Raw Material Security of Construction in the Far East

S V Vavrenyuk [1], G A Korableva[2]

[1]Ministry of Construction of the Russian Federation branch of FGBU "TSNIIP Russian Ministry of Construction" DalNIIS, ul. Borodinskaya, 14, Vladivostok, 690033, RF

E-mail: t.rusanova@dalniis.ru

Abstract. The studies of the volcanic rocks of the far Eastern deposits shows the need and the prospect of their wide use as aggregates for the heavy concretes, lightweight concretes for various purposes, insulating materials, mixed binder.

1. Introduction

To reduce the cost the construction must rely on the local raw materials base, especially when it applies to the Far East with its vast territory, remoteness, bad roads and high transportation costs.

At the same time the Far East has huge reserves of minerals in the form of volcanic rocks which can be used to produce the local building materials and products.

Industrial reserves of such rocks are found in Primorsky, Khabarovsky, Kamchatsky Regions, Magadan and Sakhalin Territories [1-4].

Volcanic porous rocks are represented by volcanic slags, pumices, agglomerate tuffs and porous basalts. Volcanic glasses are represented by perlites and obsidians. In the Primorsky and Kamchatka Regions there are 2 deposits of zeolitized rocks.

In the last century the porous rocks were widely used for industrial construction of the Far Eastern region to produce the lightweight concretes for various purposes. At the present time the natural porous aggregates are practically not used, except for single cases of making the small pieces such as wall stones.

2. Analysis of raw material base

The resumption of lightweight concrete production in the Far East using the local natural raw materials is economically feasible and it is necessary in order to eliminate the foreign supplies. Economic feasibility is determined by the presence of huge industrial reserves, relatively low cost of its extraction and processing, a number of advantages of the lightweight concrete constructive characteristics with regard to full-strength concretes on dense aggregates. Reduction of the buildings mass, high deformation properties of lightweight concrete ensure the reliable operation of buildings and structures under the influence of dynamic loads in the seismic conditions of construction which is relevant for the Far Eastern region.

Long-term complex study of these rocks conducted in DalNIIS showed the prospects of their use as aggregates of concretes for various purposes - structural, structural and thermal insulating, heat-resistant, thermal-insulating; mineral additives in cements, concretes, solutions; as components in low-grade cement binders [5-14].

Volcanic slags are mostly widespread in Kamchatka (industrial reserves are ten million m^3, promising reserves are hundred million m^3), where they were widely used in construction (house building, road and hydro-engineering construction).

The Far East pumice is represented by deposits of the Kamchatka Territory and the Sakhalin Region. In Kamchatka (forecast reserves of more than 20 billion m^3), on the Sakhalin and on the Kuril Islands - a few hundred million m^3.

Agglomerate tuffs and porous basalts are represented by deposits in the Primorsky (Borisovskoye, Pushkinskoye - tuffs, Baranovskoye – basaltic andesites) and Khabarovsk territories (Svyatogorskoye, Lianskoye - tuffs).

On the volcanic slags of the Paratunskoye and Sovietskoye deposits (Kamchatka), the structural concrete has been obtained having the strength class B22.5 ... B40 with a freeze-thaw resistance 200-500 cycles. Slag in the form of crushed stone and sand with the addition of natural sand was used as aggregates. The grade class of concrete varies by the ratio between a coarse grain (5-20 mm) and fine grain (0-5 mm) fractions. Increasing the amount of sand results to improve the strength characteristics due to concrete compaction. A fine-grained (with the content of sandy aggregate fraction up to 70%) dense concrete of grade classes B15 ... B25 has been obtained, however it is with the increased (495-530 kg) cement consumption.

Determination of the protective properties of B15 ... B22.5 grade classes concrete based on the Paratunsky slag showed the passivating concrete properties in relation to the reinforcement. Freeze-thaw resistance grade of concrete can vary from F200 to F700 depending on the cement consumption, the grain composition of aggregates, water-cement ratio; fine-grained F 200-F300.

Cement consumption in structural concretes based on the Paratunsky slag correspond to the normative ones and practically correspond to the cement consumption on the slag of the Sovietsky deposit. Shrinkage and creep of concretes on these slags are within the limits of value characteristic for expanded-clay concrete and other types of lightweight concrete. By compressive strength and tensile strength, structural concrete on the Paratunsky slag meets the normative requirements of SNiP 52.01.2003.

