Strengthening of pressed building materials

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Abstract. The acceleration of hardening of compositions, based on cement and low cement binding materials, is possible in special conditions of concrete mixtures consolidation when a disperse system “binding aggregate” is being consolidated by a small amount of water. These are so-called methods of vibration pressing and pressing. Vibration pressing presupposes a binary mechanical influence on the consolidated mixture – vibration and pressure, generated by a power installation of a press or a set-on weight the strength of which is widely variable. No need for mixture plastic state sustention in the conditions of such influences imposes special requirements both for the mixture composition design and modes of its consolidation and strengthening. At present, a recovery of industrial powder wastes which do not possess the binding properties, while being produced by the traditional methods of building materials manufacture with the use of easy-to-place mixtures (vibration pressing, tamping, and casting), is not exercised on a large scale as there appears the necessity to increase the amount of the used binder based on Portland cement clinker above the normal level.

1. Introduction

Theoretical bases of low workability mixtures molding were considered earlier [1,2]. It is known that while designing the majority of building conglomerates on the basis of cement binding materials it is necessary to solve two tasks simultaneously:

1. Optimization of the aggregate grain-size distribution must support the minimum hollowness. This is solved by the selection of grain-size distribution discrete parameters. Although, in this case the amount of used binding material increases in order to provide the required rheology of the mixture of dry components and water.

2. Continuous curve of the grain-size distribution while a little increasing the hollowness of grain materials provides the optimum flow of the binding agent glue balancing the surface area of aggregates with their hollowness.

2. Relevance of research

Hardening of systems of contact molding happens at minimum required for this process amount of the mixing water as a part of concrete mixture. Application of recovered industrial powder wastes possessing a little hydraulic activity is not widely spread due to the rise in a price of the finished product [3-5]. Violation of balance between the required low strength and high amount of cement used (primarily CEM I and CEM II) makes the traditional technologies economically non-efficient also due to the high cost of plastifying agents with a high technologic effect. The technology of producing building materials on the basis of pressing excludes these weaknesses. The producers of equipment for...
manufacture of molded articles suggest in their advertisements the amount of the used binding material within 3...7% of the mixture volume. These values of the amount of the binder used are lower than, for example, in heavy concrete mixtures of B10-B15 classes where the amount of CEM I cement used makes up 9...12%.

3. Aim
Production of pressed materials with high strength on the basis of low cement binder.

4. Theoretical part
For manufacture of molded products there were used the materials the properties of which are given in Table 1 below.

