March 16, 1965 D. A. JACKSON 3,173,884

CONCRETE COMPRISING GALENA ORE AGGREGATE, CALCIUM ALUMINUM HYDRAULIC BINDER AND STANDARD AGGREGATES

Filed July 13, 1962

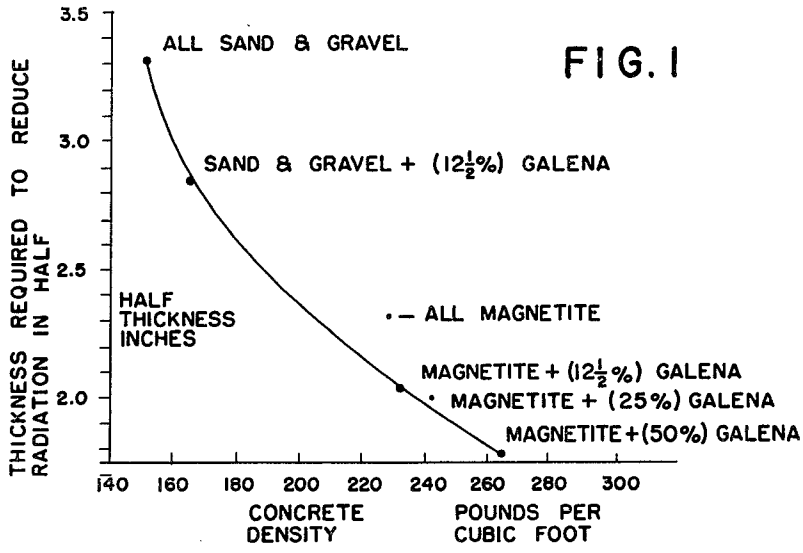


FIG. 1

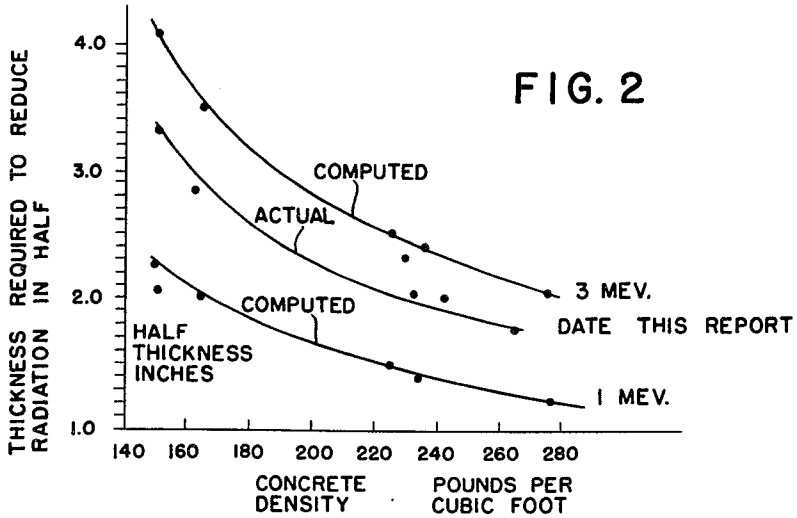


FIG. 2

INVENTOR

DAVID A. JACKSON

BY Kent W. Worrell

ATTORNEY

United States Patent Office

3,173,884
Patented Mar. 16, 1965

3,173,884

CONCRETE COMPRISING GALENA ORE AGGREGATE, CALCIUM ALUMINUM HYDRAULIC BINDER AND STANDARD AGGREGATES

David A. Jackson, 651 E. 119th St., Chicago, Ill.

Filed July 13, 1962, Ser. No. 209,758
9 Claims. (Cl. 252—478)

This invention relates in general to a special concrete best described as of a high density type, because it is of a higher specific gravity than the usual concrete, but more particularly it relates to an improved radiation shielding using galena ore, which has a very high specific gravity with a sized aggregate and a suitable cement as a binder which has many high and superior quality characteristics compared with those which are presently used in concretes for high density purposes.

This concrete has an important use in the nuclear energy industry where a large scale production may be required as a result of the use of nuclear reactors, particle accelerators, X- and gamma ray therapy radiation and radio-active materials in providing shielding material for the protection of operating personnel against the biological hazards of such radiation. Several government agencies and industrial concerns are also proposing plans and materials for fall-out protection chambers utilizing a high density concrete of this type which is adapted to be used in the building of these chambers and other structures for shielding purposes.

