight ratio of water to cement contained in the fresh concrete. This, in turn, may reduce kneadability and workability of the fresh concrete. Low kneadability results in more energy required for kneading. This increases load on a kneading machine, and thereby shortens life of the kneading machine. Low workability, i.e. small slump, increases diffi-

culty for pumping and placing the fresh concrete into a form. Also, a dedicated large kneading machine is required for kneading the fresh concrete containing the heavyweight aggregates.

[0009] The present invention aims to solve such problems.

Means to Solve

[0010] A method according to the present invention is for manufacturing concrete. Cement and water are put into a form, and cement paste is made of the cement and the water. Next, aggregates are put into the form to distribute the aggregates in the cement paste, to make fresh concrete in the form. Finally, the fresh concrete is solidified to make concrete in the form.

Advantageous Effects of Invention

[0011] According to the present invention, putting the aggregates into the form separate from cement paste to make fresh concrete in the form, instead of placing fresh concrete containing aggregates into the form, enables to prevent inhomogeneous distribution of the aggregates caused by kneading the fresh concrete. Putting the cement paste first and the aggregates later enables to knead the cement paste in the form before putting the aggregates into the form. Unlike the case of putting the aggregates first and the cement paste later, no air remains among the aggregates. This enables to enhance strength and density of the concrete.

[0012] Viscosity of the cement paste makes the aggregates to slowly move down in the cement paste. This enables to achieve substantially homogeneous distribution of the aggregates in the cement paste.

[0013] The homogeneous distribution of the aggregates enables to realize high strength and excellent shielding performance against radiation. Very high density of the concrete can be achieved, and this enables to reduce a size, and/or to increase a capacity, of a radiation shielding container.

Brief Description of Drawings

[0014] Referring to the accompanying drawings, embodiments will be described in detail. The embodiments and the drawings are provided only for more complete understanding of the present invention. They are not intended to limit the present invention in any meanings.

Fig. 1 is a flowchart illustrating an example of a manufacturing method;

Figs. 2 and 3 are vertical section views illustrating an example of manufacturing steps of concrete; and Fig. 4 is a perspective section view illustrating an example of concrete.

Embodiments

Raw Materials

[0015] Raw materials of concrete includes cement, water, and aggregates.

[0016] The term "cement" means powder materials with ability for solidifying by hydration.

[0017] The cement is preferable to have high fluidity. This enables to enhance workability of cement paste.

[0018] The cement may contain Portland cement. The Portland cement may have particle diameters of about 10 μ m.

[0019] The cement may contain one or more types of admixtures, such as silica fume, fly ash, calcium carbonate powder, and the like. The admixtures may enhance fluidity of the cement. The admixtures may have particle diameters of 1 μ m or smaller. A weight ratio of the admixtures in the cement may be no less than 5%, and may be no more than 20%.

[0020] A weight ratio of the water to the cement is preferable to be no less than 15%. This enables to reduce viscosity, and thereby to enhance workability, of cement paste. The water is preferable to be 25% or less as heavy as the cement. This enables to increase strength and density of the concrete.

[0021] The aggregates are preferable to contain one or more types of high density materials, such as iron, steel, tungsten, lead, other metals, and the like. This enables to increase density of the concrete, for example, to 5.0g/cm³ or higher.

[0022] The aggregates are preferable to be 5 or more times the weight of the cement. This enables to increase density of the concrete. A weight ratio of the aggregates to the cement is preferable to be no more than 10 times. This enables to increase strength of the concrete.

[0023] The aggregates are preferable to have shapes with unlikelihood of causing voids in the concrete. Hollow or complicated shapes may cause voids, which decrease strength and density of the concrete. Thus, the shapes of the aggregates are preferable to be solid and simple, such as spheres, cylinders, prisms, or the like. Aggregates with various shapes may be mixed.

[0024] Maximum dimensions of the aggregates are preferable to be 1mm or larger, and minimum dimension of the aggregates are preferable to be 0.3mm or larger. This enables to prevent the aggregates from floating on the cement paste and involving air.

[0025] The term "maximum dimension" means the largest length out of a height, a width, and a depth. For example, it means a diameter of a sphere, a height of an elongate column, and the like. The term "minimum dimension" means the smallest length out of a height, a width, and a depth. For example, it means a diameter of a sphere, a bottom diameter of an elongate cylinder, and the like.