| No. | NS  | DP  | A   | S   | EL  | L   | C  | BR  | SF  | MS  | KS  | FP  | W   |
|-----|-----|-----|-----|-----|-----|-----|----|-----|-----|-----|-----|-----|-----|
| 1   | 65.1| 3.4 | 3.4 | 31.3|     |     |    |     |     |     |     |     | 31.3|
| 2   | 60.5| 10.5| 10.5| 28.9|     |     |    |     |     |     |     |     | 28.9|
| 3   | 80.7| 8.9 | 8.9 | 10.3|     |     |    |     |     |     |     |     | 10.3|
| 4   | 70.3| 17.6| 17.6| 14.0|     |     |    |     |     |     |     |     | 14.0|
| 5   | 52.3| 9.7 | 9.7 | 15.6|     |     |    |     |     |     |     |     | 15.6|
| 6   | 31.0| 38.9| 4.3 | 25.9|     |     |    |     |     |     |     |     | 25.9|
| 7   | 29.7| 38.8| 4.4 | 24.8|     |     |    |     |     |     |     |     | 24.8|
| 8   | 66.4| 10.1| 6.6 | 16.9|     |     |    |     |     |     |     |     | 16.9|
| 9   | 54.9| 8.4 | 17.4| 13.7|     |     |    |     |     |     |     |     | 13.7|
| 10  | 26.1| 46.3| 18.6| 7.0 |     |     |    |     |     |     |     |     | 7.0 |
| 11  | 14.0| 61.0| 4.7 | 1.9 | 18.3|     |    |     |     |     |     |     | 18.3|
| 12  | 12.4| 1.2 | 5.3 | 56.4| 24.8|     |    |     |     |     |     |     | 24.8|
| 13  | 28.7| 7.9 | 37.2| 28.2|     |     |    |     |     |     |     |     | 28.2|
| 14  | 19.9| 10.8| 47.9| 21.5|     |     |    |     |     |     |     |     | 21.5|
| 15  | 14.4| 43.9| 1.5 | 30.0|     |     |    |     |     |     |     |     | 30.0|
| 16  | 58.9| 1.7 | 8.2 | 28.6|     |     |    |     |     |     |     |     | 28.6|
| 17  | 23.6| 19.0| 45.6| 11.8|     |     |    |     |     |     |     |     | 11.8|
| 18  | 13.7| 56.6| 10.1|     |     |     |    |     |     |     |     |     | 10.1|
| 19  | 9.6 | 8.8 | 11.6| 56.0| 16.1|     |    |     |     |     |     |     | 16.1|
| 20  | 6.4 | 17.3| 56.1| 15.4| 7.8 | 14.3|    |     |     |     |     |     | 14.3|
| 21  | 5.9 | 13.1| 49.0| 8.3 | 14.8| 19.4|    |     |     |     |     |     | 19.4|
| 22  | 27.5| 6.2 | 10.8| 1.5 | 15.2| 28.8|    |     |     |     |     |     | 28.8|
| 23  | 29.7| 7.0 | 2.2 | 32.8| 28.3|     |    |     |     |     |     |     | 28.3|
| 24  | 3.0 | 2.7 | 61.6| 12.6| 20.1|     |    |     |     |     |     |     | 20.1|
| 25  | 18.6| 15.7| 51.6| 14.1|     |     |    |     |     |     |     |     | 14.1|
| 26  | 35.6| 43.3| 7.4 |     |     |     |    |     |     |     |     |     | 13.7|
| 27  | 19.0| 32.5| 10.2| 16.8|     |     |    |     |     |     |     |     | 21.6|
| 28  | 16.0| 14.7| 11.0|     |     |     |    |     |     |     |     |     | 11.0|
| 29  | 19.0| 15.4| 60.6| 16.2|     |     |    |     |     |     |     |     | 16.2|
| 30  | 18.3| 60.6| 17.1|     |     |     |    |     |     |     |     |     | 17.1|
| 31  | 13.6| 52.1| 30.0|     |     |     |    |     |     |     |     |     | 30.0|

Note: NS – Nickel Slag; DP – Waste of Dolomite Production (Dolomite Powder); A – Wet Ash Discharge; S – Granulated Blast-Furnace Slag; EL – Waste of Electroplating Industry (the amount used is given for the wet state); L – Lime-Containing Wastes; C – Portland Cement of CEM II/B-Sh 32.5H Class; BR – Burnt Rocks; SF – Silica Fume; MS – Waste Molding Sands; KS – Sand of Karabash Slag; FP – Fire-Clay Powder; W – Water.
Sand after breaking the slag of nickel production (NS) is represented by a vitrified product of black color with a small quantity of anorthite and spinel. Taking into account the conditions of composite hardening NS should be considered as hydraulically passive material.

Wet ash discharge (A) of Chelyabinsk Thermal Power Station displays insignificant hydraulic activity only at alkaline excitation in the conditions of high temperatures (not lower than 90°C).

Dolomite powder (DP) and lime-containing wastes (L) are the by-products of Mechel production. Fine dolomite powder (DP) contains up to 35% of dolomite and limestone, periclase and consequently hydration products of the latter, brucite. Lime-containing wastes (L) are presented by a mixture of undissociated calcium carbonate, calcium oxide (4-40%) and products of its hydration. The material belongs to quick-slaking binders.