The principal objects of the present invention are therefore to provide a high density concrete which has an increased specific gravity, considerably more than the specific gravity of any concretes now currently used; to improve the radiation shielding properties against radiation and radio-active materials; to afford means for providing a uniform quality or homogenity of the mass; to provide an improved substitution for other concrete materials which hitherto has been difficult or impossible; to provide a concrete of this type which is also fast-setting in comparison with other concretes and with the requirements therefor by the Atomic Energy Commission; to provide a concrete in which the immediate setting strength is attained in much fewer days than is ordinarily required and in which the final setting strength is greater than many shielding specifications; to effect a greater space saving not only of the aggregate materials themselves, but also of the final building structure, the space which it occupies and the shipping and storage space which it saves by means of such reduction; and to the great number of economies which result in the use of this cement, not only in the saving of space, but also in the amount of labor in erecting the forms, in shipping the material, in storing the material, and in the actual cost thereof.

Other objects of the invention will appear in the specification and will be more apparent from the accompanying drawings in which FIG. 1 represents a chart in which the thickness required to reduce radiation in half is compared with the density of the concrete in pounds per cubic foot and FIG. 2 is a chart in which the thickness required to reduce radiation in half is compared with the concrete density in pounds per cubic foot and compared with outside curves for gamma ray energies of 1.17 million electronic volts and 1.33 million electronic volts respectively.

The present materials include some of which the specific gravity and prices are given for the purposes of comparison, and is not limited with galena ore to an aggregate such as magnetite, or calcium aluminate hydraulic binder cements such as Lumnite, and water. As a specific concrete, and in variations thereof, the present high density material has many unique advantages.

DENSITY

In this consideration, the specific gravity is calculated or obtained by dividing the mass in cubic feet by 62.4, the weight of one cubic foot of water. The approximate specific gravities of a number of materials are included to show their relative differences when included in a particular mixture as hereinafter set forth:

Table I

SPECIFIC GRAVITY

PbS	Galena	7.5.
Fe_3P	Ferro. Phh	6.5.
$2Fe_2O_3\ 3H_2O$	Limonite	3.6–4.0.
TiO_2Fe_2O	Ilmanite	4.50 coarse; 4.60 fine.
Fe_3O_4	Magnetite	4.55 coarse; 4.53 fine.
$BaSO_4$	Barite	3.52.
Cement	Ordinary	2.35 150# cu. ft.
Cement	Portland	3.15.

In supplying any aggregate, a quantity of different sizes are furnished, and the following Table II contains an approximate analysis of the proportions of different materials which are contained, for example, in several important aggregates.

In the following table, the gradation of the different ingredients, galena, magnetite and sand and gravel may be taken as given. In using dense aggregates, the addition of galena will obviously increase the density and cut down the whole or half thickness required; it is not restricted only to the heavy aggregates, but can be used with ordinary sand and gravel aggregates and with other cements, where certain specific requirements are desired, such as setting time and compression strength, and where availability of materials are concerned.

Table II

Gradation	Galena	Magnetite		Sand and Gravel	
		Coarse	Fine	Coarse	Fine
Total Passing:					
1"	----------	100.0	--------	100.0	--------
¾"	----------	99.2	--------	96.2	--------
½"	100.0	63.0	--------	54.0	--------
⅜"	99.3	26.7	100.0	26.7	100.0
#4	91.2	3.1	96.2	3.1	96.7
#8	72.3	----------	72.0	----------	83.5
#16	47.6	----------	45.3	----------	64.0
#30	26.7	----------	29.7	----------	42.1
#50	13.4	----------	16.3	----------	15.3
#100	3.4	----------	7.1	----------	3.7
Fineness Modules	3.46	6.71	3.33	6.74	2.95
Specific Grav	7.50	4.55	4.53	2.66	2.67
Absorption, percent by weight	0.58	0.71	0.77	1.4	1.6

In considering these ingredients, it is necessary to take certain fines with the so-called coarse aggregate, and for the above mixtures, the approximate percentages of the different sizes composing the aggregates are set forth in Table II.

SAMPLE MIXTURES

In the following examples, magnetite, sand and gravel are mixed with different percentages of galena ore by weight, which will show the results obtained for the different mixtures in Table III.