3. Materials and technologies obtained on the basis of raw materials development and their application

The production of high-strength concrete of a certain grade class concrete depends on the applied technology of concrete mix compaction. The institute has developed a technology for obtaining concrete of any class for structures.

Strength and deformation characteristics of structural concrete on the volcanic slag of the Paratunskoye deposit according to the grade classes B40, B30, B22.5 respectively: strength under axial tension 2.57 -2.95 - 2.17 MPa; prismatic 50.0 - 40.9 - 28.6 MPa; modulus of elasticity 24,6 - 23,7 - 20,2 MPa; shrinkage deformation $\approx 40 \times 10^{-5}$.

Along with the use in civil and industrial construction structural concrete based on the slag of Kamchatka deposits can be used in hydroengineering construction and road construction. Fine-grained high-strength concrete can be used for prefabrication of concrete, precast concrete and pre-stressed structures and products (lateral trusses, beams, columns, crossbars, roof slabs), special structures (pile head walls, pressure pipes, facing tiles, power transmission towers) on condition of their exploitation in a non-aggressive, slightly- and medium-aggressive environment.

Structural and thermal-insulating concretes of grade classes B2.5; B3.5; B5; B7.5; B12.5 were obtained on crushed stone and sand from volcanic slags, they are of F35 - F150 freeze-thaw resistance grades, with medium density up to 1600 kg / m^3 with cement consumption of 250-300 kg / m^3. The coefficient of thermal conductivity of concretes on the slag of the Paratunsky deposit is in the range of 0.40-0.49, of the Sovietsky and Kozelsky deposits is in the range of 0.32 - 0.47 W / m^0, depending on the grade class of concrete. To reduce the density by 200-300 kg / m^3 the use of expanded perlite sand, expanded polystyrene granules, air entraining admixtures into concrete has been developed and recommended. Strength classes of (B3.5 ... B12.5) and freeze-thaw resistance (58-318 cycles) are preserved therewith, the concretes have increased heat shielding properties, good protective ability in relation to the reinforcement and the necessary watertightness. Strength characteristics of slag perlite concrete based on Paratunsky slag are by grade classes of B7.5 - B10 - B12.5 respectively: cube strength is 10.8 - 13.3 - 17.2 MPa; prismatic is 10.3 - 11.9 - 13.8 MPa; K = Rprism / Rcube 0.95 - 0.89 - 0.80; charactiristic resistance to compressive strength is 7,6 - 11,9 - 10,9 MPa; the tangent modulus of elasticity is 7.6 - 11.9 - 10.9 x 10^{-3}. Prismatic strength of the B7.5 grade class concrete is higher

than the normative parameters for SNiP 5-01-2003 by 45%, and of the B10 grade class concrete is by 12.6%. The modulus of elasticity of B7.5-B10 grade classes concrete is lower than the normative by 19 and 7% respectively and that under the action of dynamically used load during the operation of buildings and structures in seismic regions has a positive effect on their operation. Full shrinkage of slag perlite concrete can reach up to 1.5 mm/ m (grade class B35-perlite content is 50% of the total aggregate volume). Reducing the dosage of perlite reduces concrete shrinkage. Slag polystyrene concrete based on the slags of the Sovietsky and Kozelskoye fields with an average density of up to 1400 kg / m^3 in dry conditions and strength classes of B3.5 - B7.5 was developed. The coefficient of thermal conductivity in this case is reduced by 8-14% compared to slag concrete. Freeze-thaw resistance grade of such concrete is within F35 - F75. Checking the moisture state of walls fragments made from slag polystyrene concrete after the impact of artificial rain with wind showed a slight (from 0.8 to 2.5%) increase in moisture content.

To obtain structural and thermal-insulating pumice-concrete it is advisable to use enriched pumice. On the fractionated aggregate it is possible to obtain pumice concrete of grade classes B3.5 ... B15 with a density of 800 ... 1000 kg / m^3, thermal conductivity (grade class B5 and B7.5) 0.198 ... 0.267 W / m ° C, freeze-thaw resistance grade is F50 - F75 .