Phase composition of waste molding sands (MS) of Stankomash Chelyabinsk Company Casthouse Production is presented mainly by sustainable low-temperature modification of silica and a small quantity of kaolinite. From the point of particle-size composition MS can be considered as a highly-efficient inert additive possible to correct particle-sized compositions of mixtures.

Phase composition of fire-clay powder (FP) of Mechel Fire-Clay Production wastes is mainly presented by the clay minerals: kaolinite as a part of the product achieves 20%. High values of porosity and dispersion predetermine a high adsorbing capacity of fire-clay powder (FP) great quantity of which as a part of mixture will require special modes of decompression after molding by means of pressing.

Granulated blast-furnace slag (S) of Mechel is mainly presented by a glass phase of variable composition; grain-size distribution of slag complies with the values of GOST 26633 for concrete fine aggregate.

Burnt rocks from Kopeisk mines wastes (BR) are presented by a product of oxidating self-roasting of mine rocks. Rocks with a prevailing part of silica product (up to 18%) and clay soil (up to 18%). According to X-ray phase analysis there are present calcium aluminates, field spars and a combustible matter in the composition of burnt rocks. In the work there was used a mixture of grains passed through the cover with the 10 mm cells size.

Optimization of Aggregates Mixture Composition

Composition of the mixture with the minimum amount of the binder used while complying with all the standardized quality parameters of the product will be efficient from the point of production economic performances. The value of intergrain hollowness of the mixture composition can be a criterion for the optimum choice of mixture composition. With a decrease of its value the volume content of the binder paste which is necessary for the provision of united structure reduces as well.

For manufacture of wall materials on the basis of industrial wastes a method of vibration pressing was used. During the experiments molding pressure was taken as equal to 15 MPa, molding cycle was within 10-15 seconds.

For manufacture of commercial prototypes there was used the press by TEROK production (France) the matrix of which allowed obtaining articles in the form of bricks of 140x290 mm size of the variable thickness (50–200 mm).

Compositions of mixtures and the results of physical and mechanical researches are given in Table 2.

After the samples were produced their molding strength was within 3–5 kg/cm² allowing their piling as high as up to 1,5 m inside a shop at the temperature of 18-22 degrees.

Usage of NS as an aggregate leads to the formation of products with high average density providing an obtainment of concrete with the strength of 20 MPa and higher.

In the process of hardening mixtures containing wastes of dolomite production undergo significant expansion deformations (achieving the size of about 10% with the amount of 70% of powder) [6-20].

The experiment showed that the voluminous deformations of expansion within 1% do not cause visible discontinuity of hardening samples: strength and water resistance of such compositions are satisfactory. At this the obtained limit of 20% DP usage can be probably exceeded by the inclusion of
additives in the mixture composition the contact of which with periclase leads to the formation of magnesium salts in the material structure the density of which is higher than the density of brucite.

Table 2. Summary Table of Experimental Results of Concrete Masonry Products Produced by Pressing Method.