Table III

Concrete Mixes*—Mix number	1	2	3	4	5	6
Identification:						
Galena, total aggregate, percent by weight	50	25	12½	12½	0	0
Other aggregates, percent	[1] 50	[1] 75	[1] 87½	[2] 87½	[1] 100	[2] 100
Cement (Lumnite), pounds	564	564	564	564	564	564
Galena	3,090	1,395	660	440		
Magnetite Fines	120	1,300	2,250		2,675	
Magnetite Coarse	2,970	2,895	2,375		2,675	
Sand				1,250		1,340
Gravel				1,820		1,870
Water	392	383	380	300	330	300
Absolute Volume, cubic foot Cement	2.87	2.87	2.87	2.87	2.87	2.87
Galena	7.09	3.23	1.58			
Magnetite Fines	.42	4.61	7.98		9.47	
Magnetite Coarse	10.36	10.20	8.38		9.40	
Sand				7.43		8.09
Gravel				10.92		11.22
Water	6.28	6.15	6.10	4.81	5.30	4.81
Weight per cubic foot, pounds, wet	264	242	232	162	229	151
Compressive Strength, pounds per square inch:						
1 day	1,180	1,315	3,840	4,390	4,050	3,545
3 days	2,310	3,260	5,685	5,985	5,625	5,805
Linear absorption coefficients, per inch	.384	.340	.335	.240	.293	.206
Half thickness, inches	1.78	2.01	2.04	2.85	2.33	3.32

*Cubic Yard Proportions—Weights Materials, Absolute Volume in Cubic Feet.
[1] Magnetite.
[2] Sand and gravel.

These different combinations of ingredients will provide sufficient points to locate a curve A in FIG. 1, in which concrete density in pounds per cubic foot and measured from 140 to 280 pounds forms the base of the graph with the thickness required to reduce radiation in half as the altitude measured on a vertical line from the base, from 1.5 inches to 3.5 so that the necessary mixture for producing in one-half wall thickness in inches may be read directly on the vertical line.

That this curve is substantially in accordance with the accepted practice in determining the wall half thickness, is perhaps more clearly set forth in FIG. 2 in which the data of this curve is introduced between the known curves for one mev. (million electronic volts) and 3 mev. so that the data obtained from this curve is approximately for 250 mev. and therefore entirely in accord with the density required for high density concrete at the Argonne National Laboratory for U.S. Energy Commissioner.

STRENGTH

At the time of setting up these mixes, a 12" x 12" x 1" slab was cast and submitted to a testing laboratory to determine the absorption coefficients using Cobalt 60. This has two gamma ray energies of 1.17 million electron volts and 1.33 mev. respectively. These were calculated to half thickness from the relationship:

$$T\frac{1}{2}=.693/u, \text{ in which}$$
$T\frac{1}{2}=\frac{1}{2}$ thickness
u=absorption coefficients

FIG. 2 illustrates the relationship of this data from the literature (Concrete for Radiation Shielding, E. J. Callan, ACI Journal, vol. 50, September 1953, pp. 17–44). The curve for this data is approximately where it may be expected; that is, between that obtained from gamma ray energies of 1 and 3 mev.

A closer look at this data in FIG. 1 wherein it is shown that the galena causes reduced one-half thickness as compared to equal density of all magnetite. The all magnetite test shows about one-quarter inch more thickness to reduce the radiation in half.

From this data, the effectiveness of galena in reducing radiation is stated as:

(*a*) Reduction in one-half thickness of one-quarter inch as compared to all magnetite when galena is blended with the magnetite.

(*b*) A reduction of about 12% in radiation when galena is blended with magnetite.

SPEED OF SETTING

From Table III, it is noted that the compressive strength in pounds per square inch of the 12½% galena, magnetite mixture was 3840 pounds within one day after casting, and that the compressive strength after three days for this same mixture was 5685 pounds per square inch, both well within the minimum requirements for high density concrete.

It will also be observed that by using this galena-magnetite mixture, about three times as much density can be obtained as in the use of ordinary concrete. The galena mixture thus can be made up to have much greater shielding characteristics than any other dense aggregate or mixtures as shown by the accompanying graphs in FIGS. 1 and 2.

UNIT COST

In a galena concentrate at the mine of approximately 80% content, cost may be $100.00 per ton, or $5.00 more with delivery within 500 miles of approximately $5.00 more per ton, and since a 12½% of galena results in a reduction in the amount of concrete of approximately 45% to 50% when added to ordinary concrete, and a 20%–30% reduction in volume in using magnetite and other aggregates for a saving of the material used.

Where space is a factor, the reduction to the half-thickness necessary permits availability of the usable room for building, as well as for storage.

By referring to FIG. 1 for SAND & GRAVEL, a wall thickness of approximately 3.3" is required at approximately 150 cubic feet, while sand and gravel with 12½% of galena ore requires only a wall of 2.7" at about 165 cubic feet, which is a saving of 15½% in the wall thickness with only 10% increase in weight. An all magnetite mixture, according to FIG. 1 would require a wall thickness of 2.35" against an 87½% magnetite content and about 229 cubic feet of density, or a 12½% galena ore mixture would require the wall thickness of about 2.05" for a concrete density of 232 cubic feet, thus resulting in a saving of .30" or 12.7% in wall thickness, or a gain of 3 pounds per cubic foot and 1.3 %in weight.