On the aggregate of agglomerate tuffs structural and thermal-insulating concrete of grade classes B3.5 ... B7.5 with density from 1280 to 1600 kg / m^3 was obtained with cement consumption from 200 to 320 kg / m^3, depending on the grade class. The intergranular porosity for a concrete mix with an optimally dense structure, for example, for a tuff concrete of a B5 grade class with a cement consumption of 245 kg / m^3 with W / C = 1.0 and a tuff sand content of 40% of the aggregate volume is 2.4%, and therefore such concrete does not need protection against corrosion, thermal conductivity of this concrete is 0.32 - 0.38 W / m^0 C, freeze-thaw resistance is up to F200 grade.

On aggregate from tuff the compositions of structural concretes of grade classes B12.5 ... B15 were developed, they are with various combinations of fine and coarse aggregates made of tuff, natural sand and dense crushed stone at cement consumption of PC400 D0 (ПЦ400 Д0) from 315 to 380 kg / m^3. The freeze-thaw resistance of the B15 grade class tuffcret is 200 cycles, the density of dry is about 1600 kg / m^3.

Porous sands obtained during the crushing of tuffs are suitable for obtaining mortars (masonry mortars and plasters) with grades from 4 to 200.

On aggregates from basaltic andesite from Baranovsky deposits the Institute has obtained structural concrete of B15 ... B30 grade classes out of hard concrete mixtures, with medium density from 2000 (grade class of B15, B22.5) to 2150 kg / m^3 (grade class B30). Freeze-thaw resistance of concrete reaches up to 200 cycles of alternate freezing-thawing. Such concrete is characterized by increased crack resistance in comparison with concrete on dense aggregates, which is provided by an increased tensile strength (3,7 - 5,8 MPa) and low values of the modulus of elasticity (19.3 ... 25.9 • 10-3 MPa). The safety of the reinforcement is guaranteed by sufficient alkalinity of the medium and a dense structure of concrete. Concretes based on such an aggregate occupy an intermediate position between lightweight and heavy concrete on properties.

At present, the enterprise “Terekhovsky Concrete Products Plant” produces wall stones based on the aggregate of basaltic andesite according to GOST 6133-99 with strength classes of 50, 75, 100 with an average density of 1350-1420 kg / m^3.

The preparation of aggregate from porous rocks does not require large investments and consists of mining the rock, its crushing and fractionation, in some cases - enrichment (pumice, for example).

DalNIIS has developed a technology for producing a particularly light fire-resistant, environmentally friendly aggregate from local volcanic rocks - expanded perlite crushed stone and sand, as well as grain foam glass aggregate, suitable for use as insulation of building structures (thermal insulating products, backfilling) on the basis of Primorsky territory raw materials - perlite, zeolite of the Chuguevsky deposit and basaltic andesite. The developed technologies make it possible to obtain an aggregate in a significant range of its main properties: bulk density 120 ... 300 kg / m^3, strength 0.41 ... 0.67 MPa, thermal conductivity coefficient 0.055 ... 0.063 W / m ° C, freeze-

thaw resistance of more than 15 cycles [9-13], which predetermines an extensive field of its application both in the form of backfillings and for the production of thermal insulating products - plates of concrete on various binders, broached mats, products of any shape and size by the method of pellets and structural and thermal-insulating concretes sintering.

Thermal insulation concretes with strength class of B0.35 ... B2.5 in density of D200-D600 with PC400 portland cement consumption from 80 to 300 kg / m^3 were developed on the resulting aggregate. Coefficient of thermal conductivity of concrete depending on density is 0,087-0,16 W / m^0C, freeze-thaw resistance grade is F15-F35.

When tested at Institute the foam glass granulate with mixture of 5-40 mm fractions (with a certain ratio of each fraction) was tested for coarse-grained backfilling. It has been established that the use of coarse-grained backfilling instead of the traditional fine-grained [9] will make it possible to obtain a thermal insulation of lower density, hence, of a higher thermal insulating ability. The coefficient of thermal conductivity of such a backfilling is 0.070-0.073 W / m ° C. The technology of the walls warming process using thermal insulation backfilling has been developed.

Today concrete and reinforced concrete remain the main building materials and the main component (and the most expensive) of concrete is cement. Using a binder with mineral additives and mixed cements can reduce the cost of low-height construction.

The Institute carried out research on the use of the same rocks as active mineral additives in portland cement and as a component of a mixed binder.