[0026] The aggregates with sphere shapes are preferable to have diameters no more than 6% of thickness of

the concrete. This enables to prevent reduction of density of the concrete.

[0027] Steel balls for shot blast processing, pachinko balls, balls for bearing, screws, washers, nuts, or the like may be used as the aggregates. A cutter machine or the like may be used for cutting wire rods to make the aggregates. A slasher machine or the like may be used for crushing scrap to make the aggregates.

[0028] The raw materials may include water reducing agent. This enables to enhance fluidity of the cement paste. Also, this enables reduction of water, and subsequently improvement of concrete strength. A weight ratio of the water reducing agent to the cement may be more than 0.2%. This enables to prevent the aggregates from involving air. The water reducing agent may be less than 0.5% the weight of the cement. This enables to restrain the viscosity of the cement paste, and thereby to facilitate downward movement of the aggregates.

[0029] The raw materials may include thickening agent. This enables to increase viscosity of the cement paste, and thereby to restrain downward movement of larger ones of the cement particles. This enables to prevent generation of inhomogeneity of the cement paste containing various size particles. A weight ratio of the thickening agent to the cement may be 1% or less. This enables to prevent restraint of downward movement of the aggregates, which are larger and heavier than the cement particles.

[0030] The raw materials may include reinforcing materials, such as short fibers. This enables to improve the strength of the concrete.

Manufacturing Steps

[0031] As shown in Fig. 1, the concrete is manufactured through three steps. Each of the steps will be explained below.

[0032] In a first step (S1), the raw materials except the aggregates are mixed, or kneaded, to make cement paste. The cement paste (1b) is disposed in a form (2, 3), as shown in Fig. 2.

[0033] The term "cement paste" means fluid mixture containing cement and water but no aggregates. In contrast, a term "fresh concrete" means fluid mixture further containing aggregates. Fresh concrete becomes concrete by solidifying.

[0034] The term "form" means a frame with a vessel shape for storing fresh concrete in it and defining a shape of concrete. The form may be separated to an outer frame (2) and an inner frame (3), as shown in Fig. 2.

[0035] The mixing may be performed out of a form. That is, a mixing vessel or the like may be used to make cement paste in it, then the cement paste may be put into the form.

[0036] The mixing may be performed in the form. This enables to eliminate requirements for providing a mixing vessel and carrying the cement paste. For example, the cement may be put into the form, then the water may be

put into the form, and finally the cement paste may be made by mixing in the form. The putting of the water may precede, or be simultaneous with, the putting of the cement.

[0037] Alternatively, the cement paste made out of the form may put into the form, then further mixing may be performed in the form.

[0038] In any case, the cement and the water are put into the form, and the cement paste is disposed in the form, as a result.

[0039] Next, in a second step (S2), the aggregates are put into the form. As shown in Fig. 2, the cement paste (1b) already exists in the form (2, 3). The aggregates (1a), having been put onto the cement paste, sink and slowly move down in the cement paste. The aggregates is substantially homogeneously distribute in the cement paste. Thereby, fresh concrete (1) is made in the form, as shown in Fig. 3. Making the fresh concrete in the form prevents low workability of the fresh concrete from causing problems.

[0040] In a case that aggregates are firstly put into the form and then cement paste is put into the form, air among the aggregates may be incompletely removed, and the cement paste may insufficiently penetrate among the aggregates. These may cause reduction of strength and density of concrete.

[0041] In contrast, in the case that the cement paste is put into the form in advance and the aggregates are put into the form later, prevention of air from being left among the aggregates, and sufficient penetration of the cement paste among the aggregates can be achieved. This enables to increase strength and density of concrete.

[0042] A feeder machine, such as a hopper, may be used to put the aggregate into the form. The feeder machine may have a port for emitting the aggregates. The port may be located above a surface of the cement paste, to cause the aggregates emitted from the port to drop into the cement paste. The gravity accelerates the aggregates to facilitate the aggregates to move down in the cement paste. Varying a height of the port above the surface enables adjustment of speed of the aggregates moving down within the cement paste.