The following aggregates may be obtained at approximately the prices shown per ton at the locality of use:

Table IV

12½% OF GALENA

SiO_2	Sand and gravel	$5.00 at site.
Fe_3O_4	Magnetite	19.00
Fe_3P, Fe_2P, FeP	Ferro Phosphorus	90.00
TaO_2FeO	Ilmenite	25.00
Pbs	Galena	105.00
$2Fe_2O_3H_2O$	Limonite	40.00
$Fe_2O_3H_2O$	Goethite	40.00
$BaSO_4$	Barite	35.00

Thus it is seen that a 12½% increase in the present cost of high density concrete using galena and magnetite resulted in a price savings alone from 20–50%, with the Ilmenite and Ferro Phosphorus mixture. Where structural members are to be protected by sheet or brick lead, it seems evident that a homogenous cement mixture using a 12½% galena mixture can approach the required shielding alone as the percentage additions are increased in a manner consistent with a maximum for compressive strength.

CONCLUSION

Since half thicknesses of walls can be reasonably computed in inverse proportion to density, a comparison is made in FIG. 2 with a testing company who used a Cobalt 60 source, where the energies of the 3 mev. graph and a one mev. graph compare favorably with the actual line between them which may be calculated as approximately 2.40 mev.

The actual tests of the middle curve in this FIG. 2 fell almost exactly within the range estimated by the computed results from the American Concrete Institute Publication on Concrete for Rod Shielding, published 1962.

No difficulty was encountered in the workability of the concrete using the various percentages of galena with other high density aggregates. Since the one-half thickness of a shielding concrete is in inverse proportion to its density, it is obvious that galena with a gravity of approximately 7.50 may be used with many other minerals, enhancing their protective qualities.

It is also noted that the ore itself may be ground to floatation fineness and used straight in those areas where a preformed container is in a protective position.

While the use of galena ore in different proportions has been described in some detail, approximately the best results were obtained with the ingredients and percentages of mixtures herein shown and described, but the invention should not be limited exactly to mixtures as many variations of these proportions may be made without departing from the spirit and scope of this invention.

I claim:

1. Extra high density concrete for radiation shielding having high structural strength, comprising galena ore aggregate in combination with calcium aluminate hydraulic binder cement, and standard aggregates.

2. Extra high density concrete for radiation shielding, in accordance with claim 1, in which the galena ore aggregates are homogenous throughout the concrete, increased proportions of this ore compared with standard aggregates correspondingly increasing density and radiation shielding and high structural strength of a wall structure in which the galena ore is contained.

3. An extra high density concrete for radiation shielding having high structural strength, which comprises magnetite, galena ore, calcium aluminate hydraulic binder cement and water.

4. Extra high density concrete for radiation shielding, in accordance with claim 3, in which a wall made of galena ore and a standard density aggregate and with calcium aluminate hydraulic binder cement has a one-half thickness as compared with regular ore and regular cement which decreases proportionally as the ratio of the galena ore aggregates increases.

5. An extra high density concrete for radiation shielding, and having high structural strength, according to claim 3, comprising aggregates of magnetite (Fe_3O_4), galena ore (PbS), calcium aluminate hydraulic binder cement ($Ca_3Al_4SO_4$) and water (H_2O) all intimately mixed and allowed to set.

6. An extra high density concrete for radiation shielding and high structural strength, according to claim 5, in which a mixture of 87½ magnetite aggregates and 12½% galena ore aggregates, by weight has a weight per cubic foot of 232 pounds, a compressive strength in one day of 3840 pounds per square inch, and in three days of 5685 pounds per square inch.

7. An extra high density concrete for radiation shielding and high structural strength, according to claim 5, in which a one-half thickness of wall with galena ore is blended with magnetite, in comparison with equal density of all magnetite and requires approximately one-quarter of an inch less thickness to reduce the radiation one-half.

8. An extra high density concrete for radiation shielding and high structural strength, according to claim 7, in which the linear absorption or radiation is 12 percent less when 12½ percent of galena ore is mixed with magnetite than when an all magnetite mixture is used resulting in a reduction of space, volume and cost to obtain an equivalent result.

9. Extra high density concrete for radiation shielding, having high structural strength, including galena ore aggregate in combination with other aggregates, a calcium aluminate hydraulic cement binder, and water, in which the specific gravity per unit square foot is materially raised by the galena ore, resulting in reduced amount of concrete to effect predetermined shielding, where by saving in material, high structural capacity for building and storage, and reduction in unit cost is obtained.

References Cited by the Examiner

UNITED STATES PATENTS

2,726,339	12/55	Borst	252—478 X
2,887,392	5/59	Lolley et al.	106—104

CARL D. QUARFORTH, *Primary Examiner.*