The activity of mixed binders depends on the dosage and specific surface area of the ground rock as well as the activity of the clinker binder. Mixed binder of pozzolatic portland cement of grade class 300 was obtained as a result of combination with portland cement of PC400 D0 grade class at a ground volcanic slag dosage of 40-50% and zeolite up to specific surface of 300 m^2 / kg and of pumice and perlite of 400-500 m^2 / kg. A low-grade binder of the cement type for mortars in accordance with GOST 25328-82 was obtained when the rock was dosed in the binder composition up to 70%.

On mixed binders were obtained such concretes as: heavy concrete on dense crushed stone and natural sand of the B10 grade class with a density of 2250 kg / m^3 (50% addition of the Chuguevsky zeolite), lightweight concrete of the 12.5 grade class with a density of 1600 kg / m^3 (50% addition of tuff, tuff aggregate). Low-grade binder (up to 70% of the rock) can be used to produce sand mortar with strength class of 150-200. The increase in the strength of concretes and solutions in time (90 days and more) indicates the pozzolatic activity of the mineral constituent of such binders.

4. Conclusions

The concretes developed on natural porous aggregates were tested in practice in the conditions of Kamchatka and Primorsky territories. To help builders, the institute has developed a number of normative and technical documents for the production of various types of concrete on aggregates made of volcanic rocks and structures based on them. The Institute's developments can be widely used in the construction in the Far Eastern region and other territories that have reserves of porous volcanic rocks.

Volcanic porous rocks, glass from the Far Eastern deposits can and should serve as a reliable raw material base for the construction industry.

References

[1] Geology of the USSR 1976 Khabarovsk Territory and the Amur Region Mineral resourses *Moscow Nedra* Vol . 19.
[2] Geology of the USSR 1977 Kamchatka the Kurile Islands and the Commander Islands Mineral resourses *Moscow Nedra* Vol. 31.
[3] Geology of the USSR 1977 The Primorye Territory Mineral resourses *Moscow Nedra* Vol .32.
[4] Geology of the USSR 1977 The Island of Sakhalin Mineral resourses *Moscow Nedra* Vol. 33.
[5] Kuznetsova L A Antropova V A Orentlikher L P Vavrenyuk S V 2005 *Experience of using concrete of 22 5-B45 grade classes on porous aggregates of the Far East* "The All-Russia Conference on Concrete and Reinforced Concrete Moscow p. 75-79.

[6] Orentlikher L P Vavrenyuk S V 2008 *Aggregates in lightweight concretes exploited in hard climates 11th international interuniversity scientific-practical conference of young scientists post-graduate students and doctoral students* Moscow
[7] Vavrenyuk S V Korableva G A 2009 *Volcanic rocks of the Far East as raw materials for the production of aggregates in concretes* Technologies of Concrete **5** p. 16-17.
[8] Vavrenyuk S V Korableva G A Antropova V A 2012 *Concretes on porous aggregates from volcanic rocks of the Far East Monograph* Vladivostok FEFU Publishing House
[9] Vavrenyuk S V Tumanov V P Orentlikher L P 2006 *Granulated lightweight aggregate* - porobasalt Technologies of Concrete p. 6.
[10] Davidyuk A N 2006 *Lightweight concrete based on quenched culletis - the future of frame fillings* Technologies of concrete **10** p. 16-19.
[11] Davidyuk A N Savin V I Kostin A A Fedoseev A V 2015 *Lightweight concrete of new generation on granulated foam glass* Concrete and reinforced concrete **5** p 2-6.
[12] Kolosova M M Nagibin G E Pomiluykov O V 2002 *Granulated foam glass is a universal environmentally friendly thermal insulation material* Building materials equipment technologies of the XXI century **1** p. 12-23.
[13] Pogrebinsky G M Iskorenko G I Kanev V P 2003 *Granulated foam glass as a perspective thermal insulation material* Building materials **3** p 28-29.
[14] Kuznetsova L A Dymsky V M Korableva G A Kobyshcha T N 1992 *Activated mixed binders and concretes on their basis* 9th International Congress on Chemistry of Cement India Delhi November pp 23-28.
[15] Vasilovskaya N G Druzhinkin S V 2007 *Mixed binders with a zeolite containing rock of the Sakhaptinskoye deposit* Construction Materials **12** pp 30-31.