[0043] The port may emit predetermined amount of the aggregates per unit time and be simultaneously moved with predetermined velocity toward a substantially horizontal direction. This enables to drop a predetermined amount of the aggregates per unit area.

[0044] Finally, in a third step (S3), the fresh concrete is solidified to make concrete. The fresh concrete is left, or cured, for predetermined period in the form. Thereby, the fresh concrete gets hard to be concrete.

[0045] Gradual solidification of the cement paste in parallel to the slow downward movement of the aggregates in the cement paste produces termination of the downward movement of the aggregates at appropriate positions. This prevents the aggregates from concentrating in lower area of the concrete, and thereby produces

substantially homogeneous distribution of the aggregates in the concrete, as shown in Fig. 4.

[0046] It is important to appropriately adjust speed of the downward movement of the aggregates to coincide with solidification speed and height of the fresh concrete. The solidification speed of the fresh concrete depends upon atmospheric temperature, humidity, and the like. The speed of the downward movement of the aggregates depends upon the viscosity of the cement paste, sizes and weights of the aggregates, entry velocity of the aggregates into the cement paste, and the like. high viscosity of the cement paste decreases the speed of the downward movement of the aggregates. The viscosity can be adjusted by the water/cement ratio, the amount of the thickening agent, and the like. After the putting of the aggregates, the form may be vibrated. This fastens the downward movement of the aggregates.

[0047] Appropriate adjustment of these parameters enables to substantially homogeneously distribute the aggregates in the concrete.

[0048] The vibration of the form also has an effect to realize dense piling of the aggregates.

Example

[0049] A concrete container was manufactured by using the following materials:

- (1) silica fume cement, sold by Ube Mitsubishi Cement Corp., 10kg;
- (2) water 2kg;
- (3) water reducing agent, which is sold with a trade name "MasterGlenium SP8HU" by BASF, 0.1kg; and
- (4) steel balls for blasting, which is sold with a trade name "Steel Shot NB240" by Nicchu Co., Ltd., 70kg,

where the weights are not amounts used, but just showing proportions.

[0050] The concrete container has a hollow cubic shape. Each edge has a length of 1.4m, and each wall has a thickness of 80mm. It is separated to a top wall, or a lid, and a body. The body is used for storing radioactive waste in it, and the lid is used for putting it on the body.

[0051] Forms were provided, which have shapes according to those of the lid and body of the concrete container. The form for the body is shown in Fig. 2. The form has an opening at a top side.

[0052] The silica fume cement, the water, and the water reducing agent were put into the form from the opening. These materials were sufficiently agitated in the form to be homogeneous. About a third of the form was filled with obtained cement paste, as shown in Fig. 2.

[0053] Then, a hopper was used to put the steel balls into the form from the opening. The hopper has an exhaust port. The exhaust port has a width, and emits a row of the steel balls simultaneously. The hopper drops about one to three rows of the steel balls per second out of the exhaust port. While dropping the steel balls, the

exhaust port was horizontally moved along the opening of the form. The exhaust port traveled several rounds along the opening. As the upper remaining cement paste decreased, the movement speed of the exhaust port was gradually reduced, about 1m/s in the first round, and about 0.1m/s in the last round.

[0054] Thereby, the form was filled with fresh concrete made of the cement paste and the steel balls, as shown in Fig. 3.

[0055] Then, by leaving the fresh concrete until solidified, the concrete container was obtained.

[0056] The concrete container had a compressive strength of about 100MPa, i.e., 100N/mm², a bending strength of about 7MPa, i.e., 7N/mm², and a shielding rate of 85% against γ -ray radiated from Cesium 137.

[0057] The volume of the concrete is about 0.84m³. About 1.90m³ radioactive waste can be stored in it.

[0058] If a container is made of normal-weight concrete using Portland cement, a thickness of about 230mm is required for achieving the same shielding rate. If the container has the same size, the volume of the normal-weight concrete is 1.91m³, and only about 0.83m³ radioactive waste can be stored in it.

Diameter of Steel Balls

[0059] In the same manner as the example described above, several concrete containers were manufactured, while the thickness of the walls and the diameters of the steel balls were changed.