| No. | Average Density, kg/m³ | Holes Content, % | Strength Limit, MPa, at Natural Humidity | Coefficient of Softening after Saturation |
|-----|------------------------|------------------|-----------------------------------------|----------------------------------------|
|     |                        |                  | curve compression                         | curve compression                       |
| 1   | 1210                   | 31.6             | 0.6                                      | 2.9                                     | 1.0                                     | 1.0                                     |
| 2   | 1290                   | 28.1             | 1.6                                      | 7.8                                     | 0.97                                    | 0.96                                    |
| 3   | 2230                   | 10.6             | 1.7                                      | 13.3                                    | 1.02                                    | 0.86                                    |
| 4   | 2225                   | 10.5             | 2.9                                      | 22.0                                    | 1.03                                    | 0.97                                    |
| 5   | 1920                   | 11.9             | 2.2                                      | 14.5                                    | 0.85                                    | 0.80                                    |
| 6   | 1400                   | 26.1             | 0.9                                      | 6.0                                     | 0.96                                    | 0.90                                    |
| 7   | 1470                   | 21.5             | 0.9                                      | 6.8                                     | 0.90                                    | 0.76                                    |
| 8   | 1520                   |                  | 0.4                                      | 4.3                                     | destroyed                               | destroyed                               |
| 9   | 1530                   |                  | 0.4                                      | 2.0                                     | destroyed                               | destroyed                               |
| 10  | 1680                   | 17.9             | 2.7                                      | 13.5                                    | 1.13                                    | 0.87                                    |
| 11  | 1670                   | 12.5             | 1.9                                      | 13.3                                    | 0.93                                    | 1.05                                    |
| 12  | 1580                   | 25.9             | 1.3                                      | 11.1                                    | 0.73                                    | 0.70                                    |
| 13  | 1400                   | 19.9             | 1.1                                      | 7.7                                     | 0.75                                    | 0.73                                    |
| 14  | 1690                   | 26.4             | 2.0                                      | 14.2                                    | 0.60                                    | 0.80                                    |
| 15  | 1440                   | 13.4             | 1.2                                      | 9.6                                     | 0.73                                    | 0.73                                    |
| 16  | 1720                   | 9.3              | 3.4                                      | 18.0                                    | 0.88                                    | 0.84                                    |
| 17  | 2350                   | 11.1             | 2.0                                      | 12.6                                    | 0.7                                     | 0.98                                    |
| 18  | 2280                   | 17.1             | 1.2                                      | 17.2                                    | 0.95                                    | 0.88                                    |
| 19  | 2090                   | 8.5              | 0.7                                      | 8.3                                     | 0.50                                    | 1.00                                    |
| 20  | 1850                   | 25.1             | 1.8                                      | 19.4                                    | 1.12                                    | 0.87                                    |
| 21  | 1660                   | 27.2             | 1.4                                      | 14.8                                    | 1.01                                    | 0.79                                    |
| 22  | 1440                   | 24.4             | 2.1                                      | 15.2                                    | 1.29                                    | 0.88                                    |
| 23  | 1540                   | 22.7             | 1.7                                      | 17.6                                    | 1.01                                    | 0.78                                    |
| 24  | 1520                   | 27.2             | 1.3                                      | 11.7                                    | 0.96                                    | 0.87                                    |
| 25  | 2210                   | 8.6              | 1.3                                      | 13.9                                    | 1.10                                    | 0.99                                    |
| 26  | 1530                   | 20.4             | 1.0                                      | 5.1                                     | 0.87                                    | 1.02                                    |
| 27  | 1550                   | 20.3             | 2.0                                      | 13.3                                    | 0.81                                    | 0.81                                    |
| 28  | 1650                   | 15.9             | 0.9                                      | 5.4                                     | 1.11                                    | 0.78                                    |
| 29  | 1740                   | 16.2             | 2.0                                      | 12.6                                    | 1.10                                    | 0.90                                    |
| 30  | 1830                   | 13.2             | 2.9                                      | 18.6                                    | 0.95                                    | 1.05                                    |
| 31  | 1880                   | 13.8             | 0.9                                      | 8.8                                     | 0.78                                    | 0.93                                    |

5. The practical importance
Additional inclusion of ash as a part of mixture composition allows obtaining products of guaranteed B7.5 class with the average density lower than 2000 kg/ m³.

6. Conclusions
- Lime-argillaceous binder possesses a high hydraulic activity the increase of which can be reached by additional mutual wet-grinding of the binding material components;
- In the normal conditions of compositions hardening the water-soluble hydrate entities with the strength higher than 7, 5 MPa are formed on the basis of this binder;
- Taking into consideration the attractive decorative properties of rocks with the usage of burnt rocks they can be recommended for the internal brickworks of industrial and public facilities;
• Including microsilica in the composition of lime-argillaceous binder contributes to the enhancement of system strength without change of its water resistance.

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