[0060] In the case of 45mm thick walls, 1mm and 2mm diameter balls produced high density concrete. However, 3mm diameter balls caused scattered arrangement, and thereby the density of the concrete decreased.

[0061] In the case of 100mm thick walls, 6mm diameter balls produced no problem. However, 7mm diameter balls reduced the density of the concrete.

[0062] The experiment clarified that the diameter of the steel balls is preferable to be 6% or less of the thickness of the wall.

Water/Cement Ratio

[0063] In the same manner as the example described above, several concrete containers were manufactured, while the water/cement ratio was changed.

[0064] The water/cement ratio from 15% to 25% produced homogeneous concrete. However, the water/cement ratio over 25% reduced the strength of the concrete in an upper area of it. The water/cement ratio below 15% produced too high viscosity of the cement paste to make the steel balls to sufficiently move down.

Amount of Water Reducing Agent

[0065] In the same manner as the example described above, several concrete containers were manufactured, while the amount of the water reducing agent was

changed. The diameters of the steel balls were fixed to 2mm.

[0066] The water reducing agent from 0.2% to 0.5% as heavy as the cement produced homogeneous concrete. However, 0.2% or less water reducing agent caused the steel balls to involve air, and thereby reduction of the density of the concrete. 0.5% or more water reducing agent produced too high viscosity of the cement paste to make the steel balls to sufficiently move down.

[0067] The above described embodiments are examples to make it easier to understand the present invention. The present invention is not limited to the example, and includes any modified, altered, added, or removed variations, without departing from the scope of the claims attached herewith. This can be easily understood by persons skilled in the art.

Reference Signs List

[0068]

1: concrete; 1a: aggregate; 1b: cement paste; 1c: fresh concrete; 2: outer frame; and 3: inner frame.

Claims

1. A method for manufacturing concrete, the method comprising:

putting cement and water into a form;
making cement paste of the cement and the water;
then putting aggregates into the form to distribute the aggregates in the cement paste, to make fresh concrete in the form; and
then solidifying the fresh concrete to make concrete in the form.

2. The method of Claim 1, wherein the aggregates are five times or more and ten times or less as heavy as the cement.

3. The method of Claim 1 or 2, wherein the water is fifteen percents or more and twenty five percents or less as heavy as the cement.

4. The method of anyone of Claims 1 to 3, wherein the putting of the aggregates comprises:

providing a feeder machine having a port for emitting the aggregates;
locating the port at a predetermined height above a surface of the cement paste; and
emitting the aggregates from the port with substantially horizontal movement of the port, to bury the aggregates into the cement paste.

5. The method of anyone of Claims 1 to 4, the method further comprising:
- vibrating the form to facilitate the aggregates to move down in the cement paste, after the putting of the aggregates. 5
6. The method of anyone of Claims 1 to 5, wherein the aggregates has a maximum dimension of one millimeter or larger. 10
7. The method of anyone of Claims 1 to 6, the method further comprising:
- putting at least one of thickening agent and water reducing agent into the form. 15
8. The method of anyone of Claims 1 to 7, wherein putting the cement and the water separately into the form; and 20
- then agitating and mixing the cement and the water to make the cement paste in the form.
9. The method of anyone of Claims 1 to 7, wherein mixing the cement and the water to make the cement paste in advance; and then putting the cement paste into the form. 25
10. A concrete, manufactured by the method of anyone of Claims 1 to 9. 30

35

40

45

50

55

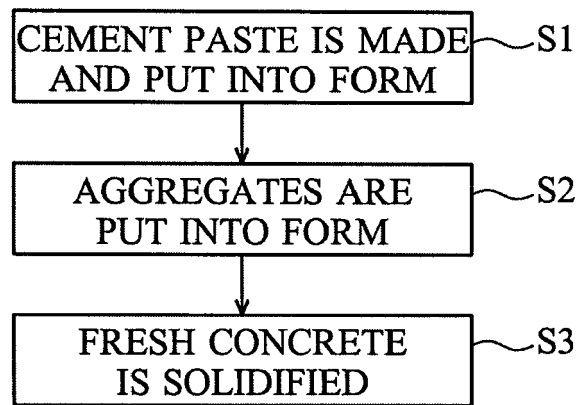


Fig. 1

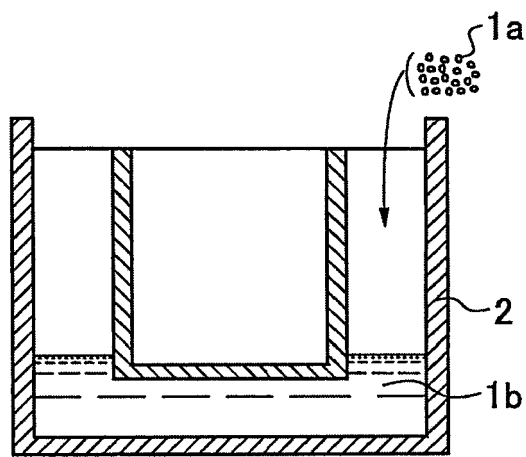


Fig. 2

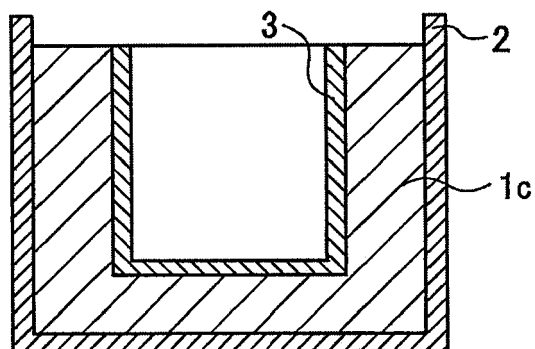


Fig. 3

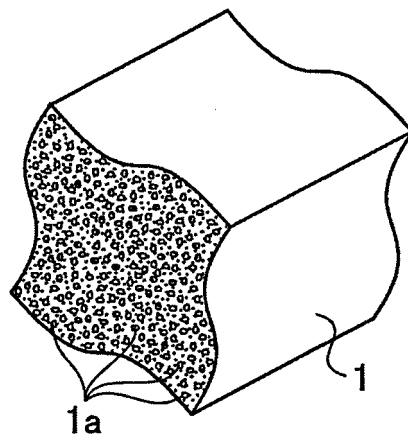


Fig. 4



EUROPEAN SEARCH REPORT

Application Number
EP 16 19 6600

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP H08 129100 A (HITACHI LTD) 21 May 1996 (1996-05-21) * the whole document *	1-10	INV. G21F9/16 G21F1/04 G21F9/30 G21F9/34 G21F9/36
X	DE 195 36 370 A1 (SICOTAN KUNSTSTOFF [DE]) 10 April 1997 (1997-04-10) * column 2, line 27 - column 5, line 5; claims 1-15 *	1-10	
X	FR 2 925 753 A1 (COMMISSARIAT ENERGIE ATOMIQUE [FR]; SOGEFIBRE [FR]) 26 June 2009 (2009-06-26) * page 13, lines 11-21; figure 1 *	1-10	
X	EP 1 394 813 A2 (KOBEL STEEL LTD [JP]; TAISEI CORP [JP]) 3 March 2004 (2004-03-03) * paragraphs [0011] - [0049]; figures 1-8 *	1-10	
			TECHNICAL FIELDS SEARCHED (IPC)
			G21F C04B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 11 April 2017	Examiner Lohberger, Severin
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03/02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 19 6600

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

11-04-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP H08129100 A	21-05-1996	NONE	
DE 19536370 A1	10-04-1997	NONE	
FR 2925753 A1	26-06-2009	AT 513299 T EP 2225762 A2 FR 2925753 A1 WO 2009106730 A2	15-07-2011 08-09-2010 26-06-2009 03-09-2009
EP 1394813 A2	03-03-2004	CN 1497612 A EP 1394813 A2 JP 4369135 B2 JP 2004099425 A KR 20040010251 A TW 1300407 B US 2004067328 A1	19-05-2004 03-03-2004 18-11-2009 02-04-2004 31-01-2004 01-09-2008 08-04-2004

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2015222913 A [0001]

Non-patent literature cited in the description

- **FUJIKURA et al.** Development of high performance radiation shielding containers for contaminated soil in Fukushima. *Fujuta Technology Research Report*, 2012, vol. 48, 61-66 [0005]